ol. X, No. 1 SUMMER 1969 *Editor:* DH BUTANI

PRODUCTIVITY

JATIONAL PRODUCTIVITY COUNCIL JOURNAL

Computerisation II

THE FIRST SPECIAL ISSUE ON COMPUTERISATION, PUBLISHED IN THE SPRING OF THIS YEAR, was intended to create an awareness, particularly at Policy and Intellectual levels, of what is going in the wide world, in the field of computerisation, so that adequate steps may be taken to see that we do not lose in competitive strength in the coming years, for it is obvious to us that **India has to prepare right now for the world of the 1970s*** and the chances of a noncomputerised society, as against a computerised one, are like those of the professional versus the amateur, in armed conflict.

Such a warning was given even to Europe, not very long ago, by a great French intellectual, Monsieur Jean-Jacques Servan-Schreiber : "Electronics is no ordinary industry but the base upon which the next stage of industrial development depends. The first Industrial Revolution replaced manual labour by machines. We are now living in the second Industrial Revolution, which is replacing the labour of the brain with new machines — computers. **If Europe lags behind in electronics, she could cease to be included among the advanced areas of civilization within a single generation".**

In a remarkable article recently published in the New Statesman, Mr. Wedgwood Benn warned that it would eventually be **possible for government departments to discover and record all the differing needs, desires and circumstances of every single man, woman and child in Great Britain, and act accordingly.**

The New Statesman itself was not slow to point out the enormous political implications of such a Computerised Society: "If 'desire and need' machines can be installed in each household, connected directly to central computers in Whitehall, then we have a participatory democracy of a kind no one has yet dreamed of. We must link this prospect, moreover, with an enormous

*Italics ours throughout, except on page 4

growth of the knowledge industry . . . . . By the knowledge industry I mean the new mechanical instruments by which information can be communicated far more effectively than by the old type of textbook alone. It is still in its very infancy, but **it must in time immensely increase the effectiveness of mass education. Thus we will — or we can if we choose — have a participatory democracy which is universally literate, well informed and wholly articulate.** In theory, then, communication between governed and governors can be complete, comprehensive and almost instantaneous."*

It was in order to prepare ourselves for such contingencies that we published a world-wide survey of Computerisation in the last issue of the Journal. Nevertheless it was an Unfinished Story, for the necessary analytical and technical details — the Logic and the Mathematics of the computer—were still wanting to complete the entrancing global picture of computerisation, revealed in the Spring Issue.

Even as a world survey, it needed quite a bit of supplementation, which has been accomplished in this Summer Issue. Massive material on France, Czechoslovakia and the Netherlands has now been made available. The Labour Point of view has been presented in this Issue by Mr. Ted Silvey of the Research Department of the AFL-CIO. The Impact on Management has been worked out in a series of Special Articles written by the topmost people in the world of Computerisation. Specialised Industry Applications, born out of actual experience, are now exclusively available for the readers of this Journal, by the courtesy of the giant corporations, engaged in this field for decades, in the USA and West Germany. Medical and Educational Applications of the computer have been presented in much greater depth than last time. For the **connoisseur,** Computer Mathematics have been worked out to ultra-sophisticated levels. Then **the Computer world of the 1970s** has been laid out, both for the visionaries, as also **for the hard realists, who would think it worthwhile to invest in ideas.**

As such, this Special Issue is a Supplement, a sort of sobering, deeper draught, needed by those readers of PRODUCTIVITY whose curiosity about the potentialities of the **Computer Wonderland** was roused by the earlier issue. To make it complete, a Special Inter-Disciplinary Group was set up, at our special request, by the Industrial Team Service of the St. Mark's Cathedral, Bangalore, to study the Technical, Economic and Social Aspects of Computerisation. This has been published in the Section on Special Studies and is meant to furnish an answer to the many questions asked of us.

The fact of the matter is that during the last decade a mystique about the Computer has developed to which the popular writers, such as Donald Fink have contributed not a little. In a Book on Computers and the Human Mind,† from which we have borrowed the last article—The Computer Plays the Checker Game — the author, despite his comprehensive, rationalistic analysis of Computer Processes, really, in a sense, strengthens this mystique, which should be the business of the intellectual to dissolve, for **Computerisation is not Black Magic, rather the antithesis of it.**

In fact, there are fairly long passages in Fink's Book, which are rather intriguing in spite of their proved rationale: "...The computer can perform many 'intellectual' tasks more accurately and more cheaply and much, much faster than human beings can perform them. The large electronic computer of today can process numerical information about a million times as fast as a

*Paul Johnson in the *New Statesman*, 28 March 1969

†First published by Heinemann (London) 1966, pages 280, besides, an Appendix on A Fortran Program for Computing π, Further Reading, Index etc., Price Shillings 30. Now available at the Academic Books Limited, E-1, Jhandewalan, Rani Jhansi Road, New Delhi 1

man. Being a machine, it can work long hours without fatigue and without making mistakes. The computer's ability to store and recall masses of detailed information is far ahead of the best performance of human memory. It can store within itself, in tiny magnetic cores or films, hundreds of thousands of digits and recall any one of them in less than a millionth of a second. **With such vastly superhuman resources of speed, accuracy, endurance, and memory at his command, the computer scientist can devise computations of such grand scope that they can, in fact, imitate many forms of human thought . . . . . By systematic comparisons of the patterns of logic, at million-per-second speeds, computers can explore the realms of the intellect in details never before perceived . . . .** A machine can operate in an apparently 'intelligent' fashion without benefit of detailed instructions provided by a human operator . . . . . **A machine can display behaviour strangely imitative of human intelligence, and that it can do so with highly abstract instructions.**

". . . . . Computers can manipulate all manner of symbols, including the symbols of art. They can produce patterns of these symbols in unending variety. They can recognize likenesses and differences in these patterns. If a programmer can devise criteria of artistic excellence, in some field of creative endeavour, he can adjust his computer to search for and select patterns that meet these criteria and to print them out for critical appraisal. . . . . .

"The computer may be programmed with fewer constraints than the human artist has. Every artist is the prisoner of his culture, just as every computer is the prisoner of its programme. Only a few great artists in each generation break through these constraints. **The computer programme, given sufficient hours to race through the broad fields of art, may provide breakthroughs on a radically shorter time scale. . . . . .** Will a computer, having produced a fugue one of these days, print out : 'This is one of my best works'?

"The question Can Machines Create? (on a grand original scale) cannot be answered with any certainty today. The answer can only be a guess . . . . . The best guess we have : Machines can conceivably create on a grand scale if the creative methods of the brain can be reduced to computer science. The computer need not imitate the brain in every detail of its creative power, but, in all probability, it must use heuristics ; that is, it must adopt shortcuts similar in principle to those used by the brain to bring the order of creation out of the chaos of its environment.

"In the end, we must concede that every computer is a part of nature ; it must operate according to a limited set of natural laws. **Given the power to encompass** ENOUGH **natural law, we may guess that it can attain all the conclusions implied in natural law — even to the writing of poetry.**

"A key issue thus emerges. What part of the human system is used in its programmes for thought? It may be a trivially small portion of the total. If so, the prospect of providing similar capacity in a computer system is not so forbidding. One bit of evidence is at hand : The elementary processes of perception and reaction in mankind proceed so slowly that, in the waking hours of a whole lifetime, the human mind can process, consciously, no more than 50 billion bits of information. If all these bits were stored in the human memory they would take up less than 1/20,000th of its total capacity. **The input perceptions and output reactions of a computer can match those of a human lifetime in a few hours.** Again, the billion-times speed advantage of the computer cannot be gainsaid.

"Future computer techniques may always fall short, but not by definition. Just as we can visualize the concept of infinity (that is, can think generally of a number larger than any particular number we have ever put into words), **so can we visualize a machine and programme whose hierarchy of abstractions contains one echelon above the highest echelon of**

natural thought. Further, we may conceive that this extra echelon need not be 'thought out' by man (who, by definition, does not possess the mental equipment for the task). It **might** be produced by extrapolation from previous designs. In this sense, **intelligent machine may forge into the unknown."**

Very obviously, we are here in the very quagmire of mysticism ; and this country can hardly afford it, whatever its rationale. We have had already too much of it in too many spheres. **What this country requires is massive injections of rationalism ;** and bonafide computerisation is really the ultimate in rationalisation.

It is therefore in the public interest that subject to the rather severe limitations painfully worked out in the last issue of the Journal—**a scrupulous regard not only for the interests but also for the sentiments of Labour through the rigid avoidance of computerisation in spheres, where there is the remotest possibility of not only employment but the employment potential being adversely affected** — we adopt a **Policy of Planned Computerisation** in select areas, where it would work as an employment booster — such as the establishment of the Computer industry itself, with its enormous gadgets of hardware and software — and where above all, it has **the proven capacities of creating a life of abundance for the common people.** ●●●

Do We Abdicate to the Computer ?

"..... with more urgent things to deal with, is it worth losing sleep over the remote, science-fiction vision of machines growing independent of men and eventually 'rebelling'. *One would be rash to dismiss the possibility of such independence* and even in current technology, with computers helping to design, build and programme computers, there are hints as to how it might arise. Hannes Alfven, the Swedish physicist, in his pseudonymous book *The Great Computer*, outlines a plausible route. Yet it will be some decades before men are able, let alone willing, to omit the 'Off' switch from the machines, or give them direct access to energy and raw materials.....

"But will we *abdicate* to the computer ? That possibility arises already; in fact, *it is no longer a question of whether we abdicate, but how much.* To what extent should we allow computers, applied at a high level of decision-making in government and other activities, to determine our actions? I can hear a rustle among the computer experts. 'It's not like that at all, as you know perfectly well. Even operating at 10 Downing Street, the computer would not be a little tin god telling the Prime Minister what to do. The machine merely gives the results of complicated analyses, done according to programmes written by human beings. It can make the Prime Minister, or anyone else, better informed, and may even suggest courses of action, but it no more makes the decision than the engineer's slide rule designs the bridge. Computer proposes; man disposes. Nor need it ever be otherwise'.

"No understanding of the hardware and software can save us from the fact that the computer is already a machine of fantastic power. What is more, it is powerful in the very quality that 20th-century men most admire and feel most lacking in themselves: rationality. The computer is pre-eminently an embodiment of uncontaminated logic, able to make unerring deductions at high speed from volumes of information with which no human being could cope. It magnifies the role of pure reason in human affairs. If you recoil from the idea of being led by computers, you must believe that the human brain, the only serious rival to the computer for ordering our affairs, has other qualities and interests. . . ."

—Nigel Calder on "Brain *versus* Computers," the New Statesman, 17 March 1968

Human Aspects of A Computerised Society

Simon Ramo*

It is becoming common to envisage man in the future as an anonymous cog in a vast interconnection of machines, cables, signals and moving vehicles—all controlled by computers. In this dreary picture of the coming world, every action of society, down to its infinite detail, will be planned and pre-set. Man will be a mere number turned up by the computer, a docile and instructed participant in the operations of the economy, and an apathetic, nonparticipating, disinterested bystander in the decisions. It will be difficult to distinguish man from a machine.

THE ANTICIPATED ROBOT-LIKE STRUCTURING of society becomes conceivably realisable because of what technologists tell us can be caused to exist soon: a pervasive, automatic, **electronic information system that senses all the data needed to control our daily operations,** then processes this information on a mass scale in accordance with all-embracing, programmed rules that can and will be evolved over the years, then finally communicates this information everywhere to the co-operative, responding machines and men.

Production, distribution, accounting, transportation, banking, education, government, law-making, engineering, medicine, and most other operations and pursuits of man will be altered in their organisation and practice to adapt to such an information control-system concept.

As the role of the human participant in the gathering, flow, contemplation and utilization of the information that keeps the world going becomes more a job for the electronic machine, the need for a new man-machine partnership emerges.

This coming of new man-machine partnerships to extend the human intellect and to make possible the superior handling of all of the information and intellectural activity with which man and his world are now engaged should be a step eagerly contemplated and enthusiastically anticipated.

Is such a development not the greatest boon that science and technology could ever give to society?

The civilisation would have a vastly increased over-all brainpower, with the machine partner taking on the more mundane tasks, the high-capacity handling of needed information with a speed appropriate to busy, complex life.

Automaticity in the providing of all of the material requirements of man, all neatly and efficiently controlled and planned, should follow. **The human brain would then be able to rise to higher plateaus of cultural and social growth.**

*Vice-Chairman of the Board, TRW Inc., U.S.A.

Why then the concern, even alarm, as broadening electronic technology appears ready to bring the information-automation age to full bloom?

The advent of the computer age appears to carry with it the threat of the long dreaded "planned economy", or worse, **an automated socialism without free enterprise or unfettered creativity,** without individual initiative and the advantages of competition and incentives and, more especially, without the freedom to allow indivdual aspirations to rise to new heights.

However, there is a much more likely and attractive path. It leads to a free economy of a new form and unprecedented level.

An ubiquitous electronic information network appears to make possible a robot society because all the information—from airplane schedules to pickle distribution—needed for control can be made available in the right place at the right time. However, this technology can also be used to enhance democracy and free enterprise.

To assume a future robot society is to assume also the design, production and installation of millions of economical, reliable, interconnected electronic devices placed everywhere, picking up, processing and disseminating information.

Each citizen would be associated with a "super" telephone-TV set telling him where to be and what to do, this as part of a universal control system covering every business and individual.

If such a system were truly operational, it could be used to make it possible for men to participate from the comfort and privacy of their homes, in "instant democracy."

All this advanced computer and communication technology, properly employed by a mature society, could make possible the dissemination to every citizen of all items of information worth his contemplation and evaluation for the democratic selection o goals.

Such a national network of computers, communication gear, electronic memory units and information consoles could inform, gather opinions and process this polling for the making of decisions.

The same system that can tell millions of people exactly what to do, as though they were robots, can just as well ask them to choose from a group of well-presented alternatives what they prefer to do.

The citizens of the future, so far as technological potentials are concerned, could be able to tune in on the discussion of issues and take part by expressing their reactions electronically in two-way communication from their homes. The results, automatically and speedily processed by computer, could be disclosed to all and used in the deliberations of legislatures and councils.

The decision to move toward a robot society or, instead, in the direction of **on-line democracy,** or toward any form or variation in between, is not made by technology. It should be made by the people who create and use that technology.

Technology can help make possible a more informed, more interested, more active citizenry; the tapping and using of citizen opinion as a way of life; the creating of new, powerful citizen participation in decision-making at a level not even imagined in all the previous "pretechnological" history of man.

As to the feared planned economy, it cannot really be successful and therefore cannot abide no matter how much control over detail and data it has, unless the consumer is in the loop.

Perhaps the Soviet Union has proven this point by demonstrating that, although the government can plan what to produce, it cannot force the citizen's utilisation of and demand for the products.

If a computer network which is fully developed and widespread can communicate with everyone to ensure the working

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credit for Designing and and Conceptualisation of the Computer Cartoons in this Special Issue goes ely to the NPC Artist, Sri P.R. Vohra—*Editor.*

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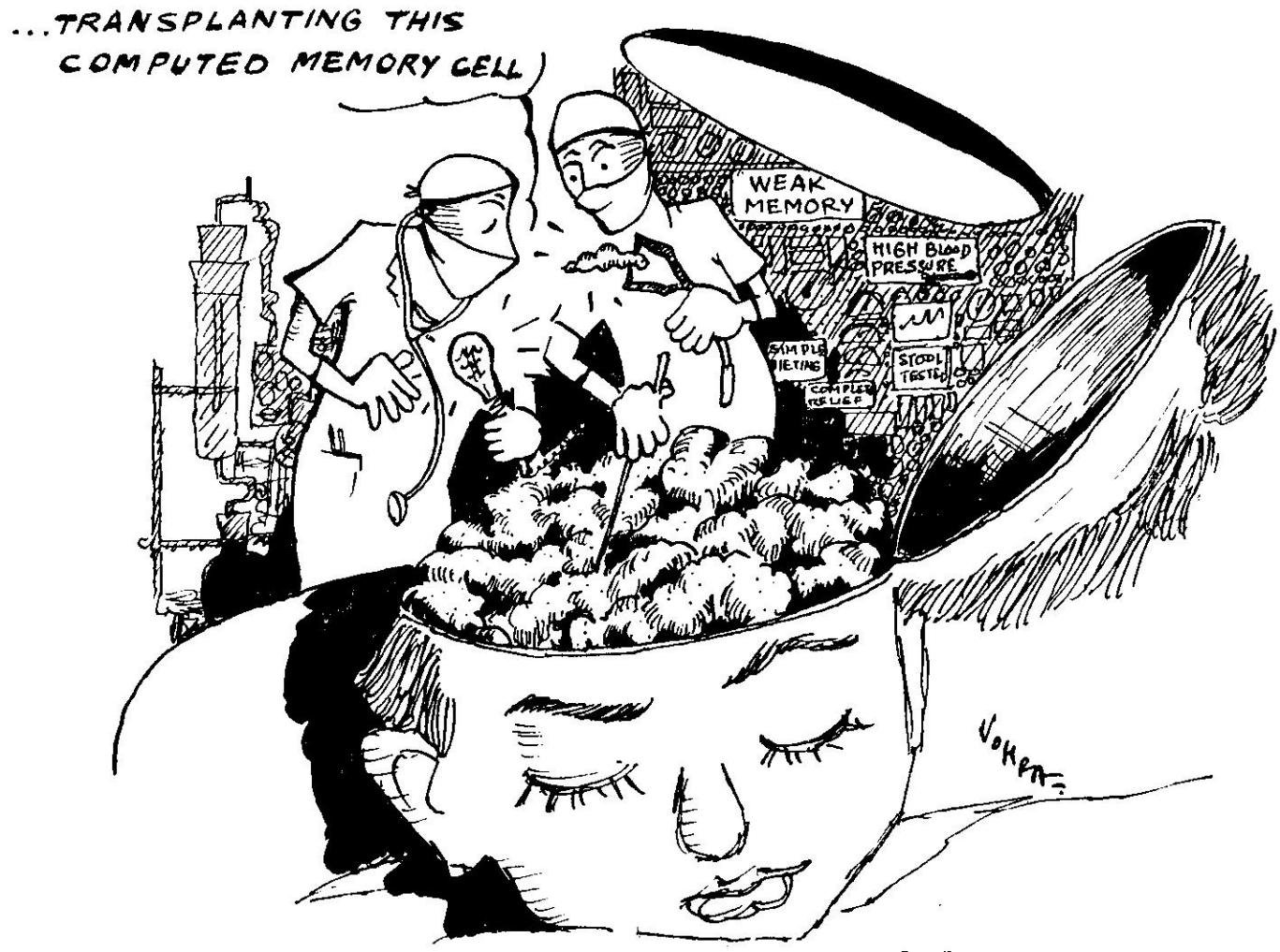
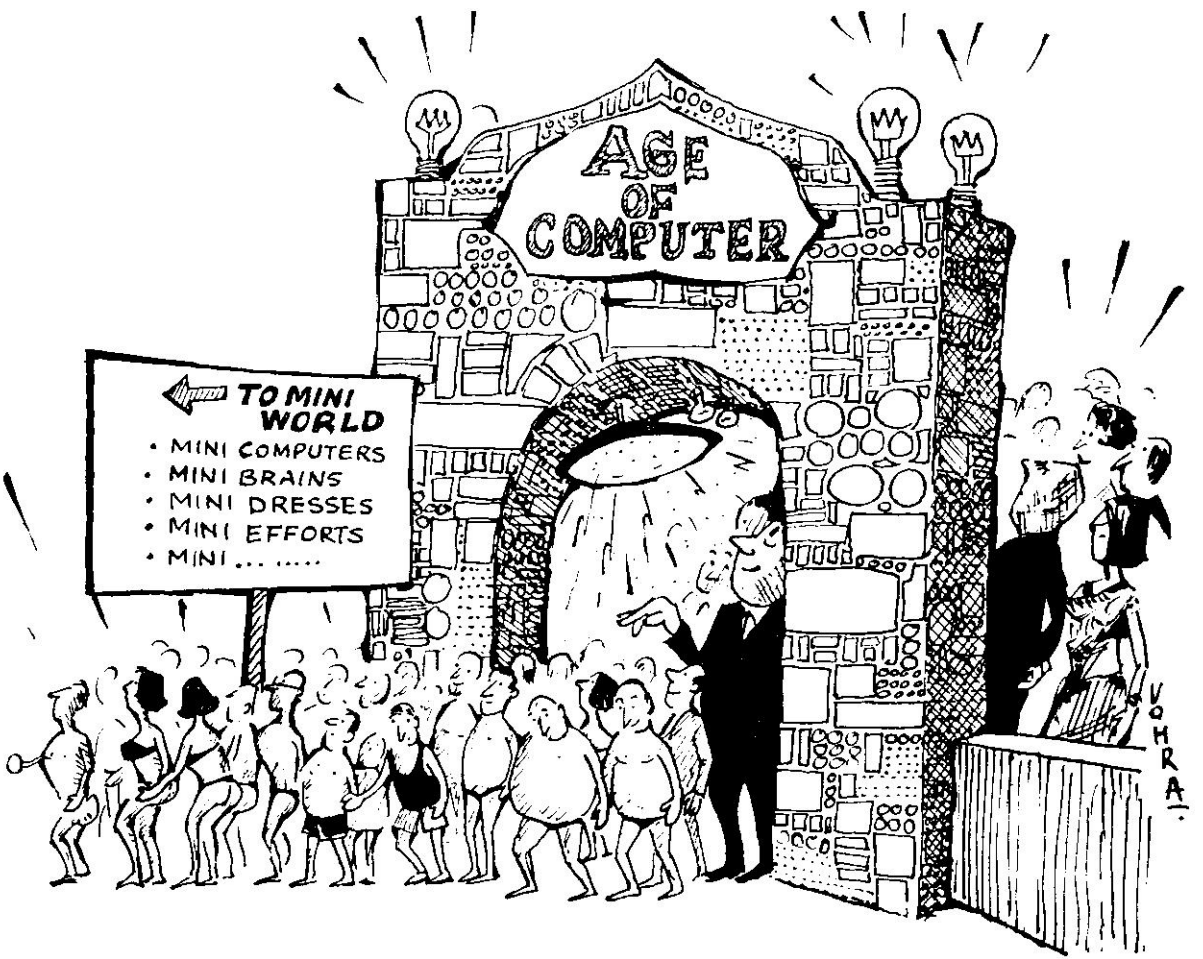

...TRANSPLANTING THIS COMPUTED MEMORY CELL
WEAK MEMORY
HIGH BLOOD PRESSURE
SIMPLE DIETING
COMPLEX RELIEF
STOOL TESTED
VOKER

of the economy as planned, it can just as easily also ask everyone what products and performance he wants.

The foundation of true free enterprise is the free market. The more that people are really free to choose how they will spend their money, and the more that the producer is willing and able to offer his ideas and goods for sale in the free market, then the closer a society comes to realizing the full potential of free enterprise. A nation that has conceivably managed to attain such a high saturation of computer-run information flow, reaching every nook and cranny of its economy, has the ingredient for the kind of free market that civilization has never before known.

Rapid dissemination of ideas for new products and quick follow-up into production of the popular proposals would serve to stimulate other ideas. So creativity, imagination and optimum application of resources in the sense of direct response to public will, would all be enhanced.

Science and technology, in every instance, offer men choices. They do not determine the direction society must go. ●●●



Cheapening The Conversational Computer

Donald Michie*

In this article, the author describes the work done at the Department of Machine Intelligence and Perception, University of Edinburgh, Scotland, U.K., indicating the notable economies achieved in time and money, in conversational computing.

'AFTER GROWING WILDLY FOR YEARS, THE field of computing now appears to be approaching its infancy. Recent revolutionary technological advances will eventually take us far beyond our newest, biggest and best computers'.

These are the opening words of a recent report made to the President of the United-States of America by one of the panels of his Science Advisory Committee. The development of multi-access computing, including the use of the public telephone network for "conversational" systems and for computer-to-computer linkages are prominent among the new advances.

Time-shared installations serving simultaneously dozens of remote terminals are becoming commercially available in the USA and the first American firms are already appearing on the British domestic scene with offers of these facilities for sale or rental.

In Russia, the State Planning Committee has ordered the development of a three-level computer grid (national, industrial sector, and factory levels) for aiding the co-ordination of economic planning.

Multi-access computing, in which many users interact simultaneously with a singl machine, is associated in most people's with astronomical costs. Understandably so the great American pioneering effort in thi direction, "project MAC" at the Massachusett Institute of Technology, has been costing

*Professor Donald Michie was recently appointed to a personal chair of machine intelligence in Edinburgh University's Department of Machine Intelligence and Perception. After early experience with World War II prototypes of the electronic digital computer, Dr. Michie embarked on a career as an experimental biologist, and is the author of some 80 publications in the field of genetics, reproduction, immunology and, more recently, computer science. After his return in the early 1960s to his earlier interest in computing and machine learning, he was Visiting Associate Professor of Electrical Engineering at Stanford in the United States of America and Royal Society Visiting Lecturer in Russia. He also conducted in 1964 a survey of computer science research in British universities on which he reported to the Science Research Council. This year he is being joined by H.C. Longuet Higgins, FRS, and R.L. Gregory, both from Cambridge, whose interests in this area are concerned with memory and with visual perception respectively. The new Department's post-graduate course is just completing its first year.

one million dollars per year merely to maintain. Most current attempts to construct commercially viable successors are tailored to very large and expensive systems.

Poor Man's System

I propose to describe a "poor man's system" for conversational computing, based on a family of new computing languages called "POP"—the current incarnation being known as POP-2*. Before I do this, however, I must first say something about why the question of *language* is all-important and, in general, the distinction between the "hardware" and the "software" of a computing system.

The hardware of a computer comprises everything you can touch and see—the central processor, the control console, the high-speed memory, the various forms of mass storage (magnetic drums, discs, tapes and the like) and the various peripherals, such as card readers, card punches, paper tape readers and punches, high-speed printers, cathode ray tubes for graphic input and output and remote terminals such as teletypes or keyboard displays.

A Fair Picture

Add to this any satellite computers needed to control and co-ordinate the ebb and flow of transactions between the central processor and the peripherals, together with cables and fittings for communication between the various parts, and throw in for good measure a few non-standard peripherals such as microphones for voice input, or scientific recording instruments feeding their captured data into the machine, and you have a fair picture of the hardware which makes up a modern computing system.

As it stands, however, this impressive-sounding list is of less use than a car without an engine or a man without a head. What do we need before life can be breathed into the mass of dead electronics? The life-giving factor is the **programme of instructions,** which will not only transform the mass into a machine, but will dictate precisely **which** machine, out of an infinite range of possible machines, **this** machine is going to be. If we read a new programme into it we turn it from a chess-playing, or tax-calculating, or weather-forecasting machine into a type-setting, or music-composing, or Russian-into-English machine.

In this article I shall be talking about a programme for turning a general-purpose digital computer into a **conversational** machine. This means a machine with which the users can converse in a flexible fashion, using a programming language which enables commands to be executed on the spot, and comments and requests to be exchanged between machine and user in a way reminiscent of ordinary conversation.

Software is Expensive

The first point to be made is that **software is very expensive.** It is not at all like the book of instructions which is given you free with your new motor car. These instructions would be priced in shillings, supposing you had to pay for them, as compared with hundreds of pounds for the "hardware" comprising the car itself, making a cost ratio of less than 1 : 1000.

The software/hardware cost ratio in computing is, by contrast, in the region of 1 : 1. This comes about as follows:

(i) A non-trivial programme is an exceedingly complicated affair.

(ii) Programmers must be employed to write non-trivial programmes.

(iii) The cost per programmer is about £6,000 per year (salary plus overheads plus the cost of the computer time which he uses to test the programmes he produces).

*The development of POP-2 and its Multi-POP implementation has been supported with funds from the Medical Research Council, the Science Research Council and the University of Edinburgh. Valuable advice and criticism have been given at various stages by Mr. Christopher Strachey, Dr. Michael Foster and Professor John McCarthy.

(iv) A large software project can employ a team of scores, or even hundreds, of programmers for periods of time measured in years.

An American commercial project to put on the market a multiaccess system has already consumed more than 1,000 programmer-years. In the case of this particularly ambitious project, much of the programming investment, amounting to tens of millions of dollars, has now been written off. The extreme intellectual difficulty of the task led to false starts which later had to be abandoned.

The costliness of software production is not a passing phase. Hasan Ozbekhan, Director of Planning at the System Development Corporation, California writes: "By 1975 computer hardware will become at least one and probably two or more orders of magnitude cheaper than current systems while computer software will decline in cost at a far slower rate."

He goes on to say: "Software costs, depending so heavily upon the production rate of human programmers, can decline only as fast as new tools (mainly higher order languages) are developed. Because of this trend the 1975 hardware/software cost breakdown of systems, now about 50/50, will be in the order of 30/70. (It used to be 70/30 ten years ago.)"

The Pop-2/4120 Project

A software programme was launched late in 1966 to provide the research staff of the Department of Machine Intelligence and Perception with advanced facilities for conversational computing within the limits of a relatively small equipment budget. It was decided that this could be done by expanding and rationalising "POP-1", a programming language already developed within the Department by R.J. Popplestone.

The POP-2 language, like its predecessor POP-1, is geared to conversational use and provides a wide range of facilities for tackling non-numerical problems. The present version runs on an Elliott 4120 computer, consisting of the following items of hardware:

Item	Approximate cost (with educational discount)
4120 Central Processor	£ 13,680
High-speed memory (32,000 words of six-microsecond core)	21,600
Control teleprinter	2,160
Paper tape station (1 reader, 1 punch)	5,760
Multi-teleprinter controller (8 channels)	6,750
20 teleprinter stations*	10,000

The total hardware cost is thus £49,950 for users eligible for the manufacturer's discount, and otherwise about £55,500.

The Cost of POP-2

Let us now turn to software costs, since this is where the reduction in scale of expenditure is really crucial. As stated earlier, designing and writing multi-access software typically consumes dozens, and sometimes even hundreds, of programmer-years—each programmer-year costing in the region of £6,000. The POP-2/4120 system was produced at the cost of less than five programmer-years, that is, for about £25,000.

The contrast is, in our opinion, largely attributable to the great simplification of the programmer's task. He can do his job in continuous interaction with the machine, trying new ideas and correcting errors in "hot blood", while things are fresh in his mind, and having at his disposal a powerful programming language free from arbitrary restrictions and complications.

This claim is based on a careful comparative study, including cases where it has been possible

*Does not include wiring or GPO data transmission facilities

A class of post-graduate students under instruction in the Department of Machine Intelligence and Preception at Edinburgh University, with eight teletype terminals in simultaneous use

to compare one and the same job done in two alternative ways: (1) professional commercial programmers using conventional languages, and (ii) by staff of our Department using POP-1 or POP-2.

Nature of Job	Time consumed : Conventional language	POP
Programme to interpret output from a recording instrument	6 months (job abandoned uncompleted)	3 days
Programme to do statistical calculations in conversational mode	1 year	3 weeks
Programme to edit text	6 weeks	1 day

Even if we were to allow a generous factor for a hypothetical advantage in skill or speed of our own programmers over the others, it is clear that substantial savings must be attributed to the power of the language alone.

Users of the System

Typical users of the present system would be:

1. **Engineers,** for whom a multi-POP console provides the electronic equivalent of a slide rule, but with a great increase in the scope and range of the questions to which he can get quick answers.

2. **Laboratory Workers,** especially in the biomedical area. Even more than engineers, these workers are reluctant to learn the art of programming. We have accordingly provided a software package, "POPSTATS", which makes a limited range of facilities available on the basis of English-language dialogue, from which the user need switch into direct POP-2 programming only if he wants to.

In an experiment supported by the Medical Research Council, a telephone link has been established between our Elliott 4120 machine in Edinburgh (Scotland) and a laboratory terminal in the National Institute of Medical Research in London. During the 12 months of 1968, the period in which the link will be operational, we shall have the opportunity of studying reactions to the POPSTATS facility from non-programmer scientific users.

3. **Schools and Universities :** POP-2 offers aid to teachers of computer programming who must stay within realistic financial bounds.

The photograph accompanying this article shows a class of post-graduate students under instruction in our own Department in Edinburgh with eight teletype terminals in simultaneous use. Allowing for the fact that the central processor can time-share with ordinary batch work in the machine room, the cost per student can be below £1 per hour. We find that after a total of eight hours' teaching in this style spread out over four days, we can regard them as adequately equipped to swim for themselves, with occasional further guidance. The total cost, of less than £10 per head, seems a satisfactory price to pay for this basic training.

A Computer can be fed with the symbols it is equipped to digest and its output is in terms of them : the machine that can in an instant calculate the speed and distance of the remotest nebula, can it in its answer convey the immensity and the awe?

—Ronimund Von Bissing

Electronic Computers and The Human Brain

Ted F Silvey*

Science provides a true vision of natural reality. There is a new phase of evolution, the human or psycho-social phase, which operates much faster than biologic evolution, and produces new kinds of results. The psycho-social phase of evolution is in its infancy : man as dominant evolutionary type is absurdly young.

"... Man's destiny, we now perceive is to be the agent of evolution on this earth, realising richer and ampler possibilities for the evolutionary process and providing greater fulfilment for more human beings... The better realisation of man's intrinsic possibilities has barely begun. Few human beings realise more than a tiny fraction of their capacity... Man is equipped with a modicum of intelligence, but also with an array of conflicting passions and desires. He can be reasonable, but is often extremely stupid. He has impulses to sympathy and love, but also to cruelty and hatred. He is capable of moral action, but also has inevitable capacities for sin and error... The individual human brain is the most complicated and highly organised piece of machinery that has ever existed on this earth. So-called electronic brains can perform extra-ordinary tasks with super-human rapidity, but they have to be given their instructions by men. The human organism can give instructions to itself and can perform tasks outside the range of any inanimate machine. Though at the outset it is a feeble instrument equipped with conficting tendencies, it can in the course of its development achieve a high degree of integration and performance."
—Julian Huxley : *The Future of Man*

SPEAKING ON THE OCCASION OF THE 100TH Anniversary of Charles Darwin's *The Origin of Species*, Sir Julian Huxley cited the last 500 years of man's history as the age of exploration and concluded that man had pretty well pushed himself out to the ultimate frontiers of the planet Earth. He then prophesied that the next half millenium of man would be a new age of the human brain and that the exploration of the human mind is the next project to engage mankind.

*AFL-CIO Research Department, Washington

There is much new knowledge now about the apparatus called the electronic computer. It is a new machine, so new that it is not yet of voting age. My own study of the electronic computer has arisen from the new industrial technology called automation. When we work or engage the processes of living we use the marvelous combination which is our body and our brain which are now extended and replaced by non-living apparatus.

The small amount of knowledge I have acquired from my study of it has taught me more respect and reverence for the human

brain than I obtained from all the teachings of religion. There are twelve thousand million neurons in the human brain each one equipped to receive sensation through its dendrites and in turn to transmit information along its axons and across its synapses. How this function enables the formation of thought, intelligence and imagination along pathways of either deliberate or random association, is a miracle as of now beyond comprehension of any electronic genius, or even the brain neurologists themselves. The circuitry in the human brain whereby every information-containing neuron can have a relationship with every other information-containing neuron is mathematically in range of the number of the heavenly bodies themselves.

I am told that from a deck of 52 playing cards there can be dealt over two million different hands. A computer itself would be needed to determine the endless combinations of twelve thousand million fully equipped and operating neurons. But this figure would be the ultimate in cranial achievement. The brainiest human who ever lived never has used more than an infinitesimal fraction of the total.

The unused potential even in an environment conducive to utilisation gives at least a physical base for fulfilment of the promise of Huxley for brain use during the next 500 years. Perhaps it will take that full time to realise this full utilisation

Certainly, our first obligation is to realise the wonder of the human brain, to exercise it, to use it, and, in doing so, to colonise its uninhabited areas. It is conceivable that even while we yet live there can be some mental pioneering on a scale comparable in the new breakthroughs to the simpler earlier geographical California gold rush, the Cimarron land dash. The unexplored area is there awaiting the push of ideas and the settlement of new psycho-social patterns.

Mille, Micro, Nano

The electronic computer operates its circuitry in milleseconds and microseconds, even in mille-microseconds, or, as the engineers call it for convenience, nanoseconds.

Light travels at 186,382 miles a second, electricity surges through wires almost as fast. In a thousandth of a millionth of a second—a non-second—an engineer can move electricity through the circuitry of an electronic computer about 11 3/4 inches, give or take a couple of 64ths. The brain circuitry cannot function so fast, but it can operate fast enough at least to begin exploration work that is the promise and hope that Huxley offers.

Old and New Brain

One learned physician, the British Dr. ATW Simeon in his book *Man's Presumptuous Brain* accounts for this conflict within man because the cortex of man's brain—the proliferation of matter which in its present stage permits thought and imagination got going too fast for the comfort of the evolutionary ancient diencephalon. There seems to be a warfare within us, between the "old brain" and the "new brain", "...a conflict between diencephalic and cortical behaviour".

Dr. Simeon cites the embryologic growth through 200 million years, telling how all mammals have followed the same pattern of brain development, except that the human creature has enjoyed the advantage of additional growth in the frontal lobes of his brain.

The price we pay for the brain circuitry we have is that we had to drag along with the new brain the frustration of the old brain, and that the primitive brain stem which still remains in the amphibious and reptile life as well as in the four-legged mammals, also is still contained in the bone box on top of our human necks. ●●●

"My trouble is that I was brought up in the old-fashioned idea that a man, minister or *chaprassi*, has to do something in the course of a day to earn his keep".

—from the "Ditcher's Diary", *CAPITAL* (Calcutta) 27 Feb. 1969

Impact of Real-Time Data Processing Systems

TB Ward*

THE CONCEPT OF "EVOLVING GENERATIONS" which has been employed to describe the development of computers is an apt and useful one. The tremendous technological pace of hardware development produced qualitatively different classes of computer at clearly defined stages in computer history. The machines of the early fifties were really **high speed calculators** whose memory storage was used primarily for scientific and mathematical formula associated with the particular applications to which the machines were directed. The technical limitations of this stage expressed themselves in thermionic circuitry, machine language, programming, and very primtive software, and difficult, unreliable operation.

The so-called second generation of computers were characterised by solid state circuitry, assembly languages for programming and reliable operating systems

The obvious advantages of this advanced equipment widened the commercial applications to which computer-assisted solutions were directed, but generally speaking data processing consisted of **completing existing jobs "a little more cheaply and more quickly."** The method of doing these jobs was essentialy "batch processing". The given work of some "accounting period" was assembled and processed and, however short the accounting period might be, the principle of historical processing was the same.

The advent of the third generation of computers brought about an entirely different situation in industry and commerce. In addition to a greater sophistication of software, particularly in overall Executive Control programmes, there has been the enormous **revolutionary development of direct man-machine communications.** Not only has this direct input to computers eliminated the time-consuming data preparation which is still a feature of most computer installations, but, more importantly, has introduced the concept of **"real-time" data processing.** No universally agreed definition of this basic concept exists but on-line real-time data processing is characterised by a system capable of rapid response to input stimuli which may originate at terminals located a considerable distance from the central processor. There is direct communication with the computer memory so that information can be continuously fed in and processed. **The output from the computer is available at the point of transaction in**

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time to affect the outcome of the transaction itself. In other words we have the possibility of a data processing system in which the computer itself has become time-critical. The provision of large, economic core storage, with high speed cycle coupled with sophisticated software has made possible the use of multiprogramming techniques which permit a much more effective employment of the central processor. An important parallel feature, the ability of the central processor to handle a whole range of peripheral equipment, often simultaneously, has greatly extended the optimum utilisation of expensive equipment.

Problems of Real-Time Data Processing

The advantages of real-time data processing, considerable as they are, cannot be acquired without considerable effort. At a technical level there are few people with any experience of this new technique and, more to the point, very few managers are yet aware of the advantages of the new development in data processing. The "conversational mode" type of input is expensive to operate and managements need to be clear about the economic necessity of real-time updating. One of the best examples of real-time systems is the airline seat reservation system now being increasingly operated by the airlines of the world. It is in the nature of air travel that the passenger load is subject to constant changes. Last minute cancellations of long standing reservations are inevitable along with frequent route changing of individual passengers. Because the pay-load of each aircraft is economically critical, it is essential to know what seats are available right up to the moment of closing of the passenger list. It is equally important to be fully aware of alternative flights and routes and the loadings of all other related aircraft. This total information can only be achieved by completely up-to-the minute information representing the net result of a constantly changing situation.

Intrigued by the instant information available on a real-time basis many managements have applied the techniques to inventory control, believing that exact knowledge of the level of stocks at any given moment is important information. This is rarely the case. The most managers need to know about inventory levels is that the overall stocks are not becoming economically insupportable or becoming too low as to endanger the possibility of meeting the immediate future orders. The first information can be acquired by periodic accounting reports and the second by effective reordering levels. Very rarely will the expense involved in knowing "exactly how many, now" be worthwhile. The management fascination with techniques in real-time data processing expresses itself in another form. This form of processing requires direct input and gives the facilities for an enquiry operation so that a dialogue between the computer and input operator can be achieved. This can be done with a teletype, using the same machine for a print-out of the required information. But, apart from being a comparatively slow operation, a visible record on the information being processed is rarely required.

New Developments in Input

By far the most advanced method of computer input in a real-time mode is the Cathode Ray Tube (CRT) display system. By having a television type display terminal connected to the computer memory it is possible to get direct access to the information in the memory and display the required information in conventional characters on the screen. **With suitable programming it is possible to conduct a dynamic enquiry and action sequence.** The information can be updated, manipulated, stored or printed out as required. Thus **the almost perfect man-machine symbiosis is achieved wherein the vast memory content and high speed symbol manipulation of the computer can be used as an immediate extension of man's own abilities. The required data for decision-making can be available at the point of decision and at the moment of decision.**

This tremendous flexibility can, of course, only be achieved at a price. The CRT form of input is literally an expensive method

to use, as each terminal, with associated control equipment, costs about £3,000 sterling. **The more important price which has to be paid is the loss of accepted forms of verification. The ability of computers to operate at phenomenal speeds on incorrect data is known to every data processing manager.** Elaborate programming checks and operational commentaries are built into all computer systems to ensure that the data being processed is correct. With traditional forms of input (punched cards and punched paper tape) the general practice is to verify the original data by having the source documents re-punched by a second operator using a special machine which reads the original cards or tape coincident with the re-punching. Any discrepancy between the two causes the machine to "lock-out" until the difference is noted and the correct information is inserted. Thus, ignoring the low probability of compensating errors, a "clean" input tape/card is produced. This is clearly a time-consuming and expensive operation, but preferable to stopping the data processing cycle each time an error is located. It is clear that **the CRT method of input allows no form of independent verification from the original input operator.** It is possible to arrange a monitoring system to permit random checks on given input by a supervisor, but clearly this is no substitute for organised verification. Recognising the difficulty of this problem, electronic engineers responsible for the design of CRT sets have made provision for the operator to eliminate from the screen all information except that which is required to action. Helpful though this facility undoubtedly is, the basic limitation remains that information is being released into the system by the operator who originated it. In other words, whilst **the CRT system is an excellent enquiry and conversational system, it is not as yet a good general input system.**

There is a further area of doubt concerning the use of CRT systems. Not enough is yet known concerning the physical and psychological effects on operators who have to sit in front of a small screen interpreting characters which, from the very method of their creation, have a certain instability. Certain users of CRT equipment have expressed unsupported fears of a **subliminal effect on the operator's vision** and at least one major user advocates the introduction of an arbitrary break period in each hour. The current major users of CRT equipment (the various international airlines) may not yet have exposed this problem. The very nature of the work (enquiries on seat reservation) suggests an intermittent and varied activity. A successful enquiry leads to a seat reservation with the consequent filling in of documents constituting a change in activity. This may form a very welcome break from starting at a small, densely packed screen. The use of CRT sets as the major form of data input to replace conventional punching equipment implies operators who are employed full time on the limited job of creating data input for source documents. Considerable research needs to to carried out on the effects of such work.

Effect on Management

The greatest impact of real-time data processing will undoubtedly be on management. Both the quality of individual managers and the structure of management organisation will require to change in the future if sufficient advantage is to be taken of this form of instant information. The CRT screen can display the contents of the computer memory in any format for which it has been programmed. Alternative expressions of the same information can be presented, provided the necessary programmes have been pre-written. But this implies that management have thought out in advance their requirements and such is rarely the case. It is paradoxical that **the apparent simplicity of the real-time approach carries all the danger of over-simplification. Many managers appear to think that the computer system is capable, of itself, of answering questions and providing them with the answers to any problem they present.** It cannot too often be stressed that **the computer is a peculiar machine in that it does not produce anything at all. It is a symbol manipulator, with a memory bank and a capacity for obeying in-built**

instructions. The computer can only provide answers to questions which someone has pre-supposed will be asked and has written a programme to provide for this. The computer represents a tremendous extension of managerial quality; it is not, and cannot be, a substitute for managerial skill.

Few managers, even in the Western world, have any basic knowledge of computer operation. They are not geared to the speed of decision taking which the computer makes possible. They are uneasy about **the loss of visible records which an effective computer system implies** and, for all the talk about management by exception, most managers are reluctant to act merely on the selective information the computer system may have been programmed to provide. Managers tend to demand "all the information" so that they can select the best course of action. This demand is sometimes put forward under a guise of flexibility when it really is just a delaying device to arrive at an answer to the problem. In modern business few managers have insufficient information and most of them suffer from a surfeit of irrelevant information. What is required is not a lot of detailed information in order to make a decision, but a **"decision model" in the minds of management, which will determine in advance the kind of information needed to enable the decision to be made.**

Generally speaking, managers have been trained to utilise their practical experience to cope with the deviations from the norm which make up **the constant crisis situation of business.** Very few managers anticipate the possible situation and have alternative courses of action plotted out. **The presentation of information to provide for all probable courses of action is the essence of real-time data processing.** We shall need to train a new generation of managers altogether if we are to be able to take advantage of the new techniques.

It is almost inevitable that the conventional structure of management, generally in use in business, will be changed. This can be appreciated more easily if we regard the organisational hierarchy in management as a reflection of the data flow in a company. This is usually a two-way process with instructions being fed down from the Chief Executive through a pyramid of relationship to the operators at the base. The information flow is two-way as the instructions often require to be modified in the light of the practical realities existing when the instruction comes to be carried out. The role of middle management is a filtering process for both instructions and feed back information. **In a real-time situation, however, all the required information is available to top management on demand and this allows the instructions to be issued in a much more definite form without needing the interpretative function of middle management. As the consequences of the instructions can be ascertained quickly and directly, the feedback role of middle management is equally called into question. This speeding up of the information cycle also denies middle management the ability they now have to "soften the blow" of unpleasant information. The position of middle management is therefore likely to be weakened and their numbers reduced.**

On the other hand the technical complexity of the new systems will necessitate management encouraging more specialists at the top of the management pyramid and because of the far-reaching implications of their expert advice they **tend to acquire "executive" rather than "staff" status.** It is easy to understand the reluctance of a middle manager to reject the considered proposals of a computer expert or operational research analyst. In classical organisation theory the problem of the specialists is met by the so-called "line and staff" structure. This theory taken over from military practice, assumes a situation wherein the line management knows what it wishes to do and the task of the staff specialists is to determine how best to achieve the aim with the technical resources available. The computer specialists have a much more dynamic role than this; their job is to initiate change and to persuade management to utilise techniques that few of them understand. Such specialists can be

effective only if they report to the top of the management structure. **The consequences of the advice they give are so great and so few managers can ever be in a position to dispute the conditions that direct representation of the specialists at the top of the management tree is inevitable.** This development implies a consequent weakening of the middle management influence and a restriction of the future role of such managers. Thus the shape of the future management structure is likely to depart from the triangular hierarchy.

Effect on Management Development

The development of real-time data processing underlines the pace of technical development in the computer field. In the 12 years or so that computers have been applied to commercial problems the rate of change has not only been great but it is increasing. In Robert Oppenheimer's famous phrase "THE EARTH CHANGES AS WE WALK ON IT." The enormous possibilities inherent in advanced data processing will require a generation of managers quite different from that which produced our tradtional industries. It is no longer a question of acquiring many years of relevant experience in order to cope with deviations from the accepted and slow moving pattern of things. We need managers, trained in a number of disciplines, whose main attributes will be a keen and critical intelligence coupled with a flexibility of mind and knowledge of the newest thinking in the field which will enable them to see any situation as a set of logically related variables.

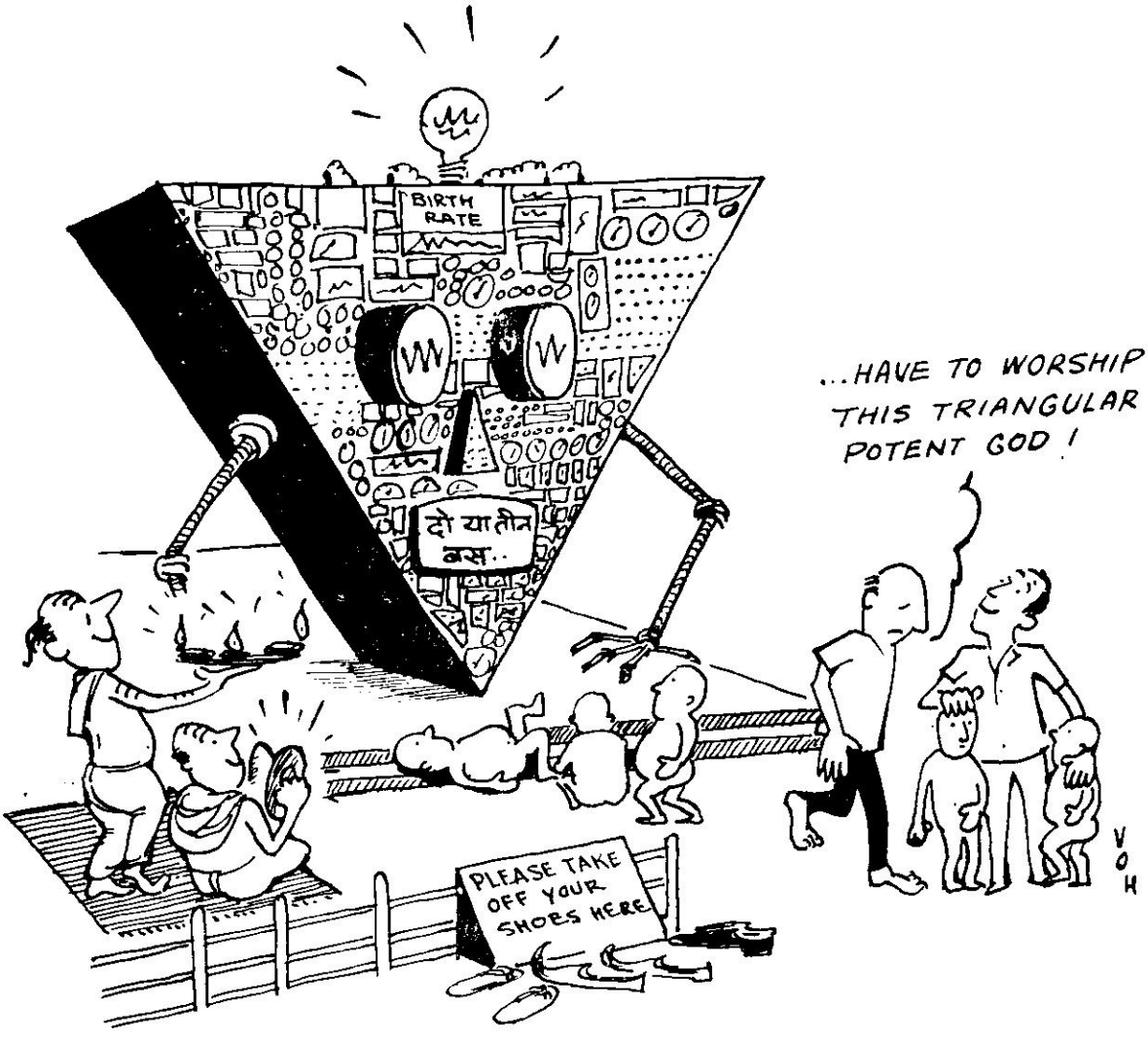
It is the decision-making propensities of management which real-time data processing will cause to be developed. Such decision taking will have little in common with the obvious deductions which constitute most of a present day manager's activities. Relevant experience with operating details will have little to contribute to the management requirements of the future. **One can readily visualise a situation wherein the top management of the future meet informally in the "information room" which has facilities for large screen presentation of information requested from the company's computer network. Simple input devices in the hands of several managers will allow the manipulation of this information to indicate the consequences of alternative strategies.**

The central parameters on which the company operates will be clearly stated and **policy decisions reached on the spot, or following a closed-circuit television conference with interested parties.** Such positive reaction to a changing situation implies a different kind of management from that which we currently employ or are even training to produce. Companies entering the field of real-time data processing will need an effective management development programme and expansive training schemes to ensure themselves of a continuing supply of the right calibre of staff. Whatever technical marvels are achieved in the next generation of computers, business will continue to be short of competent people.

Developing countries, such as India, may be able to take advantage of the experience of the more industrially advanced countries and avoid the limitations of batch processing, but only if they study carefully the lessons of that experience. ●●●

The parts also opposed introduction of automation and use of computers. Large-scale mechanised industries should form the apex of the economy with agriculture or village industries as the base, and not the other way round as the Congress had attempted.

—*THE TIMES OF INDIA*, November 5, 1968


BIRTH RATE
दो या तीन बस..
...HAVE TO WORSHIP THIS TRIANGULAR POTENT GOD !
PLEASE TAKE OFF YOUR SHOES HERE
V O H

The Electronics Industry in France*

The French electronics industry, with a turnover of 7.9 thousand million francs and a total of 130,000 employees, cannot really be assessed in relation to these two figures, which represent only a little over 1.5 per cent of the gross national product and 0.6 per cent of the country's working population. Electronics are in fact part of what is known as the "group of dominant industries", and play in the economy a driving role which is more important than these percentages would suggest. This is explained by the vitality of the industry, its ability to solve problems of "intelligence" and the repercussions of its development on that of other industries.**

OVER THE PAST TEN YEARS PRODUCTION OF electronics in France has multiplied by five, whilst that of the country's industry as a whole only doubled, and it is reasonable to expect that, in ten to fifteen years, the turnover of electronics has every chance of becoming one of the largest among the nation's categories of consumer and capital goods.

The high percentage of sums spent on research and development in relation to the turnover has enabled France to become one of the four leading manufacturing countries for electronic products, in a filed where technical evolution is occurring at very great speed. The industry can thus compete actively for foreign outlets, and over 20% of its production is exported to more than sixty countries.

The word "electronics" describes at the same time a scientific discipline and a group of industrial activities. As a scientific discipline, it is concerned today with the study of the electron and other corpuscles, and of the phenomena of propagation of electromagnetic waves in space, gas or semiconductors. The group of electronic industries is the one which manufactures appliances based on these phenomena, and incorprorates them into complex machinery.

France was the first country to develop a large-scale electronics industry, and it was this supremacy which led the French radio-electrical industry (as it was then called) to supply all the Allied armies telecommunications equipment during the First World War.

Today it is no longer possible to claim supremacy, but it can be said that, despite the ground lost during the Second World War, the French industry is once again playing an important part where both the quality of production and the manufacturing range are concerned.

*Published by the courtesy of Press Information Service of French Embassy, New Delhi.

**They have also made available to us relative statistics of turnover in various countries. Though these figures are now outdated, we have printed them here, as they represent the broad order of magnitudes.

Production

The electronics industry can be divided into three main branches :

—Components

—Consumer goods (i.e. appliances for domestic or general use),

—Capital goods (i.e. equipment for industrial, scientific and other specialised technical purposes).

Components: The components or the separate parts and assembled parts used to manufacture capital and consumer equipment are of two kinds: active components and passive components.

Passive components are the parts needed to set up circuits: resistances, potentiometers, condensers, coils, transformers. There are also certain non-electrical manufacturing parts, such as valve holders, etc.

Active components are mainly valves and tubes and semi-conductors, i.e. the parts that are essential for the modulation and control of a flow of electrons. They are the characteristic parts of electronic equipment.

Lastly, assembled parts grouping several active or passive functions are also included under this heading; for example, the more recent developments of "molecular" electronics such as integrated circuits.

Consumer equipment: This branch includes:

—Radio and television receivers;

—Electro-acoustical apparatus, i.e electronic equipment for sound recording and reproduction (record players, tape-recorders, amplifiers, public address equipment, hearing aids, microphones, etc.)

Capital equipment: This branch covers an extremely wide field :

—Telecommunications equipment, from hertzian beams to battery chargers, long-distance signalling equipment, telecontrol, telemetry, commuting equipment, etc.

—aids for marine, river and air navigation;

—radio and television broadcasting equipment;

—treatment of information, with analogue and digital computers;

—industrial applications of electronics, sensors, process control and instrumentation equipment;

—electronic measuring instruments;

—all the equipment of electronic physics, medical electronics, etc.

Links between the various branches of electronics: The production of electronic components is an "upstream" activity which supplies the other two branches. The components are the essential parts; the quality and performance of the finished goods depend on them. This explains the considerable importance attached to research in this key branch of the industry and the sums devoted to it.

The highly demanding specifications of capital equipment, mostly ordered by government departments for spatial, military, nuclear purposes etc., have led indirectly to developments in domestic equipment. Conversely, the mass production of consumer goods has served to try out certain components and has enabled the enormous expenses incurred for research and development to be paid off.

The demand among the general public and the orders passed by the State are thus the two direct and indispensable supports of progress in the component industry. In the United States, the massive and lasting aid given by the authorities enables firms to promote research and development in the field of components and capital equipment. In Japan, on the other hand, the component industry owes its development to the considerable public demand.

Factors of Production : The importance of raw materials and their share in the industry's cost prices vary widely according to whether they concern consumer or capital goods.

A great many different raw materials go into the manufacture of components. A consi-

derable number of those which must comply with highly advanced specifications have to be imported: in particular very pure metals (nickel, germanium, silicon, tantalum, high-conductibility copper) certain chemicals, certain insulating materials and protective coating materials which are practically not to be found in France.

Manpower: The following things come to attention :

—the swift increase of manpower, which has risen from 60,000 in the mid-fifties to 128,500*;

—the high proportion of management and clerical workers;

—out of 128,500 persons employed in electronics, 55,000 were management and clerical staff and 73,500 were manual workers.

The recent evolution towards an increasing percentage of highly technical personnel is particularly remarkable. Its consequences are:

—alongside the traditional categories (manual workers, management and clerical staffs), an intermediary category of technicians is arising. The proportion of manual workers is tending to fall;

—the very great importance of training in this industry.

A large proportion of the wage-earners are women. They account for about 60% of the total (44,500 women out of 73,500 manual kers) and are divided up as follows:

50% unskilled workers,

77% semi-skilled workers,

22% skilled workers.

Over the last twenty years, the electronics y has been evolving in the direction of ncreasing concentration. This movement is continuing, and will undoubtedly go on doing so in the future, owing to the pressure of competition.

Geographical position: Most electronics works are situated in the Paris region, but a number have been established further afield in pursuance of the industrial decentralisation policy followed in France during the last few years. These have settled mainly in Western France and in the South-East (Dijon, Lyons, Thonon, Grenoble, Nice, etc.). The movement of electronics out into the provinces is important: the lightness of the industry's equipment and its independence with regard to supplies and transport make it highly suitable for decentralisation. **The restricting factor is the intellectual climate required in view of the high percentage of management personnel and qualified engineers employed by the industry** (8% **of qualified engineers on the average**). The intellectual climate can not only make their lives more congenial, it is also indispensable for the recruitment of senior grades, for the education of the young. This is why **the electronics industry can only be decentralised to places which already have an active scientific life,** as is the case in Grenoble, Dijon and Angers, where a number of factories have established themselves over the last few years. It is estimated today that 35 to 40% of persons employed in electronics are working in the provinces

Importance of Research

Electronics is a new technical field of fast developing potential, whose importance can probably be better grasped in terms of the efforts being made to lead it into the future—from the money spent on research and development (see Table on page 24).

In 1970, France will be devoting to scientific and technical research and to research-development about 2.50% of her gross national product compared with 1.70% in 1963.

As a "brain" industry, electronics is the sector of activity which contains the greatest number of research workers. The large firms

*These and other figures given here are outdated ut they do give a good impression of the nature of this rowth Industry

	United States	Great Britain	France	Federal Republic of Germany
Expenditure on electronic research and development :				
—in % of the country's total expenditure on research & development	22%	12.5%	14.6%	12%
—in millions of Francs	19,200	1,190	907	810

possess modern and very extensive research centres which sometimes employ several hundred scientists from the most advanced branches. These centres are equipped to give full effectiveness to the efforts undertaken. They are usually situated in the Paris region, so that very close links can be maintained with the various government departments, with the universities and their laboratories and with the policy making organs, which are in Paris.

Alongside the industry's own efforts, a number of public establishments are endowed with large-scale research facilities, and are in the forefront of the technical subjects which they are studying: this is the case of the CNES (National Space Studies Centre) for spatial activities, the CNET (National Telecommunications Studies Centre) for all questions concerned in particular with telecommunications by satellites, the CEA (Atomic Energy Commissariat) for all matters relating to the scientific and economic study of this new form of energy, the ORTF (French Radio and Television Organisation) for the study of television equipment and for recording methods. These organisations also play a part, in broad cooperation with the industry, in orienting and coordinating the work carried out by private enterprises.

The DGRST (Delegation-General for Scientific and Technical Research) was set up in 1958 with the specific purpose of orienting research and selecting the various axes along which efforts must be concentrated.

Trends in Electronics Industry

The demand for consumer goods will develop only slowly in the coming years. This demand, which has been one of the driving growth factors of the electronics industry over the last few years, will be slowed down by the gradual saturation of the market. Saturation has already been reached where radio receivers are concerned; the slackening of television sales seems to be due to general economic considerations and these are expected to resume their upward trend until the still distant time when the market will become merely a replacement market.

The industry will become increasingly a capital goods industry, with a **preponderance of equipment for civilian purposes.** There will be a sharp rise in this field, caused by the fact that new applications are found almost daily for electronics (government departments, transport, telecommunications, health services).

The **international market** for electronics will also grow more important. Foreign out will become increasingly necessary, for development and launching of electroni equipment can only be made economic by mas production on an international scale.

Furthermore, the electronics industry undergo a new technological revolution, co sisting of an increasingly generalised use **micro-electric appliances** in the facture of new equipment.

To enable the industry to face up success fully to these fundamental modifications, t companies and the State must ensure industrial structures are suited to the needs an intensified research effort and of a read ment of production facilities to the new opp tunities.

The State services will have to develop th existing policy of supporting the nation

technical and industrial effort, and to commit themselves fully to a few major projects liable to polarise the activities of the research workers, technicians and industrialists.

Forecasts for 1970	**Value in thousand million Francs**
—Consumer goods :	
(radio, television, electroacoustical equipment)	2.9
—Capital goods :	
(professional electronics, computers, measuring instruments)	5.7
—Components :	
active and passive	2.8
TOTAL	11.4

Conclusion

The future of the electronics industry rests chiefly on the stimulus provided for it, directly or indirectly, by the major State services through their equipment programmes : directly when orders are received for capital equipment (Armed forces, Posts and Telecommunications, Radio and Television Organisation), indirectly when what is involved is the development of infrastructures on which the domestic market depends, and, as has been seen, this market is an essential support.

The State must therefore choose the most promising lines along which the efforts of the industrialists, scientists, and engineers must be concentrated, and must finance an important part of the research relating to these programmes. Indeed, the French electronics industry cannot tackle everything in its own field, and the authorities can play a decisive role in the process of selection. Already, there seems to be a tendency to pursue three main themes : spatial activities, the industrial applications of electronics, among which computers occupy an all-important place, and transmission of data.

Where consumer goods are concerned, the development and competitivity of this branch depend mainly on a broader national market, which alone can enable it to stand up to foreign competition at home and, at the same time, be competitive abroad. There are grounds for thinking that, under the Fifth Plan the public's increasing demand for sound reproduction equipment of high quality will enable these objectives to be achieved.

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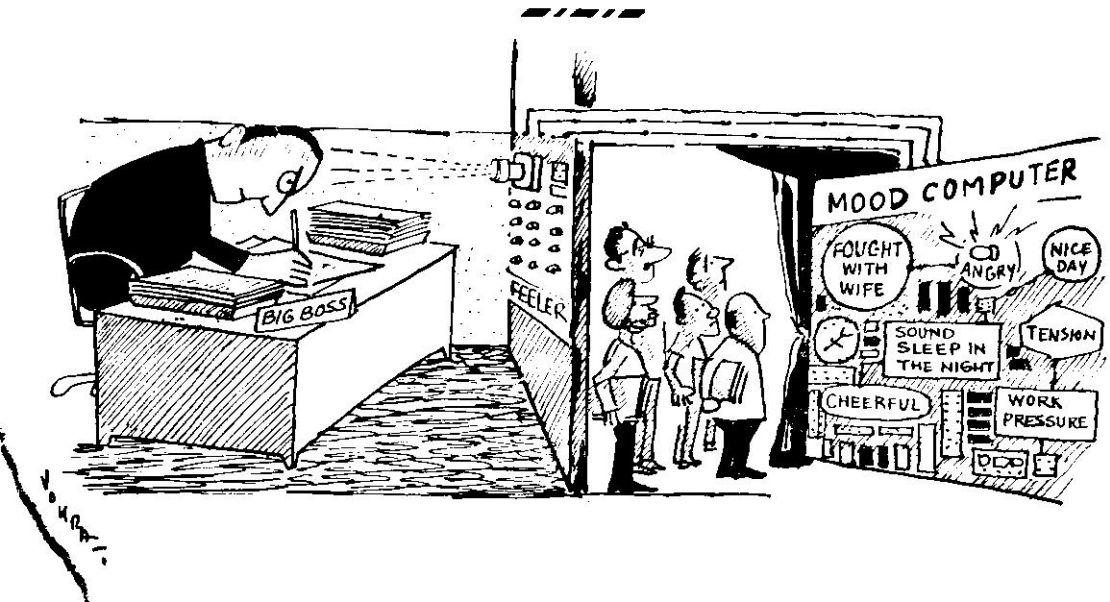
In addtion to the material printed above, the Press Information Service of the French Embassy have also furnished us additional information on the 'Development of Electronic Telephone Exchange System in France, which is of topical interest.



Development of Electronic Telephone Exchange System in France*

France will put its first electronic telephone exchange system into operation in 1969. The system will be installed in Paris and will serve two thousand subscribers. If this proves satisfactory the government will buy a lot more similar equipment in the early stages of the 6th Plan. French technicians have already had experience of the revolutionary techniques involved. In March 1966, about one thousand specialists from 27 countries met at the UNESCO Palace to review the work already achieved in this field. About 150 reports were read to the conference, and it then became clear that development had moved on from the experimental stage and that the first systems were under construction.

Mass-production has begun in the United States with ESS 1 type telephone exchange, while in Great-Britain the REX system is being developed—Germany, Sweden and Japan are now finishing work on similar projects.

Experiments on electronic telephone exchanges are being carried out in France by the CNET (National Centre for Telecommunication Studies) at their new laboratories in Lannion (*Cotes-du-Nord*). Development has been carried out in three stages and each stage has been given a classical nickname : Aristotle, Socrates and Pericles.

Aristotle refers to Europe's first totally electronic telephone exchange and has been in operation at Lannion for more than a year. It is used for internal telephone contacts at the centre. It was preceded by Socrates, a semi-automatic system. Pericles is the future Paris electronic exchange and a scale model of this system is now in operation at Lannion.

The electronic telephone exchange system differs from the traditional one in the following way: the basic task of an automatic telephone system is to make and break contact between two subscribers' lines at the beginning and end of the call. Until the present time, this operation has been carried out by exchanges using the principles of electro-magnetism, with mechanically-operated switches, to make and break contact. This is known as the "cross-bar" technique, which is easy to maintain but very cumbersome and takes up much space. This fact has made it increasingly difficult to construct new systems in modern cities.

The electronic technique does away with this unwieldy machinery. Socrates yielded a 25 to 30 per cent economy of space. Later the development of transistorised contact-switches produced a 50 per cent economy, with Aristotle. Pericles will reduce the size of the system by 75 per cent, with 32 different calls travelling through the same line, by splitting each call 8 times per second alternately as it goes through the line. This is the so-called "temporal" switch system which is a great advance on the old "spatial" system.

But even the mastery of this extraordinary technique is not the end of the road, although it has brought technicians very far already. However experts foresee the time when development work now under way will lead to an exchange system without any network at all and no physical link between callers. Every operation will be carried out by an electronic computer which will handle a telephone conversation in the same way as a computer now handles its "information". That moment has not yet arrived, but it is on the way. ●●●

*Press Information Service of the French Embassy

Development of Computer Technique in Czechoslovakia

Ing Zdenek*

Automatic computers are an efficient tool for automation of scientific, engineering and economic calculations ; for automatic processing of aggregate data in administrative, executive and registration activities ; for planning and managing industrial, trade, financial and many other kinds of organization ; as a means of direct control of manufacturing and technical processes in real time, and finally as an invaluable aid for introducting scientific methods to national economy planning and political management. Naturally, computerisation has become an important subject of interest of the technical policy makers in a socialist country like Czechoslovakia. Czechoslovakia, an industrially advanced country with a developed raw-material industry, heavy engineering capable of supplying complete plants for various industrial concerns, with a large volume and concentration of production in the processing industry, with well establi hed research project and design facilities, long-famous educational institutions of the highest level and professional schools, and a mature, traditional civilization and culture of an old country, just cannot do without a widespread application of a technique as progressive and ever-advancing as automatic computers.

BEFORE PROCEEDING FURTHER, IT MIGHT SERVE a useful purpose to first review the previous steps in the development of the applications of computer technique in Czechoslovakia. Soon after the Second World War, Czechoslovakia started independent production of punched card machines and thus joined the ranks of nine such countries in the world. Their export assignments notwithstanding, the producers of these machines were thus in a position to outfit various Czechoslovak production, trade and administrative organizations with almost 1,400 punch-card sets. Calculated per number of inhabitants—Czechoslovakia is a small country with a population of 14 million —this gives an index of about 100 sets per 1 million people: a high value indeed. On the

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other hand, it was just this highly developed mechanization of aggregate data processing in the administrative branch that in combination with a number of other factors, such as the extensive advancements in the national economy and — in the time of cold war — isolation and the ensuing impossibility to purchase modern computing technique from capitalist countries, that decelerated the process of transition to automatic computers.

In Czechoslovakia, the use of automatic computers, notably in scientific and engineering calculations, dates back to 1956. The first-installed URAL computers of Soviet manufacture were later on—following partial lifting of the embargo—supplemented by computers ZUSE and LGP (German Federal Republic) and ELLIOT (Great Britain). The Czechoslovak computer, whose research and development proceeded simultaneously, bears many hallmarks of the original approach of its creators. The project of computer EPOS conceived in 1958 features many advanced ideas, for example utilization of a self-corrective code, communication of time for simultaneous solution of five programmes, use of so-called masking to enable work with divided words, etc. The fundamental frequency of 1 Mcps and speed of 35,000 operations/sec, too, were highly progressive for that time and Central European conditions. Work was also in progress on a calculating punched card, analogous to the type UNIVAC 1004, in logical continuation of the production of punched card machines. For a number of reasons, those computers and their auxiliaries—external drum, tape and disk memories, high-speed printers, displays, etc., — never succeeded to be put in production at the originally planned dates. In place of a detailed analysis that would take up too much space here, suffice it to mention one of the principal reasons, namely the objective fact that ensuring in all complexity a project as extensive and diversified as computer manufacture with its rigorous claims on research, engineering and production facilities, is a task way beyond the capabilities of any small country.

Between 1962 to 1964, failure to start domestic production of computers and difficulties with importing computer technique on a large scale from abroad, gave rise in Czechoslovakia to a situation when the extent of computer applications lagged far behind the actual demands of industry, trade, administration, science, education and other institutions : in 1964 there were in operation in Czechoslovakia only 25 small computers, for the most without adequate ancillary facilities, software and engineering services, and of 14 different types.

This state of affairs became the butt of severe criticism and detailed analysis which led to the elaboration of a **nation-wide plan for the development of computer technique for the 1965 to 1970 period.** Following a careful assessment of the degree to which the various organizations were and would be ready in the way of material, organization and personnel to absorb computer technique, bearing in mind that preparations for putting a computer in operation take two to three years, ascertaining the investment cost and the feasibility of covering the financial outlay for the purchase of computers abroad by foreign exchange, and determining the conditions of delivery, the originators of the 1970 plan formulated its main principles of strategy as follows :

In the sphere of scientific, engineering and economic calculations :

—high claims on machine time and for own computers are registered by a large number of manufacturing and economic organizations, and in particular, by scientific, engineering, design, project, technology-coordinating and economic institutions; many of those organizations and institutions are relatively well prepared to introduce automatic computers ; they have practical experience in the way of computer solutions to their problems, and are in the process of clearing up the material, organizational and personnel questions prior to the installation of own computers ;

—in all likelihood the requirements of those organizations could be satisfied by automatic computers obtained from sources accessible without hard currency, i.e.

from the Soviet Union, which are of a good technical standard and available in sufficient quantity;

—practically immediate, broad-scale introduction of computers is therefore envisaged for this sphere.

In the sphere of automation of aggregate data processing :

—because the scope, technical standard and structure of machines installed in computing centres fail to satisfy modern requirements, many organizations of both productive and non-productive kind clamour for machine processing, notably in typical administrative agendas ;

—those organizations are more than ready to introduce further mechanisation: their many years of experience with punched card machines make them well disposed toward quick mastering of the know-how of calculating punch operation. They are, however, inadequately prepared for automation of aggregate processing of data; experiments run on small computers unsuitable for such purposes have been of limited extent and little significance ;

—there is no immediate possibility to outfit the national economy with medium automatic computers from accessible sources (home production, import from socialist countries);

—therefore, it is impossible to immediately begin widespread introduction of automatic aggregate data processing; the way open at the present time is to start verifying and checking this technique in selected and, from a broader viewpoint, suitable organizations best prepared for its introduction and capable of its quick mastering, while ensuring maximum possible support to the introduction of modern punched card technique. In the course of the second phase, which started in 1967, it was possible — thanks to the import of medium computers — to gradually introduce automated management and administration on a broad scale.

In the sphere of finance, statistics, records and national economy planning and nation-wide control :

—there exists an objective necessity of the widest possible application of mathematical methods and computing technique, notably as a tool for analysis and gathering of data for planning and control on all levels to the largest possible extent ;

—there exists real possibilities of applying this technique to selected cases, as partial experiences with the solutions to some problems, mainly from the field of national economy planning are available ;

—in view of the limited scope of the demands (only a few computers are in effect involved), it will be best to look for some other than the usual means of covering those demands (import from capitalist countries);

—as this application of computer technique is of particular social significance, it is deemed necessary that in this sphere automatic computers — though in a limited number — should be introduced as fast as feasible.

In the sphere of computer control—in real time—of manufacturing technologic and other engineering processes:

—to keep pace with the world-wide trends of development, it is objectively necessary to apply computer technique to higher forms of automation in various branches of industry, particularly in heavy engineering, mechanical engineering and transportation ; it is common knowledge that large capacity turbosets operating on high steam conditions (such as the 200 MW sets for power stations) urgently demand a higher degree of automatic control ;

—since the theoretical and engineering problems of automatic control of some of

the sets are well in hand by now, it will be possible to gradually effect their practical verification;

—at the present time, computers fit to work in applications of the kind mentioned above are available from domestic production; because of the complexity and high cost of this type of computer technique, purchasing it from abroad means to pay not only for the computer itself but for extensive project studies as well; import from capitalist countries should not, therefore, be counted upon except in extraordinary and perfectly justified cases;

—it seems more than necessary to make a practical check of the theoretical conclusions arrived at in our research laboratories in the course of their studies for several years past; in fact, it is just this field of automation which by improving the quality of final products, effecting savings in raw materials and power in large-output plants, notably those of heavy industry, brings the most outstanding effects to the national economy.

In the sphere of integrated (total) system of control:

—it is strongly recommended that a thorough check be made of this, mostly perspective, application of computer technique inasmuch as systems that combine the individual uses of automation and computer technique into a homogeneous system of control and thus raise the control of a group of industrial works operating as a single concern to higher levels represent, both socially and from the point of national economy also, the largest single contribution of automation and the peak of application of computer technique ;

—at the present time, while practical experience is still lacking in Czechoslovakia, work is in progress on the theoretical elaboration of the pertinent problems, mostly in connection with the assignments outlined in the preceding paragraph;

—it is time to take steps towards partial verification of the principles of integrated total control to 1970, so that the necessary theoretical and practical findings could be incorporated into the projects of plants to be realised later on;

—The reason why the problems of integrated control have been included in the programme is that integrated computer data processing is unusually effective economicaly; **isolated processing of individual administrative and executive agendas and automatic control and regulation of industrial production proceseses solved separately lead in the first place to direct, not too substantial, savings realised mainly through the reduction of manpower; by greatly enhancing the speed, quality and accuracy of control, the integrated system, on the other hand, brings about indirect savings many times higher than the direct ones.**

The conception just outlined has been discussed and accepted by the Government with the provision that this programme is to be followed in the future when planning and coordinating the use of computers, and that by ensuring the temporary development of comcomputer technique through import from abroad, conditions and facilities are being created for mastering the home production of computers and computer technique in the scope, structure and assortment corresponding to the technical and economic resources of Czechoslovakia.

The conception of the computer technique development—assuming that about 200 computers valued at 1.5 milliard Kc's will be put in use between 1965 and 1970 — sees the primary task of these machines as consisting in their application to some of the serious problems in the production and distribution of electric power and metallurgic materials, in the development of chemical complexes,

industrialisation of agriculture, transportation, design, project, research and development institutions (particularly in mechanical engineering), improvement of control and planning on all organizational levels (starting with works and ending with national economy), and in gradual automation of administrative activities. Some of the typical examples of the use of computers envisaged in this connection are as follows :

Coal mining—operative control of large mines and open-cast mines, including the planning of mining and coal winning ; optimum solution to the problems of coal transport in the mining district, perspective planning of mining, preparation of capital construction plans in accordance with an analysis of the results of geologic prospecting;

Metallurgy—automation of the agenda of metallurgy marketing; automation of administrative and planning activities of large plants; automatic control of selected production processes in integrated metallurgic works;

Chemical industry—automation of administrative and planning activities in large concerns; optimalization of process control, automation of scientific and engineering calculations;

Power engineering—control of the electrification system; digital control of large thermal power stations; control of cascades of hydraulic power plants; automation of scientific and engineering calculations;

Mechanical engineering—automation of engineering calculations in design and project organisations and research institutions; complex processing of information for control and management; control of selected production processes;

Consumer goods and foodstuffs industry—automation of administrative, managerial and planning activities (including market research and selection of the optimum assortment) ;

Building industry—automation of engineering and economic calculations, planning work and administrative agendas;

Transportation—operative control of railway traffic, optimisation of the utilisation of railway lines, records concerning the rolling stock (foreign in particular), automation of administrative work;

Agriculture—automation of planning and economic agendas: sowing rotation, fodder bases, records of means of mechanization, spare parts etc. ;

Czechoslovak Academy of Sciences—mostly scientific and engineering calculations.

Other spheres in which intensive use of computers is envisaged include national economy planning, nation-wide records, reports and returns, social security, all on the level of central organs.

Because the work preparatory to putting a computer in use is highly exacting on many counts, the State-endowed research and development assignments include a number of problems primarily aimed at acquiring the know-how of the control of technologic processes, systems of integrated control and computer operation in real time. By way of illustration of what is involved, let us mention the system of central operative control of the production cycle "steel plants — soaking pits—blooming mills" in the NHKG integrated iron and steel works in Ostrava, control of the converter process in the integrated iron and steel works in Kosice, system of optimization in a petrochemical establishment (SLOVNAFT Bratislava), digital control of electric power station units, and two problems from the sphere of socialist economy :

—operative control of metallurgic production to ensure speedy supply to our socialist industry, mechanical engineering in particular, simultaneous with deliveries to foreign markets, especially those of the member countries of the international organisation INTERMETALL, and

—operative control of consumer goods production (of shoe manufacture in the first stage) to conform to customers' requirements.

The last two tasks are of a long-term character; the results achieved in their solution are to be generalised to the highest possible degree and applied to other organisations. The same procedure is planned to be employed with all the other assignments that are being followed on the nation-wide basis.

How far has the programme progressed so far? Between 1964 and 1967, Czechoslovakia installed a total of 110 computers valued at more than 700 million Kc's. Of this number 46 were Soviet computers MINSK 2/22. After these computers had been provided with further ancillary equipment (tape reader and punch teleprinter) and **extensive software developed in Czechoslovakia,** their original application—scientific and engineering calculations — has been extended to data processing where the machines have proved equally successful. A lot of excellent work resulting in close cooperation, exchange of experiences, ideas and programmes, etc. between various computing centres, has been and is done by the "MINSK Users' Club", organized on the common interest basis.

Over thirty UNIVAC 1004 and GAMMA computers have been installed to carry out aggregate data processing, while forty small computers, ODRA from Poland and MSP 2A of local manufacture perform scientific and engineering calculations in research institutes, project and design offices, and in University and College laboratories.

Altogether 18 medium automatic computers of different makes, mostly ICT and EELM (Great Britain) and IBM (USA) were purchased and installed in the few years past. The installations were effected so as to provide information about modern systems of data processing in the most important fields of application, establish prerequisites for further large-scale introduction of computer technique to management on all organisational levels (works, establishments, national economy) branches, and to some of the most important domains of activity (heavy industry, mechanical engineering, finance and banking, transportation, internal trade, social security, education). In this connection particular emphasis is laid on the experimental and trial character of the installation of medium computers in systems of data processing, where attention is focussed on the complex way of organising the flow of information, on the range, character and use of software, selection and training of personnel (analysts, coders, operators).

Equal attention is accorded to work done in preparation of the installation of **computers intended for production process control; though such computers are the ones most likely to afford an outstanding economic effect, preparation for their putting in operation is the most demanding of all.** The installation of the two computer-embodying control systems in the integrated iron and steel works that were best prepared to receive them (we are referring to the above-mentioned cases of control of the "steel plant — soaking pits— blooming mills" cycle, and of the convertor process whose results measure up to the best of European standards) is to be followed by installation of computer control systems in chemical industry, integrated coal dressing plants, power engineeering (to control the turbosets of large-capacity power stations; the national electric system has been computer-controlled for several years by now), cement factories and airport traffic.

The hitherto successful fulfilment of the computer development conception helped to alleviate the prevailing serious shortage of machine time—in the years past, because of their great dearth, computers were assigned to their users by the Government, and machine time allotted by a central despatching office—and thus was laid the foundation for the next, qualitatively different stage of computer technique development.

At the present time, a computer is no longer looked upon in Czechoslovakia as something out of ordinary but is gradually becoming a common piece of technical apparatus wherever and whenever technically feasible and economically advantageous conditions for its installation exist. Industrial establishments and other organizations are now in a position to purchase their computers so long as they have the

necessary means of foreign currency or are granted sufficient credit. Government endowments are offered to organisations in which the use of computers is regarded as socially profitable but which have not enough own means to purchase one (health services, educational institutions, science and research), or where the cost and social significance lie out of bounds of the possibilities of the organisation; to verify novel, hitherto unproven but promising scientific and engineering principles.

Of the broad spectrum of computer technique problems let us say a few words about the following three: service computing centres, personnel training and economic efficiency.

Next to organisations that are in a position to fully exploit an automatic computer, there exists a whole number of establishments and institutions whose scope of machine processed agendas is relatively small. Such establishments and institutions are to be served by a network of computing centres distributed throughout the country, especially outside the principal industrial and administrative centres, so that even from the regional point of view the application of computer technique would be uniform and help in introducing modern methods of control and management. "Computer Technique Establishment", an organization entrusted with the operation of the computing centres throughout the country, also ensures the processing of all records and statistics useful for nation-wide purposes.

A large enough number of specialists is a *sine qua non* for a successful introduction of automation. Czechoslovakia, with its long tradition in the training of professionals on high school and university levels, has very good prerequisites to satisfy this condition in all respects. Universities, technical and commercial colleges offer courses to future analysts, coders and operation engineers in their departments of mathematics and physics, mechanical and electrical engineering, and economics in a range and diversity that takes full care of the prospective needs of the computing centres. A similar situation exists in high schools, various professional, trade and business schools where the training of technical personnel (coders, operators, servicemen) proceeds in specialised classes.

Next to school training, short-term and long-term courses are also held by the computer manufacturers, Kancelarske Stroje, a special service organisation engaged in technical servicing of computers in Czechoslovakia, some large organisations using or owning computers, and finally by social organizations (Czechoslovak Scientific and Technical Society and Socialist Academy).

Very much in evidence and hardly agreeable is the dearth of leading specialists and experts with scientific qualification; of course, this is a world-wide problem, not one special to Czechoslovakia. A study is now being made of the means and ways to mitigate this serious deficiency.

As to the economic efficiency of computer technique, it can be stated with authority that computer technique has proved uniquely efficacious wherever prerequisites and facilities conducive to its introduction had been created in advance. Judging by the experiences of Czechoslovak computing centres, **the returnability of the means outlaid for computers ranges as follows :**

punched card sets	3.4 to 4 years
calculating punch	3.5 ,,
small, simple computers	2.5 ,,
small, automatic computers	2.5 to 3.5 ,,
medium automatic computers	2 to 4 ,,
control computers	3 ,,
other means of computer technique automation	up to 5 years

In manufacturing organisations, installation of a computer has the following positive results :

—lower cost of information processing

—lesser administrative and control apparatus

—better exploitation and utilization of materials :

—effect on waste reduction

—effect on reduction of abnormal supplies of material, finished products, and lowering of supply norms

—effect on reduction of unfinished production, means of circulation and down times

—shorter dates of construction in progress, reconstruction, repairs and completion of large engineering and technologic plants and complete plant equipment.

The economic effect—expressed in terms of savings accrued—is evaluated far easier in cases in which automation technique and computers represent additional investment than in those in which automation has been considered a part of the complex—as is particularly the case in new capital construction plans—where automation technology and methods of control affect one another to such a degree that it is very difficult to distinguish between the effect achieved through automation and the overall results attained through the realization of scientific and technical advances.

It may be assumed for the future development of computer applications that the share of immediate direct savings (e.g. labour cost, interest on lesser supplies, cost of goods circulation) will gradually diminish, while that of indirect savings in the sphere of control and management will increase, thanks to the managing personnel being furnished with uptodate and comprehensive information and thus able to base their decisions on an ever-increasing amount and several alternatives of processed data.

What are the prospects of future computer development in Czechoslovakia ? Since Czechoslovakia, unlike other industrially advanced countries, has been delayed for several years in the development of automation—especially of its higher forms including computers—the main trends of long-term development will be established on the basis of the generally accepted, world-wide tendencies. Thus the crucial point of the problem of setting up a long-term programme of automation in Czechoslovakia lies, not in general prognoses concerning research, development and applications of computers, but in the question of which of the applications of automation and computer technique, already solved or undergoing solutions, are to be realised in Czechoslovakia. and to what extent, in which fields and time intervals; and further, what are the degrees of economic efficiency that are likely to be attained by the various applications. This is the basic task with which the Government's technical policy as regards long-time perspective development of automation is confronted. Its solution essentially falls in two stages :

In the first stage, say within the next three to four years, all efforts should be directed towards finishing the existing programme; this is to be done by continuing the process of introducing automation and computer technique applications that have been tried out and mastered, above all, to the field of scientific and engineering calculations and routine agendas of administrative management. To ensure the necessary number of computers a franchise contract has been signed for the GAMMA 140/5 computer between the American BULL-General Electric Company and Czechoslovak TESLA which is already taking steps to start production. About 300 to 350 of these computers will be needed for aggregate data processing between 1968 and 1971. The 70 to 80 computers required for scientific and engineering calculations during the same period are planned to be a part of domestic manufacture (ZPA), in part imported from USSR and Poland. Computers for process control and experimental verification of control systems in yet other branches are to be imported as before.

Next to their applications in industry, agriculture and building trade, a special place is envisaged for computers in the tertiary sector. Thus, for example, in public health and medical services computer technique is to be employed in diagnostics (study of vital functions in patients, particularly under post-operation conditions), in the management of health services (records and analysis of the state of health of the population) and in the control and distribution of pharmaceutical production. In the field of education, computers are planned to be applied to pedagogical and scientific activities to enable the students to get acquainted with and

acquire practical experience of this technique. Of outstanding import is the application of the method of automation and trainers to various domains outside the educational system itself. It has been conclusively proved that a lot can be gained by delivering intricate machinery and apparatus (e.g., airplanes, complete plant equipment) together with their models for trainers for schooling the service personnel and operators. After 1970, the use of such models will have become a matter of course. The ways and means of computing technique open new vistas for full application of mathematical methods in all scientific disciplines and engineering branches: from this aspect, **computer technique represents a remarkable step towards objectivisation** and substitution of exact methods for the frequently intuitive or empirical approach and solution to scientific and engineering problems.

In the realm of development, design and construction activities, computers are expected to offer the optimum solution from a number of possible alternatives; this holds especially true about the design and project work, production preparation, shortening and amelioration of pre-production and production stages, improvement of the functional properties of products, etc. An equally important role will be played by computers in the sphere of scientific, engineering and economic information especially in automatic processing of library funds, recording of inventions and patents, bibliographical searches, documentation, etc.

A task of unusual significance is the application of mathematical methods and computer technique to State administration.

The economic reform — relying on a combination of trade relations and central control —now in progress calls for a more intensive conceptual and perspective activity on the part of State organs in the process of carrying out the structural changes and **ensuring correct proportions in the national economy** with the full support of modern methods and economic tools of control. The essential matter involved in this process is to learn to know and master the laws governing the relations between goods and money, and to **substantially increase the independence of decision on the part of the lower levels of control.** This is accompanied by fundamental changes in and raising of the quantitative and qualitative demands imposed on planning, statistics and accounting. Those changes bring forth a strong need of mathematical methods and maximum utilization of all means of computing technique in the sphere of central control.

What this involves in the domain of control and management of industrial and trade organisations, is to apply computers to the individual organisational levels/works, establishment/concerns on the basis of existing experiences. The next step will obviously include gradual integration and joining of the individual control levels into an organic whole. It is assumed that smaller establishments too will resort to full use of computers by taking advantage of services offered by computing centres. Also, step by step a shift will be effected in the economic efficacy of the use of computers in automatic data processing from savings in administrative costs to an increase in production efficiency resulting from an increase in the level of their overall control, thanks to computer technique.

The development of computer applications in heavy industry (mining, power engineering, metallurgy, chemical industry, building materials) is favourably affected by considerable concentration and large capacity ranges of the manufacturing establishments and organisational units with semi-continuous or continuous production processes. Next to automatic data processing, the characteristic feature of automation in this field of endeavour will be further infiltration of computer control technique in technologic processes, and adaptation of its principles on such a scale as to make those applications affect the level of control in heavy industry to a decisive degree. This will naturally take five years at the least, while a much longer time will be needed for carrying out large-volume applications of control technique in this field and for bringing the control systems into a single integrated system of control.

In processing industry (mechanical engineering, consumer goods and foodstuffs industry), the character of production processes, the structure of the individual branches and the size of establishments seem to point out data processing, planning and operative production control as the most promising domains for computer technique applications. Direct control of technologic processes is expected to be applied in bulk productions of the processing industry at the time complexly mechanised and automated production is brought in.

In building industry, agriculture, forestry and water conservation computers will play their part in automatic data processing, economic calculations and optimisation (e.g., of lines of communication, use of the CPM methods in the solution of large projects and selection from several alternatives, following and planning of movements, repairs and utilization of machinery, optimization of sowing rotation in agriculture, etc.)

The means needed for ensuring the second stage of development after 1972 are of such an extent as to make import of computer technique on a large-scale completely unprofitable for Czechoslovakia. It is, therefore, planned to gradually build up in Czechoslovakia—relying naturally on a broad international cooperation in research, development and even production of both computers and their ancillaries (card and tape readers and punches, memories, printers, automatic plotters, analogue-digital convertors, data transfer devices, document reading instruments, etc.) as well as in the development and verification of extensive programmes and other software — the production of computer technique to a scope and assortment well capable of meeting the world's technical standards, yet economic enough to make the proposition advantageous.

A study about the part to be played and position to be held by automation in Czechoslovakia has been prepared within the framework of general considerations on the long-term development of national economy to 1980. Three basic alternatives — maximum intermediate and minimum — of a long-term perspective conception of automation and computer technique were worked out. Following discussions in Government organs, the intermediate version was accepted to serve as a basis for a further elaboration of the plan of automation and computer technique development. According to this version it is expected that 1850 computers valued at 14 milliard Kcs (inclusive of the cost of supplementary and ancillary equipment for taking and transfering data) will be installed between 1968 and 1980. To realize this programme, an average of 80, and later on of 150 computers must be put in operation each year ; considering the high wear-tear of this technique, we must count with the necessity of having to exchange the machines in in the course of six to eight years.

Survey of Computer Development in Czechoslovakia

	1957	1960	1964	1968	1972	1980
Number of computers in operation	1	7	25	160	400	1,600
Total computer capacity (operat/sec)	10^2	10^3	10^4	10^5	10^7	10^9
Total cost-price (million Kcs)	3×10^0	2×10^1	10^2	7×10^2	5×10^3	1.4×10^4

In the span of several years, automation and computer technique has succeeded in arriving to the forefront of interest and in becoming the principal and most important trend of scientific and technical development. That it is so is among others attested by the fact that after 1970, the yearly investment in computer technique will be the same as the investment for the five year period preceding 1970. ●●●

Automation in The Netherlands Postal and Telecommunications Service

H Reinoud*

THE NETHERLANDS POSTAL AND TELECOMMUNICATIONS Services (PTT) is a State enterprise and as a service institution it performs the following tasks :

(a) the conveyance of messages — posts, telegraphs and telephones ;

(b) the transport of small goods — packets, parcels ;

(c) money movements — "giro", money orders, bill collecting, postal payments and post office savings bank ;

(d) the provision of wire broadcasting ;

(e) the collection of radio and television licence fees ;

(f) the installation and maintenance of transmitting equipment for radio and television broadcasting ;

(g) the performance of services for other Government transactions, e.g., payments in virtue of Social Insurance Acts and Government pensions, the management of the Government Motor Transport Service and Government Office Machines Service.

*Director-General, Netherlands PTT, the Hague

Most of these tasks are legally assigned to PTT, which, in fact, enjoys a State monopoly for some of these services, e.g. the conveyance (against payment) of letters not exceeding 500 grammes in weight.

For other services, such as the public telegraph and telephone traffic, PTT has no monopoly according to law, but in practice it takes a monopolistic position. The Telegraph and Telephone Act 1904 makes allowance for the operation of a telegraph and/or telephone service by both state and private enterprises because the Crown can also grant concessions to private companies or persons. However, all the concessions that were granted to private undertakings were cancelled again in the course of years.

As far as some services are concerned (e.g. parcel post, "giro" service and savings bank) PTT has to compete with private enterprises.

Problems of a Growing Enterprise

Especially during the last ten years, several developments—mainly the increasing prosperity and the growth of the population—caused an enormous increase in the demand for the services rendered by the Netherlands PTT and for many of these services the end

of this growth is not yet in sight. Two important problems confronting such a growing enterprise are the necessity of taking effective measures to cope with the increasing mass of operational activities and the question **how a continuously growing enterprise can be kept manageable.** In addition, many other important problems must be solved such as financing, training of staff etc., but it will not be possible to discuss these problems within the scope of the present article.

The quantitative problem of the enormous amount of operational activities has also affected the accounting sectors of the Netherlands PTT. As the labour market became tighter and the demand for the services rendered by PTT grew, the solution to this problem became a pressing need.

The PTT administration is also more and more confronted with the qualitative problem of manageability. Owing to the growth of the enterprise, the problems of management increase both in number and in complexity and **the role of the accounting system as the supplier of information to the various levels of management is getting more important.**

Organisation and Coordination of Automation

It was soon realised by the PTT management that the use of electronic data processing equipment in various parts of the enterprise could be an important aid in solving the aforementioned problems.

In this way it would not only be possible to reduce the personnel problem,* but moreover, a further growth of the activities could be looked forward to and in certain cases even stimulated. At first it was investigated whether PTT itself would undertake the design and construction of electronic equipment. However, after some study trips to the USA had been made, it became clear that within a reasonable period of time, relatively cheap "general purpose" machines would appear on the European market. In the first instance, it was only intended to automate the Postal Cheque and Giro service, but it was soon realised that a number of other PTT accounting systems would also have to be considered. It was felt desirable to institute a committee within the enterprise to study and coordinate all aspects of automation. This "Committee for the automation of mass accounting systems" was given the task to discuss the general aspects of automation and to coordinate the various investigations in this field. The Committee, which reports progress to the General Directorate, is divided into sub-committees and working-groups, which include representatives of the departments involved in a certain project. The investigations themselves and the technical preparation of the automation projects are carried out by specialised central branches. However, the meetings of the committee and its sub-committees and working-groups have provided an excellent opportunity to attune the ideas of the research workers to the wishes of the agencies involved in certain accounting processes. The discussions held within the framework of the committee have no doubt contributed to creating considerable understanding of the importance of automation.

At the moment, a reorganization of this central consultation committee is being prep in order to arrive at a better adaptation to t present state of automation.

Mass Accounting Activities

In the past, **most accounting services the Netherlands PTT were up agains shortage of personnel to such an ex that the proper operation of these ser was often endangered.**. The situation even so serious that, on account of this shortag of personnel, private persons could not new accounts with the Postal Cheque and Service for a considerable period of time,

*The personnel problem is not to be understood as one of redundancy as in the Indian context, but of the existing personnel not being able to cope up with the sheer magnitude of the job, and of the difficulty and expensiveness of getting training and retaining personnel under boom conditions.

that **part of the service was, in fact, no longer in operation. Thus it was obvious that the PTT used the computer in the first place as a welcome substitute for human labour.**

Since 1961 the PTT pressed into service four computer centres, mainly in behalf of five mass accounting systems :

(a) *Postal Cheque and Giro Service :* At the end of 1967 the number of postal giro accounts with this service amounted to about 1.5 million and the number of transactions in 1967 to about 285 million. The current accounting is carried out in two computer centres by means of well over 20 computers of the IBM-1401 type. Part of this equipment will be replaced soon. If the service would still be operated by the use of conventional methods, approximately 6500 employees would be required, whereas the automated service now only employs a staff of about 4200. The computers of the Postal Cheque and Giro Service temporarily keep also the accounting of the motor-vehicle tax for 2.2 million motor vehicles.

(b) *Post Office Savings Bank :* The post Office Savings Bank has a computer centre (NCR-315) at Amsterdam for the current accounting and the calculation of interest. The conversion from manual to automatic operation is in full swing and is expected to be completed this year. At the end of 1967 the bank had about 5.6 million savings accounts. The entries (deposits and withdrawals) in 1967 amounted to about 11.2 million.

(c) *The Central Accounting Branch :* This Branch controls the computer centre of PTT headquarters. The computer centre is equipped with a UNIVAC III- 1005 combination, a Univac 418 computer with a random access Fastrand-drum, in which 130 million alphanumerical characters can be stored — and two Card Punching printers, which are in particular intended for printing, in one run, and punching the punched cards.

The three most important accounting systems which can be kept by means of this computer equipment are :

(i) the pay-roll and personnel accounting for 66,000 PTT-personnel; (ii) the telephone, telex and land mobile radio charges collection for about 1.7 million subscribers, for which about 10 million bills are being despatched annually ; (iii) the collection accounting of the Sound and Television Broadcast Licensing Service, which is charged with the collection of radio and television licence fees of about 2.8 million radios and 2.6 million television sets, for which annually about 8 million bills are produced.

Automation of the above-mentioned accounting systems developed more or less independently of each other. General directives are given by the management, and the problems that are of importance for the various auto-projects are being studied by commissions. For the rest no integrated handling of the automation is applied, and a step-by-step automation is preferred.

However, now that the automation of the most important PTT-branches has entirely or almost entirely been completed, the question of an accounting system that is as integrated as possible is once more topical. For many years to come this subject will remain of the utmost importance for the PTT branches involved in automation.

Integration of Automated Processes

From the very beginning much attention has been paid to one aspect of integration, that is, the integration of the accounting system of the Postal Cheque and Giro service and that of the bill collecting services by means of simple punched cards. After the punched card had been chosen as the input document for the accounting of the Postal Cheque and Giro service, attempts had to be made to ensure that the transfer orders concerning the amounts charged by the collecting services should be received by the Giro service in the form of punched cards, suitable for input without

needing further treatment. For this purpose it was required that the punched card contained the account number of the creditor (beneficiary), that of the debtor (payer) and the amount due.

For the Sound and Television Broadcast Licensing Service—the first bill collection accounting system, which was applied by means of the computer at PTT headquarters—this integration led to quite another manner of collecting the radio and television licence fee. Formerly, licence stamps obtainable from the post offices had to be affixed to a licence card each month. Now a system had to be applied by which the licence fees had to be paid in advance for one year at a time. In the present system the bills for radio and television licence fees are produced in the form of punched cards by means of the central computer at PTT Headquarters. These cards can be used as either a transfer or a deposit card. For those debtors who have their radio and television licence fees regularly debited from their postal giro account, the account number has already been printed on the card by means of the computer. The debtor's signature is sufficient to have the transaction effected by the Postal Cheque and Giro service without the necessity of further coding. As the bills that have been paid are returned to the Sound and Television Broadcast Licensing Service, it is possible to use these card bills again as machine readable input for checking purposes. **The annual cost involved in this manner of collection is 4 million Dutch Guilders less than the cost of the old manual system.** After completion of automation of the aforementioned bill collection systems, further attempts have been made to restrict the activities involved in the collection of bills. First of all it was tried to stimulate automatic transfers, the "collections", as they are called. In this system the debtor authorises the bill collection accounting branch to have amounts transferred from his postal giro account without his intermediary. The advantages of this system are less cost, a quicker collection of the amounts due, and the possibility for the Postal Cheque and Giro Service to spread the activities connected with the transfer. Of the telephone bills, about 50 per cent are collected in t manner. For the Sound and Televisio Broadcast Licensing Service this percentage i much lower at the moment. However, means of directed propaganda this percentage is rising quickly.

For the collections referred to here, we ma ask ourselves if it is really necessary that t two services—the Collection Accounting the Postal Cheque and Giro Service—produc and handle such great quantities of punch cards, and if it is not possible to exchange data in another manner. This is indeed possi ble by the exchange of magnetic tapes. How ever, in that case two conditions have to be First of all, the magnetic tape produced by th computer of the bill collection—in this the magnetic tape supplied by the UNIVA III—should be suitable as input tape for t computer of the Postal Cheque and Giro Se vice, the IBM 1401. Besides, the debt should be informed about the debiting of account for amount due. As this could not effected by means of the punched card, solution had to be found. Initially, the fi condition—the exchangeability of the netic tapes—could not be met. The releva suppliers of computers were either not int sted in this problem, or they could not fi solution. As this exchangeability was of su great importance, attempts were made solve this problem within the PTT, and finally succeeded. When it also proved to possible for the Postal Cheque and Giro Serv to replace the giro card as notification of credit by an information on the daily statement account, the integration of the bill accounting with that of the Postal Cheque Giro Service was again a little further adv

The effect of the automation of the P pay-roll accounting system on the P Cheque and Giro Service was quite diffe from that of the automation of the af mentioned bill collecting systems. It was only when it was decided to pay the salaries giro—in other words, when the payment salaries in cash was changed into transfers the postal giro accounts of the employees

first punched cards were used in this system, which were later replaced by magnetic tapes). It stands to reason that such a method of paying salaries promotes the giro payments traffic; it results in a demonstrable decrease of giro deposits and in an increase in the number of paid cheques. Although this change in the methods of paying is undoubtedly of great importance, there is another significant trend resulting from the automation of the various PTT accounting systems. The deposits on the accounts with the Post Office Savings Bank are mainly made in cash through the post office counters. This way of saving fits in with the systems of paying salaries in cash. When this payment in cash was converted into payment by giro, an extension of the possibilities of making deposits was required, as deposits made by giro cannot be entered immediately in the savings bank book and the saver is in a way forced to keep a record of the balance of his account. For this reason a method of saving was developed in which deposits are transferred from the postal giro account to a savings account; after each deposit or withdrawal the saver receives a statement of account indicating the old and the new balance of the savings account, in the same way as is done for the postal giro accounts. The automation of the pay-roll accounting followed by the payment of salaries by giro has thus led to a closer co-operation between the Postal Cheque and Giro Service and the Post Office Savings Bank. There is every indication that further integration of the automated accounting systems of these institutions can be expected in the future.

The automation of the Postal Cheque and Giro Service has also affected the counter services in the post offices. The counter services largely consist of deposits and payments in behalf of account-holders with the Postal Cheque and Giro Service. **In the long run the advanced forms of data processing and distribution will cause a considerable decrease in the money traffic at the counters,** but this will undoubtedly take tens of years. However, at a shorter term—possibly 5 to 10 years—interesting developments in the field of paying-in and paying-out machines may already be expected. **These developments will diminish queuing at the counters and will permit deposits and payments to be made at any time, day or night.**

Meanwhile an integration of a completely different nature is likely to present itself. As has already appeared from the foregoing, a number of very large accounting systems relating to private individuals and corporate bodies is kept by the Netherlands PTT. As seen already, the accounting systems comprise:

1.5 million postal giro accounts:	Postal Cheque and Giro Service
2.2 million motor-vehicles :	Postal Cheque and Giro Service
1.7 million telephone subscribers' lines :	Telephone service
300,000 subscribers to the Wire Broadcasting Service :	Telephone Service
5.6 million Savings Accounts :	Post Office Savings Bank
2.8 million radio sets :	Sound and Television Broadcast Licensing Service

These different accounting systems contain a considerable amount of identical data (e.g. name and address) of the same persons. However, each of the automated accounting systems has a different numbering method and the data in a particular system can only be obtained if the relative numbering method is used. Any changes in the recorded data of persons included in the accounting systems must, therefore, be made separately in each system.

For some time the PTT have studied the possibility of standardization of the numbering and/or coding methods used in the enterprise, in order to permit bilateral or multilateral communication in the form of an exchange of machine readable information between the various PTT accounting systems. **The aim is to set up one central machine readable file of customers in the enterprise within the next 3 or 5 years.** For each customer this file will contain name, address and place of residence and further more all the data which

have some connection with the PTT (number of postal giro account, telephone number, number of radio licence, etc.). This central file of PTT customers completely fits in with **the developments in the field of automation, which are directed towards integrated systems with a certain centralization on the one hand and remote, decentralized input and output equipment communicating with the central unit by means of data transmission on the other hand.** The basis of such a system is formed by a large random access memory. In order to be able, before completion of this system, to process the changes of address in the various PTT accounting systems in a more efficient way, PTT already has computer programmes available to standardize the names of persons and the addresses, which are now still contained in the machine readable files in many different ways. For this purpose a code of name, address and place of residence was developed consisting of the first two symbols of the family name, name of the street and place of residence as well as the units and tens of the number of the house. The eight symbols together are called the "octogram". By means of this "octogram" the number of, e.g., the radio licence belonging to a certain name, address and place of residence can be obtained from a random access memory.

With such a central file of customers, the PTT will be in a position to offer the public a better service, e.g., in case of house moving, it will be sufficient to send only one notification of change of address to the PTT, after which the new data will automatically be included in the various PTT accounting systems. It will also be possible to supply statistical material to PTT in a more efficient way by means of the central file. Finally, a central file of customers may in the long run make an important contribution to the mechanization on the forwarding process in the postal service. The address code, which the PTT intends to introduce shortly, will, of course, be included in this central file of customers. This will open up new possibilities for addressing printed matter posted in bulk, as the method of addressing can then be adapted to suit the requirements made by postal mechanization. The PTT itself may see to the addessing or may supply others with the required data. Thus, in its further stages, the automation activities in the various PTT accounting systems, which were started rather independently of each, will lead to an increasing integration of these accounting systems. This integration proceeds slowly, but is a prerequisite for obtaining a better and more efficient control of the whole enterprise.

Aids Management of Organizations

In the technical literature, automation experts have so far done a lot of wishful thinking about the computer as an aid in the management of organizations. However, the practical results have, in general, been little convincing. This rather negative result can be accounted for by two important reasons.

In the first place, the system designs for management processes are much more time-consuming than those for the operational accounting processes. Here we find problems such as : what are the needs for information at the various levels of management? what decisions do they make on the basis of this information? which of these decisions can be included in the computer programme? what are the standards applied now, and what standards must be included in the automatic system in order that the computer may detect "irregularities" occurring during the process? All weak spots in the organization of an enterprise (vague division of functions and tasks, poor planning, vague or incorrect standards) should be brought out during the system analysis. **If the management processes are not sufficiently rationalised beforehand, there is the danger that an enterprise will automate and continue its deficiencies, while this is masked by the computer.** It is not unnecessary to draw attention to this fact, **as the computer i often held in such high regard and i considered with so much respect that it is forgotten that the detection of irregularities and the answers given are not more**

intelligent than the standards and information which the machine received in the form of programmes that were input by man. If a poor system analysis results in a poor programme, the computer will give, of course, very quick, but equally poor answers.

The second important reason why the computer has hardly made any progress as the supplier of information to management, especially at the lower levels, is due to the fact that so far the computers have in general handled the information by batch processing. Thus the information to be put must first be collected in sufficient amounts; moreover it must pass through a sorting stage before it can be processed by the computer. This batch processing will, in general, lead to periodical (monthly, weekly or daily) processing by means of magnetic tapes. The first and second generation computers are, therefore, in fact, unsuitable for most management processes, in which the management must have the information at its disposal at unpredictable points of time, so continually, while it must be possible to include new information immediately and permanently in the system.

Management processes are, in the first place, communication processes, in which, in general, permanent communication must be possible between the managers wishing to supply or receive information on the one hand and the computer on the other. It will only be by means of the third generation computers that the automation in this field of management will have the opportunity of full development. These computers can be provided with random access storage units permitting information processing per item. Such units will permit increasingly quicker access and will become increasingly cheaper (according to the American Federation of Information Processing Societies: in 1950 $ 2.61, 1965 $ 0.20, 1970 $ 0.10 to $0.05 and in 1975 $0.005 per bit). Furthermore, it will be possible to apply data transmission, message switching and remote processing, so that "discussions" can be held between the computer and the functionaries involved in the management process (real time systems).

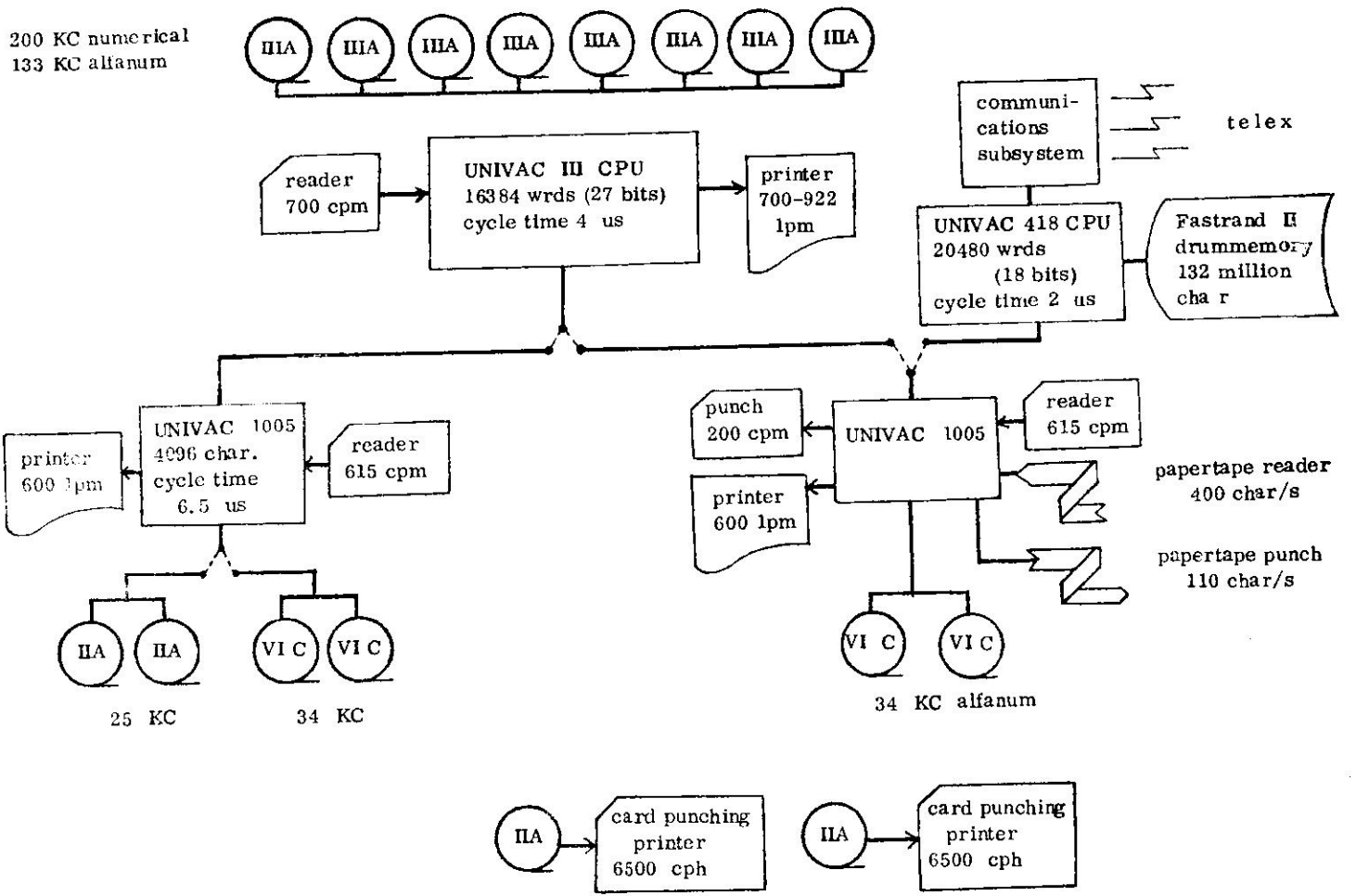
In the next few decades, we shall have the remarkable development that the **conventional telephone exchanges will gradually be converted into computers** (connections can be established very quickly by means of computers), whereas the "conventional" computers will be developing into communication equipment for management processes. What the results will be for the PTT and how revolutionary the changes involved will be, can hardly be predicted yet. However, two things can be stated with certainty. In the next fifteen years all conventional aids which have so far been available to the management of large decentralized enterprises as "tools of management" will be affected by this development. Owing to the advent of the modern computer, a theoretical reconsideration of these tools of management (book-keeping, budgeting, statistics and also the structure of the organization) is urgently required. Moreover, during the next fifteen years considerable successes will no doubt be recorded in the struggle against the "terror of paper", which is now afflicting all large and growing enterprises. Paper is used in the enterprise mainly for two reasons:

i. To record information (often in the form of card indices) for later use. This function will largely be taken over by the file memories. The information stored in such a way will be available to any competent functionary by means of data transmission.

ii. As a means of communication (mostly as forms in x-fold) to transmit information to other functionaries in the enterprise. It will be possible to reduce this flow of forms by means of data transmission and message switching.

In 1980, the organization of large enterprises such as the PTT will in many respects be clearer, simpler and less "bureaucratic" because all sorts of (administrative) organizational schemes to keep all levels of management informed will become superfluous. However, it will take some time before that stage will be reached.

COMPUTER CENTER: NETHERLANDS POSTAL AND TELECOMMUNICATIONS SERVICES, THE HAGUE



As was already stated, within the PTT the stress has so far been laid on the automation of the operational mass accounting systems. Only in the last two years has there been a shift towards the automation of management processes: making decisions and checking the implementation of decisions made.

Apart from some occasional applications *inter alia* in the field of calculation of correlation and regression for purposes of market analysis and forecasts and in the drawing up of time-tables, PTT automation activities concerning management processes are centred on three fields of action :

1. Control of Flow of Material

Here we also see that the "step by step" method is applied. In 1967 a preliminary system was completed in which a high degree of integration was realized.

The system comprises :

- central registration of the stocks of the 200 PTT stores, for about 25,000 different articles;
- the registration of the material requirements of the whole PTT;
- part of the registration of the plans for large projects;
- part of the order accounting (amounts ordered and dates of delivery);
- registration of the materials used (for statistical, costing and accounting purposes).

Although these are mass systems, the quick availability of the data required for making decisions is the primary purpose of this automation. For the time being, the preliminary system is based on (daily) magnetic tape processing. Besides, a rather large number of investigations is being made, *inter alia* to suit the planning activities within the PTT to the requirements made by the computer, to include the financial aspects of the supply of materials in the system and to improve the present standards used in many fields.

The following step will be the conversion of the system into a real time system; the magnetic tapes will then be replaced by a random access memory and the use of data transmission will even further improve the supply of information to management (information permanently available, less paper required).

2. Control of Flow of Labour

Process analysis has been started, for which the personnel registration and the time-accounting of the PTT personnel have been taken as the starting points. In the same way as has been done for the flow of material, at first a preliminary system based on magnetic tape processing will be introduced, probably in the course of the year.

3. Integrated System of Information Processing

Mainly to ensure the integration of the above-mentioned process, which have already been automated, and the systems to be automated in the future, an investigation is being made by the PTT into the possibilities of arriving at a fully integrated system of information processing for management purposes. This system will be founded on a number of common data bases for persons (personnel, buyers, suppliers), objects (materials, buildings, equipment) and money. However, this long-term project will still take many years of research. ●●●

The Threat of Inflation

In almost all nations last year inflation, rising prices of goods and services, dissolved the purchasing power of people's money. Taxes, too, hit the average worker hard. French citizens paid over 38 per cent of their income for all taxes, Germans over 34 per cent, Italians nearly 30 per cent, the British and Americans well over one-fourth of their income!

—AWAKE! Jan. 22, 1969

Computerised Postal Cheque Service in The Netherlands

The Netherlands Postal Cheque and Clearing (Giro) Service, which is part of the Netherlands Postal and Telecommunications Service (PTT) was established in 1918. Its aim is to promote the making of payments without cash and it enables its customers to do so by the opening of current-accounts, called postal accounts, which are numbered sequentially. When the Service was opened the postal accounts were kept by 300 post offices. In 1923 the accounting system was centralised at The Hague. Since that time the post offices only act as cashiers of the Service; they accept deposits and pay out cheques.

In 1956 a second giro office was opened at Arnhem for the account-holders living in the provinces of Groningen, Friesland, Drente, Overijssel, Gelderland and in the Noordoostpolder. Today the Arnhem office also provides for the account-holders living in Limburg and Noord-Brabant. The accounts of the customers of the Arnhem office have numbers over 600,000. The balances, which do not bear interest, are guaranteed by the government. Transfers are made free of charge, but a small charge has to be paid for deposits and postal cheques. Orders to the Service and statements of account to the account-holders are sent free of postage. All documents used in the Service are exempt from stamp-duty.

IN THE YEARS AFTER WORLD WAR II, the daily amount of orders received from the account-holders and the post-offices has increased steadily. This development involved a great number of problems the most serious of which were staffing and office room and the agreement between the debitings and the creditings. One of the means to cope with this situation might be found in the development in the field of electronic data processing.

Soon after the investigation into the possibilities of automation in this respect had been started, it appeared that the most important aspect of the study would have to be the problem of the input, i.e. the feeding of the data into the electronic data processing machine. The forms used so far were not suitable to be processed by machines, as in practice it is not quite possible to make machines read hand-written script. Therefore the first requirement to realise automation of the accounting process was the introduction of punched cards. These cards can serve as an input medium for the processing machine, either direct or after conversion from card into tape, i.e. that the data punched in the card are written in a particular code on a magnetic tape.

It was decided first of all to use punched cards instead of limp deposit forms. Furthermore, some special flows of documents are received as punched cards, which will not be dealt with here. Finally, the introduction of punched cards for giving orders for transfers was completed, after which the cards were used for cheques also.

The customers owning a punched card installation pre-punch the cards partly or entirely, which saves the Giro Service an enormous lot of work, because the punched-card system requires coding staff, which can be recruited only in small numbers at The Hague and Arnhem. For this reason coding centres were established elsewhere in the country. After the problem of the input, the further automation of the accounting process came to the fore. In the early part of 1962 an electronic data processing machine (type IBM 1401) was installed in The Hague Giro office. Every week the processing of some thousands of accounts was changed from manual into mechanical operation. When the machine was fully loaded, a second machine was installed, etc. The same system was applied by the Arnhem Giro Office. In April 1965 the total file of accounts was moved into the procedure of automatic entry.

The customers, whose accounts are processed by the computer, send in punched cards in order to give instructions for transfers as well as to order payments by cheque. Special punched cards have been introduced for the emission of cash-cheques in order to take up cash chargeable to the balance of one's own account.

The Boards of Labour also have emitted special punched cards for the payment of family allowance.

The consequence of automation for the account-holder giving an instruction is that he receives a statement of account which is made by the computer entirely automatically.

This statement comprises the name and the address of the account-holder, so that it can be despatched in a window envelope. As the computer is able to specify all debitings one by one according to kind, serial number, amount, and number and name of the postal account to be credited, no separate debit notices for transfers and cheques are supplied. When the account-holder — who gave instructions for transfers — receives the "specified" statement he can compare the debitings with the vouchers of the corrseponding order forms kept by him. For automatic debitings the Giro office adds a notification of debiting for each debiting, and for each crediting it adds a notification of crediting. The latter are intended to be replaced by a more specified statement of account.

The possibilities to fill the envelopes mechanically with the statements of account and the supplements involved, are being considered.

Mechanical despatch of statements of account without supplements has been put into practice by way of experiment.

The problem how to eliminate the verification of the postal account numbers filled in by the account-holders is also being studied. It is being considered whether it will be possible to solve this problem by adding a check number (digit) to the number of the postal account. Another item to be studied is the diminution of punching work.

The consequence of the application of punched cards is that it involves an enormous amount of punching and check-punching, which would not be necessary if the account-holders would complete their order forms in a machine readable manner. In this field many studies have been made, *inter alia* by the PTT Dr Neher Laboratory. As a result of these studies and of some small-scale experiments a machine has been developed, which can read data supplied in the so-called marking grid of a punched card and can punch data in certain columns of the same card. In the marking grid, which consists of a number of columns bearing the figures 0-9 (from top to bottom), the account-holders have to enter the amount and the number of the postal account (to be credited) by marking the small square of the relevant figures in ink. On the card 5 columns

have been provided for the amount and 7 for the postal account number. The height of the mark in each column shows which figures are indicated in this manner.

By way of experiment a number of account-holders have been asked to give their orders for transfers by means of transfer cards which have been completed in the aforesaid manner.

DAILY OPERATION OF THE SERVICE

Preparation

The mail received by "Manual preparation" consists of order forms sent in envelopes by the account-holders. The envelopes are opened mechanically and the forms are extracted from them.

The post offices send the deposit cards and the cheque cards together with cash statements to the coding centres. After the data required for mechanical processing have been punched into the cards, a check-list is made for each post office to compare with the post office statements and any discrepancies are resolved in consultation with the post office.

The cheques paid are divided into :

a. cash-cheques,

b. sight cheques,

c. ordinary cheques.

After the totals have been checked, the cards are sent together with a statement (part of the check-list) to the "Mechanical preparation" branch of the Giro Office where the debitings and creditings are to be made. At this office the deposit cards are sorted in the sequence of the numbers of the accounts to be credited, after which they are microfilmed. Moreover, a visually readable date of entry is put on the reverse side of the cards. Then the deposit cards are passed to the Current Account department where the entries are to be made. The cash-cheque cards are sent directly to the Current Account department.

The sight cheques are sorted in the sequence of the account numbers, after which a statement is made for each account. Moreover, an entry-card for electronic processing is provided. The entry-card and the statement are sent on to the Current Account department.

The Current Account department enters the amounts of the cash-cheques in the relevant accounts, after which new cash-cheque cards are punched. The Transfer Card Books production branch addresses the cheques. The ordinary cheques are passed on to the Current-Account department, where they are processed into the magnetic-tape cheque-file.

The transfer cards are sent partly to the Order Checking branch and partly to the coding centres, where they are checked. During the checking process the transfer cards filled in as cheques are segregated.

The order checking branch sends the transfer and the cheque cards on to a coding centre. After the significant data have been coded the cards are returned to the current account department, where the debitings are processed electronically. Then the transfer cards are sent to the "Mechanical Preparation" branch to be sorted there in the sequence of the numbers of the accounts to be credited. The transfer cards to be processd at the local Giro Office are segregated from those to be processed at the distant Giro Office. After having been microfilmed and dated, the cards are sent to the Order Checking branch, where the beneficiary's name is checked against his number.

Then crediting is effected in the Electronic Processing sections. For the crediting process, use is made of the magnetic tape which was employed for the debiting process concerning the same transfer cards. The cheque cards which have gone through the debiting process are passed to the Special Orders branch where they are provided with a supplementary printed text. Moreover, the cheques are certified, after which they are sent to the beneficiaries.

The electronic processing branch transfers the data from the debitings tape to a new magnetic tape containing the data of all cheques in circulation. The data of the cheques paid are also recorded on a magnetic tape and checked

against the cheque-file tape. If debitings and payments are in agreement, the data of the cheques are removed from the tape. The report on these electronic processes is passed to the Checking department.

The statements of account made by the Current Account department are inserted together with annexed documents in envelopes which are sealed mechanically. They are partly sorted in the sequence of the places of destination and despatched to the post office in the place where the relevant Giro Office is situated.

The electronic processing sections have medium-size processing units (computers) at their disposal. Each unit comprises the following parts :

a. a central processing unit equipped with 12,000 memory locations,
b. a reading/punching unit,
c. 5 magnetic-tape units,
d. a high-speed printer.

Furthermore the sections have at their disposal a magnetic tape with the balances of the account-holders and a tape with the names, addresses and places of residence of the account-holders. Hereafter the first mentioned tape will be called the **old balance tape** and the last mentioned tape will be called the **address designation tape.**

The activities of the electronic processing sections are performed in two shifts, each comprising a chief and three operators. The working cycle comprises 16 working hours.

By means of the equipment available the payment orders processed by the Order Checking section are entered and the daily statements of account for the information of the account-holders are made.

Verification of the Payment Orders in the Order Checking Sections

Transfer Cards (debit) : The checking sections have to confirm the clarity of data presented on the transfer cards. Moreover, the signatures are checked. During this procedure the cards which are filled in to serve as cheques, are segregated and sent to a coding centre. After the cards have come back, they are sent to the electronic processing sections where the entries are made.

Deposit Cards : It is checked whether the name of the account-holder nominated corresponds with his account number, after which the cards are sent to the electronic processing sections where the entries are made.

Transfer Cards (credit): It is checked whether the beneficiary's name corresponds with his account number.

Entry of the Transactions by the Electronic Processing Sections

The entries of the transactions from the original or auxiliary punched cards are effected in two stages, viz., a first stage for the debitings (transfer cards "debit", and cheques) and a second stage for the debitings (transfer cards "credit" and deposit cards).

To prepare the first stage the information (per category of payment order) required is transferred from the debit punched cards to magnetic tape. Next the data on the tape are sorted in the sequence of the account numbers. This tape and the old-balance tape are fed into the processing machine in order to effect the first stage. The machine produces two magnetic tapes and a number of "signal" cards and balance cards.

The tapes are :

a. a debit-tape (entered transfer cards "debit" and cheques),
b. an intermediate-balance tape (active and non-active accounts with respective balance charges; the total of debitings per category of payment order and the new balance).

The signal cards contain the information relating to those payment orders that could not be executed because the balance was blocked or insufficient

The balance cards contain the total amounts of the debitings made per category of payment order per 10,000 postal accounts.

To prepare the second stage, the information (per category of payment order) required is transferred from the credit punched cards to magnetic tape. Further processing takes place as for the first stage. However, instead of the old-balance tape the intermediate-balance tape is fed into the machine.

The machine produces two tap s :

a. a credit-tape (entered transfer cards "credit" and deposit cards),

b. a final-balance tape (active and non-active accounts with respective balance charges ; debiting and crediting totals per payment order category and new balances).

Furthermore signal cards are produced to indicate accounts blocked for crediting, and balance cards which contain the total amounts of the creditings per category of payment order per 10,000 accounts.

Next the statements of account are printed. For this purpose the following tapes are fed into the machine :

a. the final-balance tape,

b. the debit-tape,

c. the address-designation tape.

By means of the final-balance tape the following data are printed on the statements of accounts

—number and total amount of the cheques and other debitings ;

—number and total amount of the deposits and other creditings;

—amount and date of the previous balance and the new balance.

The debit-tape serves to specify the debitings according to kind, amount, number of the account credited, and name of the beneficiary.

By means of the address-designation tape the statements of account are provided with the data required for the despatching of the statements in window envelopes.

The punched cards and the signal cards are sent to the Order Checking sections and a daily balance is drawn up from the balance cards and the final-balance tape.

By means of the daily balances per electronic processing unit a total balance of all accounts is made. The totals of the entries of deposits and cheques are sent to the checking department. The total amount of transfer debitings is checked against the total amount of transfer creditings. Daily a cumulative balance is drawn up, the figures of the day combined with the figures of the previous days of the current month. The cumulative balance of the last day of the month provides the basis for entries in the Main Accounting department. In behalf of the Checking department, the data of the final-balance tape, the debit-tape and the credit-tape are printed subsequently on lists (so-called print lists). To prepare the following cycle of entries punched cards with modifications in the file of accounts (opening and closing of accounts, changes in the name, the address, etc.) the address-designation tape and the final-balance tape are fed into the processing machine to obtain uptodate address-designation and old-balance tapes.

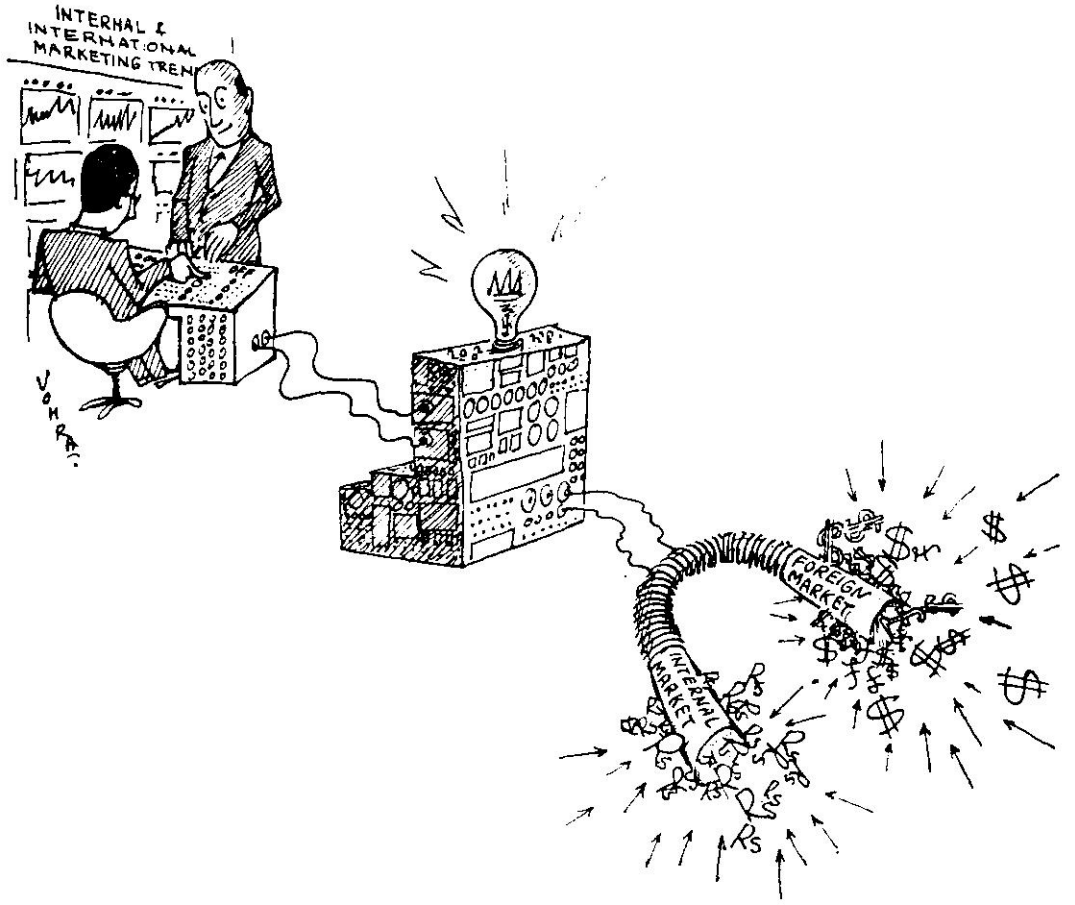
Closing Activities in the Order Checking Sections

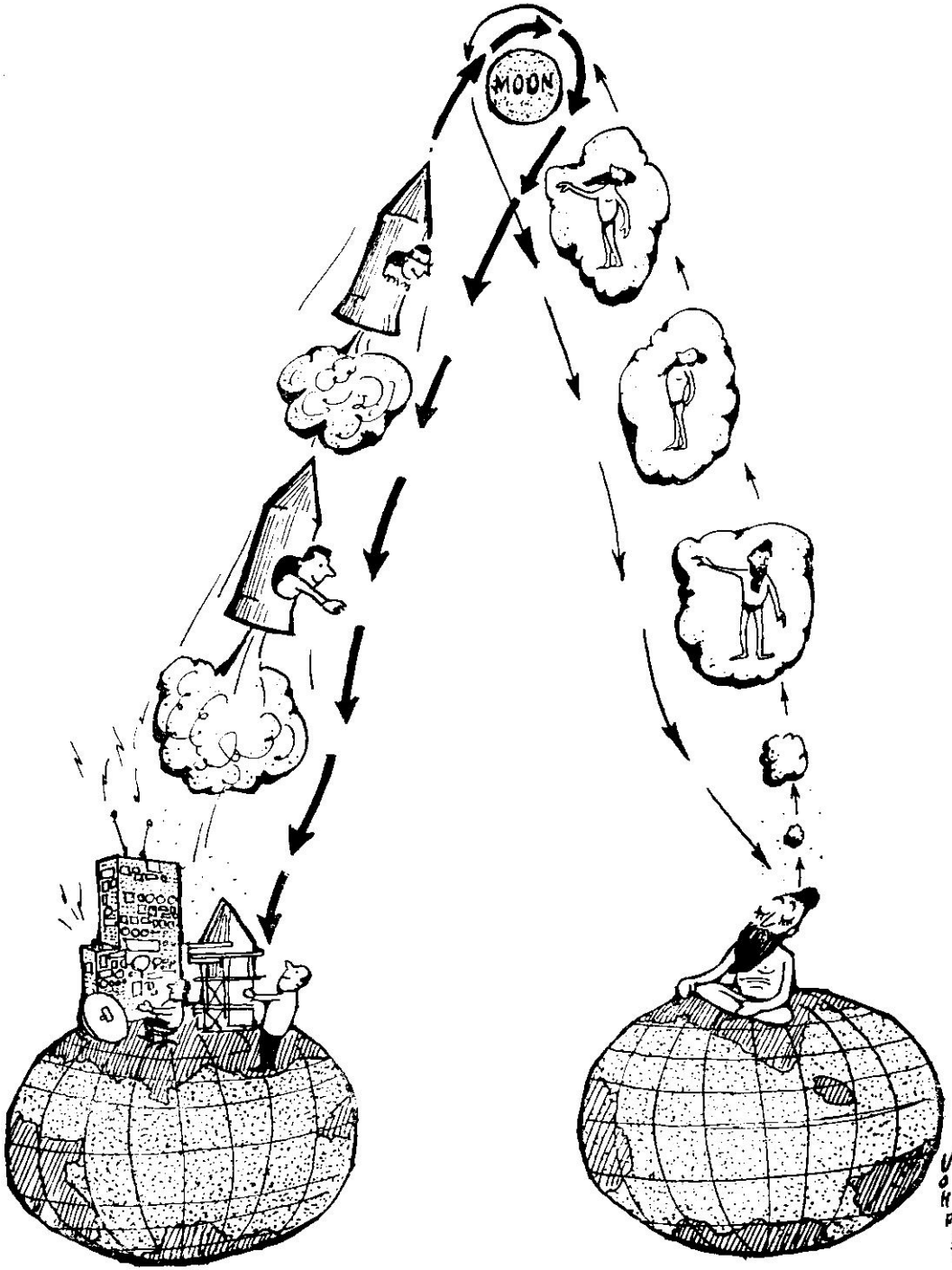
After the first entry stage has been completed, the Order Checking sections receive the relevant punched cards back and send the transfer cards to the Mechanical Preparation branch, after abstracting those which have not been entered for reasons given on the signal cards.

The Mechanical Preparation branch sorts the cards in the sequence of the numbers of the accounts to be credited. After the second entry stage the relevant punched cards are also received back, accompanied by a list made from signal cards. By means of this list the non-entered deposit cards and transfer cards (credit) are abstracted.

As a result of these activities the Order Checking sections after the second entry stage

have the disposal of all punched cards that have been entered and can be despatched as notification of crediting. These cards are sorted in the sequence of the postal account numbers. Meanwhile the statements of account have also been received in the sequence of the account numbers. The statements of account and the additional notifications of crediting (and for particular payment orders—*inter alia* automatic transfer—also notifications of debiting) are put together in window envelopes, which are sealed mechanically. The statements of account without annexes are inserted in the envelopes by means of an enveloping machine and sent to the Preparation branch where they are despatched. ●●●




MOON

A Control System for Airline Maintenance*

Truman Evans**

AT AMERICAN AIRLINES THERE IS A COMPANY-wide task group engaged in developing an integrated information system which we call the Maintenance Control System. It provides the management tools for planning and controlling the complex maintenance and overhaul workload and material logistics problems throughout the maintenance and engineering organization at various repair stations all over the country. More specifically, the object is to design a large-scale computer system by which we can plan, monitor, direct and report all maintenance activity on aircraft, engines and components.

By this we mean that there are three separate but related levels of activity involved :

(i) Maintenance of aircraft or engines and components while installed on aircraft.

(ii) Maintenance of engines and components after they have been removed from aircraft.

(iii) Maintenance or manufacture of piece parts which have been offloaded from aircraft, engines and components.

The recognition and adoption of a fundamental operating policy was necessary to implement this integrated system. Heretofore, single-purpose systems had been implemented to solve the management of particular departmental problems. Many reports were produced from the masses of data collected and these became a part of the problem. There was more information being produced than we could use, and it was difficult to choose among the offerings of the various departments, as each claimed that its system had the answer. Finally we faced up to it — **we must utilize the computer as a tool for decision-making, not as a book-keeper or a printing press.**

A major problem in the overhaul and maintenance of aircraft parts is the control of large numbers of diverse parts in process at any one time. This is further complicated by the wide range of repair processes that may be required.

Tulsa is the home of the Maintenance and Engineering Center. Over 5,000 persons are employed in the business of overhauling airframes, engines and components. Another

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3,000 persons are located at field stations where they perform what other industries call preventive maintenance. That is, every time an aircraft stays overnight at one of these stations, a certain bill of work is performed from washing its exterior to changing an engine.

An airframe must be overhauled about every 20 months. By this time, it has flown about 6,000 hours and it is brought to Tulsa for what almost amounts to a rebuilding project. Except for the outer skin, large portions of which are x-rayed, the airframe is laid bare. The interiors are stripped, walls and ceilings are dismounted and components, lines and wiring are removed. All these are routed through the shops for inspection and overhaul or replacement. For a large Boeing, this process requires about 250 direct labour personnel working 21 shifts around the clock. There are usually seven airframes in the docks every week for different bills of work. Again, from a large Boeing, some 800 parts will be removed, repaired in the Tulsa shops and returned to the same airframe. A few of these require more in-process time than the week the airframe is in the barn. There are shop pools for these items and the airframe is replenished from this supply. We have about $ 4 million invested in this kind of inventory support. American Airlines' present aircraft ownership is 205 and we anticipate a fleet total of 350 by 1975. To fly these airplanes, we own 900 turbine engines which cost about a quarter of a million dollars per copy. One hundred-ninety of these are spares which are managed about like the shop pools. In the future, we are looking at many more dollars in this category because the B747 engines are nosing $ 750 thousand each and the latest estimate for the supersonic power plants is $ 1 million a copy.

We are also going to be looking at a great many more parts from these larger, more powerful engines. But a look at today's volume of throughput is sufficient to define the problem. Last year, Tulsa processed 700 engines. From each engine there is a potential of 300 internal part numbers that may need repair in some degree. Some may be serviceable when removed and some may have to be replaced. Some parts are one-of-a-kind and others are 160 per engine. Tasks required to accomplish these repairs range from simple bench work line deburring to exotic welding processes involving grinding, plating and polishing to exacting dimensional control. The average number of task lines on a shop order is five, but there are parts requiring more than 60 individual processing steps. To handle this work, there is a service shop complex of some 250 work positions that works a three-shift day, seven days a week.

Components—they are discreet assemblies—are removed from the aircraft at the field stations and sent to Tulsa for overhaul. Components are also the external parts of an engine. There are about 8,000 individual parts in these categories and our total ownership is over 800,000. Over 500,000 of these are serialised and must be monitored individually. There are 35 component shops which process over 24,000 individual parts each month.

All this activity is backed up by 140,000 line items of inventory support which represents only about 30 per cent of our possible requirements. Exposure to need for the remaining 70 per cent is quite low or our investment would exceed the $ 73 million now on hand. This inventory is held at Tulsa primarily, but each field station has its own supply which is linked to Tulsa by a computer-based replenishment system.

This is an overview of the operating environment within the Maintenance and Engineering Division. Clearly, it demands attention approaching analog control. Quite as clearly, our 16K-1401 was outmatched. When the concepts of our integrated system were developed over a period of a year or so, we had literally no problem for securing approval of the appropriate equipment. Now we have a 360 system, model 50, with a second model 50 to be installed by mid-summer of this year.

Developing the procedures, policies and methods for a project of this magnitude and complexity required the active participation of every organization in the American Airlines

system. We started on a small scale with a seven-man task group composed of systems engineers and systems analysts. A systems engineer designs the functional system and the analyst designs the computer system. As goals became better defined, the need for support increased and now there are about 30 representatives in the taks group from all organizations within the company.

In addition, an IDP Planning Board of top management was established to guide the accomplishment of the programme and to monitor its progress.

We have said that our Maintenance Control System covers all maintenance activity in three separate but related levels of operational environment—aircraft, engines and components. Significant elements are inherent in each of these levels. These are our definitions :

Long-Range Forecast—Prediction of probable demands upon labour, material and facilities for various operating periods beyond three months.

Short-Range Forecast—Prediction of probable demands upon labour, material and facilities for various operating periods up through three months.

Scheduling—The assignment and sequencing of known demands to production facilities, allocating material, labour and capacity to meet operating requirements.

Operating Documents—A statement of basic data and information necessary to identify, route, schedule, control or process the required amount of work. Used by those who control *things*.

Feedback—The recording of operating data.

Action Documents—Information for operating levels to direct and control maintenance activities. Used by those who control *environment*.

Administrative Reports—Information for administrative levels to measure and direct overall effectiveness of maintenance activities. Used by those who *establish policy*.

When we were formulating the concept of our total system, we talked to many persons, who ranged from vice-presidents to stock clerks. We wanted to know about their problems. This is one systems project which did not start with a detailed review of how things were done at present. One reason for this was that the task group was already well-informed, having been involved in some phase of nearly all systems and procedures extant. But the main reason was because the present systems were not solving the problems. They were serving many good purposes but they were not decision-making systems or decision-indictating systems. When foremen, scheduling planners, inventory control analysts, methods engineers, managers, stock clerks, mechanics and inspectors all begin to open up and be candid about their day-to-day operating problems, visibility starts to improve for the first time. It is my conviction that *the best system is the one that is accepted* by the folks who are going to use it. How many procedures do you have that could not qualify under these terms? We had a lot of them at American. The key word is *accepted*. The key action is *contribution*. When a man from the shop joins a task group and contributes to the whole process of investigation, design and even training back in the shop, there is *willing acceptance* rather than *resigned acceptance*. These two attitudes are light years apart and so are the results.

Our conversations with these people gave us an insight that was difficult to believe at the time. Everything was geared to an insatiable quest for information. That was the wrong mission! We were not suffering from lack of information. We were, in fact, gathering too much information; not only too much but in the wrong form. Oh, the format was great. Lines and columns were neatly arranged, but it was raw data that were spewing out with no indication of where to begin to look for a condition that needed attention. Some of our daily reports stood as a solid column of computer print-outs six feet high. These were

the exception reports of just one kind of inventory transaction.

The insight had another dimension. It soon became obvious that the same information, if it was the right kind of information, would satisfy many different needs. Because a great variety of data and information is involved in our system and much of it must be stored at one time or another, we have three kinds of files—static, active and holding. Here are some of the major static files.

MDR—Master Data Record : The MDR is the single source of static information required to prepare operating documents. It is the backbone of our system in terms of reference data which tie each work item number to every necessary element of information related to it, such as its repair processes and its bill of material. Sixty million bytes have been allocated to this file.

PLF—Personnel Locator File : The PLF is the single source for static information for each employee such as assigned shop, shift, work schedule and employee number.

MMF—Master Material File : The MMF is the single source of static information for identification, procurement and related functions of inventory material. File size is anticipated to be 40 million bytes.

MCF—Maintenance Control File: The MCF contains a record of each serialised unit that has a specified service limit and also each maintenance activity that has a scheduled requirement. It will require 40 million bytes.

WIP—Work-In-Process File : The WIP contains current status in detail of all work items or jobs being processed in the repair cycle at docks/shops/vendors. This file accepts and identifies feedback data. The data will require 80 million bytes.

MIF—Master Inventory File : The MIF contains all inventory information by AAPI (American Airlines Part Identification) such as On-hand balance, Location, Value, Commitments, Consumption, and Control elements.

And some holding files are :

HST—History : The HST is actually a series of files for the storage of historical data. These files will contain data such as the type of information used on various components, labour costs, labour expended to perform maintenance operations, performance records of individual components, and records of production.

SPF—Special Projects File : The SPF contains information necessary to manage all engineering change orders. It provides the basis for continuous monitoring from conception to accomplishment and for the forecasting of associated manpower and material requirements.

MSF—Master Surplus File : The MSF contains information required to manage surplus inventory, such as :

Historical record of sales

On-hand quantities

Part supersedures.

There are other files in this system but these are representative of each kind.

The equipment we have brought together to support this system may be of some interest. The CPU is a 360/50 with 512K. It now has only two partitions, but will soon have five. In addition, there are :

nine	2311	disk drives—63 $\bar{M}$ byte capacity.
two	2314	disk drives—448 $\bar{M}$ byte capacity
one	2321	data cell—400 $\bar{M}$ byte capacity
seven	2401	tape drives
one	1403	printer—1100 lines/min
one	2540	card reader/punch

When the second 360/50 is installed, we will add :

one	1404	printer—800 lines/min
one	1403	printer—1100 lines/min
two	2701	interface with outside transmissions
two	2968	interface with our in-house transactors.

The operating system we are installing has several unique features but it is built around the MFT system—multitasking with fixed number of variables. Eventually, we want to go all the way with the MVT system — multitasking with multivariables.

Any system so all-encompassing has to be an integrated system. It must handle all the kinds of problems that we have in the airline—problems that we find in maintaining an airplane at our main base in Tulsa and at airfields all across the country : manpower problems that affect work scheduling or parts problems related to reliability. This Maintenance Control System represents the total airline problem as it relates to maintenance, including the information needed to schedule the system, to operate the system, to monitor the system and to report the system results. It could be characterised as a cross between a simulation and an analytical model of the mission of 8,000 persons.

The information required to support the system and the various ways it goes in and out of files was meticulously flow-charted. When the total system was flow-charted, then it was necessary to divide the total requirements into sub-systems or logical procedural steps as a basis for planning and segmenting the activity into workable parts. When this was done, seventeen sub-systems had been established, each according to its own logic of information flow.

Now let us talk a little about these subsystems how they will interact with the maintenance operation and their part in the data processing system.

The first step in the operations process is the development of a maintenance plan and this is done in the **maintenance planning sub-system**. This will include the procedures which will allow us to plan and schedule work on aircraft; to plan the routing of aircraft into places where the manpower and facilities are available to accomplish the maintenance. Certain elements must be present in this maintenance plan—the routing of all aircraft; the allowable operating hours, the specific work which must be accomplished according to various criteria —flight hours, calendar time, cycles. We must also have the total aircraft ownership as well as up-to-date hours on each one. We must have the maintenance workload or activity for every aircraft at all times. With all these elements of information, we can plan and schedule every phase of maintenance activity. For example, when an aircraft is due in for a main base overhaul, or an engine is due for overhaul, this sub-system will send that information to the **operating documents sub-system** which will prepare job cards and shop orders. They will state what work is to be done and where it will be done, taking into consideration the availabiilty of facilities, manpower and skills necessary. The next logical step is to report the work accomplishment back to the computer. It is called **feedback sub-system**. We will be using the transactor to report progress — when a part moves from one operation to another until it is made serviceable and sent to the assembly line or to inventory. We will be able to capture material consumption as well as manhour distribution.

The **personnel inventory sub-system** will tell us what shop a person is working in, his shift, work experience—just about everything relating a man to his work : Feedback will use personnel inventory to make certain checks on the validity of data coming into it. For example, it can make sure that an inspector's message is coming from an inspector or that a mechanic is working in the shop that matches the message he sends. One of the most significant characteristics of this system is the thoroughness of editing the input and reporting back to the source the irregularities in the input.

Feedback also reports **special projects** accomplishment which is needed by both this sub-system and the maintenance planning subsystem. Engineering change order accomplishments will be reported by routine transactor messages according to designated lines completed on the shop order.

Messages sent through feedback are used in the **progress monitoring sub-system** for

comparing what has actually happened against schedule. We can find the parts that are in trouble because of delays. If the foreman planner know this soon enough, they can do something about it so that the next higher assembly will not be adversely affected. Another function within progress monitoring is to compute committed workload. For example the foreman will know when a welding booth starts to become a bottleneck and will be able to take appropriate action.

There is a sub-system which will handle reports of **cost, performance** and **quality control.** We must have cost data to conduct and evaluate our business properly and we must be able to compare our performance with standards to see how we are doing. Is it more economical to repair or to buy a particular part? We do a lot of work on contract. We must know what it costs to perform this work.

Another sub-system is **attendance reporting and payroll.** When this goes into the system, we can account for the time and the activities of each employee throughout the day and prepare journals, payrolls and print paycheques.

There are several **planning sub-systems.** We require detailed plans for production schedules and from these we can develop budgets, facility requirements, and we can also forecast manpower requirements by shops, by machine and by skill. Production schedules and shop cycle times are the basis for determining shop pools. The production plans and the bills of material will be put together to determine our total material requirements. We are very interested in bringing all values possible from new applications in inventory management and there is a separate sub-system for this activity. We must operate on many levels—component levels to determine field station allocations to support their turnover and piece parts needed to repair components when they are overhauled in Tulsa. The functions performed here include establishing the original inventory levels, procurement, replenishment, vendor performance analysis and keeping track of inventory levels by quantity and dollar amount.

One of the most important sub-systems is reliability monitoring. Here we extract performance data from some of the other sub-systems—delay causes, pilot reports, information back from the shops concerning their findings when they examined a component, information back from the field on fixes that they have accomplished and why they removed a component.

The next step after definition of the sub-systems was determining how each would be combined with others into implementation phases. Eleven phases were the result of that determination. Many of the sub-systems are applicable to a variety of geographic locations, so the same logic will be implemented at several different points in time. The needs of our maintenance programme are quite large and complex and complete implementation will require the next six years. These implementation phases must satisfy several requirements:

i. The new system must absorb or replace existing systems in an orderly manner.

ii. The implementation phases must be tailored to our computer capacity. Data processing capabilities will increase with time. At first, the 360 system was the model 40. This was upgraded to a model 5c which gave us much more storage capacity and computation capability. Shortly, we shall have a data link in real time with SABRE system which will permit us to bring all field locations into the system.

iii. The time table must insure that escaped costs will be maximised* in the long run.

iv. **A prime requirement is the logic of the situation itself.** Proper foundations must be laid from basic data and controls established before operating applications can be successful.

*Maximised or minimised ?—**Editor**

Now, let us discuss the eleven implementation phases.

Service shops routing and monitoring is a system to sequence service shop tasks and to assure their on-time completion, to collect labour costs and prepare labour effectiveness reports.

In **component shops routing and monitoring,** the objective is to control the overhaul cycle of components, establish work accomplishment priority and to assure on-time completion, collect labour and material costs and prepare labour effectiveness and product cost reports.

In another implementation phase, the system will move into the **engine line shops.** Here we will establish schedules and monitor progress of major assemblies through these shops, collect labour and material costs and prepare labour effectiveness and product cost reports.

Maintenance planning is a system to control operating time between all maintenance actions, route aircraft and package work for maintenance visits to the main base at Tulsa as well as at all airfields where we operate.

From the basic data accumulated and the controls established during these four phases, we will have the foundation for realistic **maintenance forecasting.** Forecasting often is the first step of a large-scale system. We needed to stabilize our throughput and gain confidence in our performance measurements first. Then we will be better able to identify the factors that need to be forecasted. Airline day-to-day operations are dynamic in the extreme. Extreme measures are warranted in order to realize the great profit potential in reliable forecasting. We are developing both simulation and analytic models to forecast manpower, material and facility requirements.

Another implementation phase is **spares allocation planning.** We already have spoken of the need for parts pools. Shop pools protect a demand when the need is over a time span that is less than the shop cycle time. Field station pools protect a demand that is based on probability of need against a plan of availability. This phase is the logic that determines the quantitative dimensions of these pools and, in the case of field stations, allocates the spares ownership among them according to the forecast of exposure to need. Shop scheduling is another discipline in our system. Here mathematical models will establish shop production priorities consistent with available facilities, manpower and material. Some of the specific functions included in shop scheduling are establishing demand priorities, balancing backorders and overtime, optimum sequence of work and shop loading and balancing.

Reliability monitoring is the sub-system which will collect, store, analyse and retrieve reliability data related to components, engine and aircraft systems.

Procurement is a system for the purchase of material and control of bin levels. Included in this phase are provisioning, replenishment, manufacture for stock, material disposition and disposal, purchase analysis and inventory investment forecasting.

Dock job scheduling is a system to schedule specific jobs on aircraft during routine maintenance visits both to Tulsa and the field stations. Here we will monitor accomplishment against the schedule, collect labour and material costs and prepare labour effectiveness and product cost reports.

The final phase of the Maintenance Control System to be implemented is attendance reporting and payroll. This will expand the labour reporting system to include attendance and payroll data for all maintenance employees, including preparation of paychecks.

The portion of the system installed involves the **service shops routing and monitoring phase.** Our service shops contain 250 work positions at lathes, grinders, mills, bench, welding, heat treating, sand blasting and plating. When engines and major components are disassembled, their internal parts must be inspected and repaired. There are 3,000 candidates for this process from an engine. At the induction of an engine, notice is given the computer and, by reference to the Master

Data Record for that engine type, the computer will prepare a set of some 300 **condition analysis** and matching **trigger cards** with the same **control number.**

At the inspection stations, these sets are matched to the parts and the inspector indicates his findings on the condition analysis. Each possible condition which can be repaired is listed on the condition analysis as well as whether it is serviceable or reject. The load center moves these parts out of inspection and distributes them to the processing shops. At the same time, the stock clerk will take cognizance of the condition analysis and transact this information to the computer. He does this by using the trigger card in the transactor and dialing the line numbers for the conditions which have been indicated by the inspector.

The computer recognizes this feedback as a request for shop orders and, again by reference to the Master Data Record, will print an order that is tailor-made for each part according to the tasks that must be performed to accomplish the repairs indicated. Shop orders are produced once per shift and delivered to the load centers that control the processing shops where they are matched to their owners by control number.

Work is assigned by load center planners by placing the trigger card in the next job section of a **work assignment control board.** These WAC boards and a transactor and a material storage shelf are located convenient to each work section. The mechanic delivers finished work to this location, transacts his work accomplishment message, picks up his next job and moves the transactor cards in the WAC board to indicate that one job is finished and another is in work. As the part progresses, similar messages are sent until all work has been completed and accepted. Then a message is sent which closes the shop order and it is removed from the work-in-process file. The part is assigned a disposition by the load center and this message is also recognized by the system so the computer can continue to track the part.

Each message updates the work-in-process file so that we are able to monitor each part as it moves through the shops. Each task line shows a due date which is based on normal times for that particular step, including transportation and handling where applicable. These due dates and the completion messages tell the computer what to put on the various scheduling documents. One of these is parts in delay and due today. This is delivered to the load center about half an hour before the shift starts and lists all the parts each work position must produce in order to pass them on to the next higher assembly. When a part has fallen behind schedule to the extent that it cannot meet that assembly date, the computer reflects that condition in a document called **parts in delay by NHA.** This tells the planner and foreman that ordinary procedures will not get the job out on time—special attention is required. There are several possibilities of solving this problem and the computer automatically comes up with some additional information for a starter. It produces a document called **work item location.** This tells the status of every like part number in process at that time, including whether or not there is one serviceable in the shop pool. Most of the time, a change in assignment to next higher assembly is the answer; trading one part for another within the process. It could turn out that a temporary addition to the shop pool may be required or it may be that only overtime will solve the problem. In any event, the decision is backed up by what the system tells the planner and foreman about the situation and this is quite considerable now compared to the previous reliance on their individual hip pocket black books. The work item location can also be obtained upon inquiry and this is often done when a problem is anticipated on the shop floor before the condition reaches the computer. An abrupt change in plans usually triggers such a condition. Breaking a spindle on a vertical turret lathe might also prompt a planner into dialogue with the computer.

Our people are very serious about this system as a man-machine system. We have been giving information to our computers for years. Now we are **getting** responses from the computer. Of course, there is the initial

shock that is visible on a foreman's face when he receives his first batch of **irregularity notices.** By the time he has made the rounds of his men and picked up the right information, he begins to understand how this system is going to save him a lot of grief. He would much rather work toward getting the correct information into the computer than explain to his superintendent about the variances that reflect against his shop on account of bad input. We found that variances were caused at least as much by bad reporting as by bad performance.

We place a high value on assuring that the input is correct. We have used transactors and trigger cards for years so there is really no good reason not to expect accurate reporting. Unfortunately, we have never really known the quality of this input. At first, the transactor network fed a compiler where the information came out on paper tape. This unit was not very reliable mechanically and had no capability to edit. We replaced the compiler with a small-scale data collection computer with some editing capability but this was not the answer. Then we went to a large-scale computer with all kinds of editing and validating, but even it does not suffice. The next step is to interface directly between the transactor network and the CPU.

There are fifteen different irregularity notices. Input is edited upon receipt or during a processing chain and, if certain conditions are not satisfied, an irregularity notice is printed. It picks up the entire message that was sent, prints it out, identifies the element of the message that caused the bogey and indicates the method of returning the correct information to the computer. Usually, a transactor message with a special dial setting will work. Sometimes, a correction can be written on the notice itself and returned. If the message was a complete dud, a transcript may be required to straighten out the matter. The most common irregularity results from a task completion message being sent against the wrong line number. Each task is numbered and this is the dial setting that is required on almost every message sent against a shop order. It is so easy to set a dial at one number more or less than the one intended. We pick this up by matching the mechanic's badge number —no transactor message of any kind can be sent unless the badge is physically inserted in its slot—with the line number which also references a shop number. If the personnel file says that the employee is not assigned to that shop, the message is suspended until the condition is removed. Sometimes the foreman has neglected to send a message that he has loaned an employee to another shop. The personnel file will accept this information for the time period stipulated and take the original message back into the job stream. The foreman may also receive a notice about a man who has sent no messages during the day. If an employee is on vacation and foreman has not so informed the system, it is an irregularity. The vacation can be set up by employee number for a number of days. The programme lapses each day until all are expired and the computer reacts if it does not hear from the employee or the foreman on the first day he is due back on the job. This kind of time control is the only way we know of that has any chance of accurately accounting for each man's time.

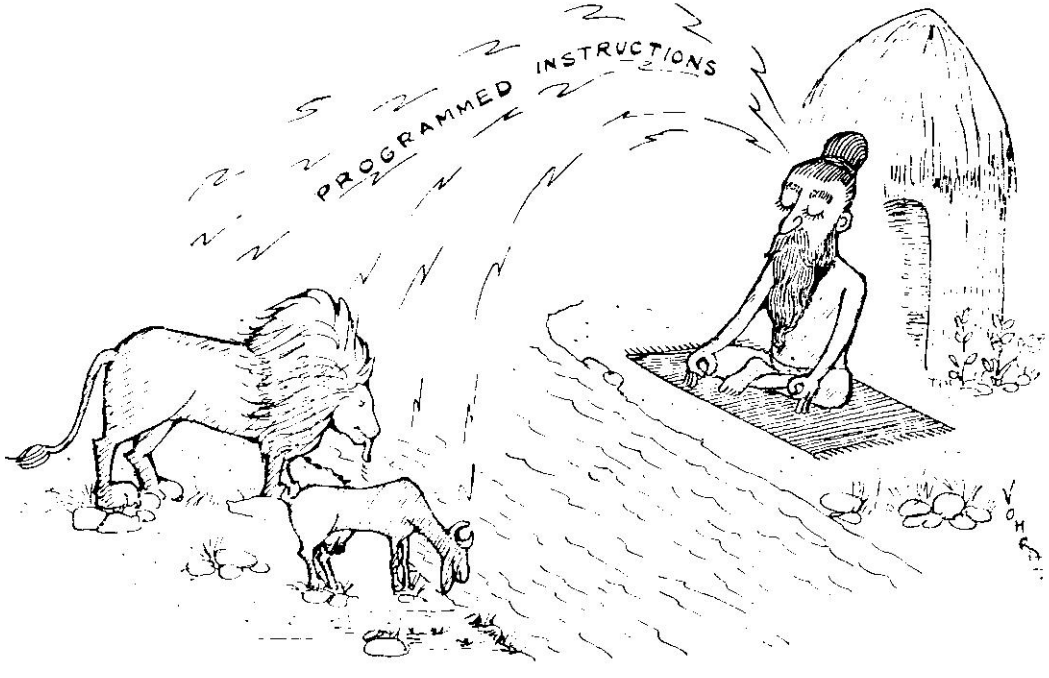
Even though we have spoken about some small details of our Maintenance Control System, this still is an overview and I would be surprised if some were not thinking about how extremely difficult this system is. We think this is the least difficult kind of system. Why? **Because this is a system in which an event is recorded at its source by the person who accomplished it at the time it happened.** This single input will update all the applicable files and it will even trigger an indicator calling for the next event to take place. It has been designed as a group effort with qualified representation of all organisations concerned. It did not come down from an ivory tower of systems sophisticates, nor was it an edict from top management. Middle management recognized the need and sold the plan both up and down the management ladder. Organization objectives have been achieved with a bare minimum of compromise. We are convinced that this will lead us toward **a better visibility of problems,** more timely decisions beforehand

and composed actions by a well-coordinated team.

Throughout most of industry today there is much complexity due to constantly changing conditions and the nature of operational relationships that must be maintained in spite of their perturbations. Some of these are difficult to sort out. Others are so crucial to career success that it is not possible for them to be discussed between talented, yet sensitive individuals. Most of us will be using some highly sophisticated softwear before long and some of us are going to be the ones to try some brand new concepts. It seems inevitable that there will be more need for faster response times to inquiries from the shop. We already see the need for a fifteen-minute response to an inquiry for non-reproduced information; this means cathode ray tubes in the shops. We already have on order a printer to be located in Dallas, but activated from Briarcliff, New York, on signal from any one of eighteen field stations.

As Industrial Engineers, we ought to be thinking about the opportunities for breakthrough. Innovation always produces the greatest gains and those of us in the Computer and Information Systems Division have possibilities limited only by our own imagination and vision. Our challenge is to use these technical and scientific complexities as tools for turning out the simplest kind of administrative approach to problem-solving and decision-making. How often have you heard it said that the closer to the action a decision can be made, the better the results will be. As a principle this is not news to anyone here. What does make the headlines is when somebody finally gets there.

American's slogan is "America's Leading Airline." This does not mean that we are the largest or that we carry the most passengers or that we make the most money. It means we lead the way. **No other airline can touch American's track record for innovations.** We feel that our Maintenance Control System is consistent with this reputation. We have some far out ideas and our management is encouraging us to try them. We think those headlines may be out soon. ●●●



E D P at The Indian Telephones

HL Subba Rao*

SINCE 1955, INDIAN TELEPHONE INDUSTRIES had conventional unit record machines. Because of the growth of the industry and also increase in the range of equipments manufactured, it was found that the conventional unit record machine was not enough to meet the needs of the industry. So a feasibility study of an electronic data processing system was taken up. Suppliers of such equipment were also invited to make a study and submit a report. After a careful study of the pros and cons of all the reports, it was decided early 1965 to instal an IBM 1440 disk system. It took 18 months to instal the system from the date of ordering the machines. Meanwhile detailed programmes were drawn up for building construction, ordering and installing air-conditioning, recruitment and training of personnel, system study and programming of the initial jobs to be taken up.

The system was installed in July 1966, all the programmes having been written after careful system study and design. After testing and debugging of the programme, regular jobs were taken up. During the few months, it was observed that at all levels of organisation, a certain amount of education was necessary regarding the needs of an EDP system and its limitations. So, regular classes and demonstrations were conducted on the necessity of standardised procedures, correct and legible editing of documents etc. After about 6 to 9 months the system got settled down.

Since the installation of the computer section, the following jobs have been mechanised:

Stock control; A B C analysis of materials; materials accounting; sales analysis; cost of sales journal with sales tax analysis; calculation and preparation of monthly incentive pay-roll of all direct workers; monthly material and labour analysis for cost control etc.

System design and programming for production planning and control, purchase analysis, cost control with card pasting etc. are in progress. ●●●

Besides a write-up on the working of EDP at the Indian Telephones, the author also furnished us a good bit of excellent advice regarding the advisability of computer installation. We have taken the liberty to print the following extracts from the author's Prologue :

Before deciding to have a computer, it is necessary that the Management conducts a feasibility study. The study should include the necessity of a computer, the jobs that could be mechanised, the savings and benefits from mechanisation, the cost of running the installation, the volume of work that could be assigned and also the character and quality of the organisation: **Is the organisation ready to have a computer**? This may include a study of how far standardisation of procedures, definition of responsibilities

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in the organisation, codification of men, machines and materials etc. has been achieved and how far it can be improved. It is also better to study the reaction of employee's Union. If the organisation has not been geared to mechanisation, the initial troubles would be enormous and installation may not show any results in the first one or two years and may in fact become a target for critics to put all the blame on the installation without studying in detail the why and how of the problem, and without thinking of improvement.

When once the Management decides to instal an electronic data processing equipment it is imperative to define clearly the objectives for which the installation would be acquired. The selection of the equipment, their operation and the necessary changes in the procedures of the organisation depend on the objectives of computerisation. It is preferable to select the principal EDP executive at this stage itself and associate him in the project.

The next step would be to contact the suppliers of computers and ask them to submit their report, recommendations and quotations for their equipments. The suppliers usually send their experts to make a survey of the organisation, volume and nature of work to be mechanised. It is their usual practice to contact various executives in the organisation and collect data and assume a certain growth for the future. The expert should also be told the objectives for which the installation has been planned. When the supplier submits his report the management should review it very critically. It is impossible for an outsider to understand completely the complexities of the organisation and the actual working difficulties, since no executive would reveal shortcomings of his department or organisation to an outsider. The report would also have been prepared with the zeal of a salesman rather than of an impartial observer, so the report would be more optimistic than circumstances warrant.

Further, there is bound to be a time lag between the acceptance of the report and the installation of the system, which may be anything from 12 months to 36 months during which many changes in the organisation might take place. In the selection of equipment not only the characteristics of the various machines and their speeds and costs but also the software support (i.e ready-made programmes available with suppliers) for each system should be considered. This may save lot of man-hours of programming and debugging (common terminology used by computer staff for testing and rectifying the programmes).

The Management will also have to consider the question of either hiring or buying a computer system. In this fast developing field of computer technology, new, better and speedier computers are coming into the market (some times cheaper also) and if we buy one, it becomes very difficult to replace them. Also when once a computer is installed and the success of the installation is established, more and more jobs will be mechanised, more often quick reports would be requisitioned. Then the existing machines may have to be replaced by faster and better machines. Also initially, a smaller machine may be taken and as the work goes on increasing, new equipment and additional units can be added. All these advantages would be there only if the equipment is hired. So it is advisable to hire the equipment rather than buy these.

The installation of a computer is a major complex project because of the cost involved, numerous activities and necessity of perfect coordination between each other. So it is vitally important to have a plan of installation and system of progress reporting. The system ideally suited is the technique of network analysis. It is better that a PERT network is drawn.

In the recruitment of personnel and training it is always advisable to seek the advice of the suppliers of the equipment. The suppliers will have certain aptitude and psychological tests which they will conduct on the candidates to find out how good they are for the jobs. If suitable candidates are available, it is preferable to take candidates from the organisation itself (since they will have a better knowledge of the working of the organisation and also would have established working relations with various departments which becomes very helpful at later stages). ●●●

Computerisation :

Technical, Economic and Social Aspects*

This article is the result of the effort of a Group got together through the good offices of Mr. Paul Siromani of the Industrial Team Service, Bangalore. Initially two papers were presented, one on the Technical Implications, and the other on the Economic and Social Implications of Computerisation, and these were discussed by the Group. The discussions were then incorporated in a paper and presented in its final form to the Group for acceptance as the Group's thinking. Those who participated were : a Manager of the Industrial Engineering Department of a Public Sector Industry, a Data Processing Officer of a Private Sector Industry, two men from an Operations Research Group, a Personnel Officer, an Industrial Psychologist, a Sociologist from the University, a President and a General Secretary of two trade unions, a clergyman and a few observers.

IT IS ESSENTIAL TO DIFFERENTIATE, AT THE outset, between **Automation** and **Computerisation**, for these are often taken as synonymous. Examples of the former would be transfer machines, compressed air carrier lines, conveyor systems, cybernetic equipment and the like. Computerisation, on the other hand, concerns the processing of data electronically and is only an aspect of automation. As its concomitant, however, its purpose is more to provide control information for decision-making than to replace or eliminate manual effort.

Applications of the Computer

The design and concepts of computer applications have gone through a ceaseless metamorphosis from the time Blaise Pascal invented an adding machine in 1642 to when the first business computer was commercially made available in 1951 at the US Bureau of Census, and since. There are two main types around which these designs and applications have pivoted—the analogue and the digital. In layman's parlance, they have been called as the scientific computer and digital computer.

The analogue computer works with physical quantities representing other physical quantities. The data fed into the computer and emanating from it are small in volume, but the processing of these data by the computer might be enormous and mathematically sophisticated. The analogue computers find their main use in solving problems relating to research, design and development, automatic control of processes, and simulation of dynamic systems either in industry or macro-analyses.

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The digital computer performs, above all, arithmetic operations on extensive data and the data resulting from the processing are also voluminous. Its main use, therefore, is in business: for various purposes like accounting, sales forecasting and information, inventory control or production planning or wherever the data require tabulation, compilation and arithmetic to get transformed into a compendium of information.

Working

There are five ingredients in the operation of a computer: i. Input ii. Arithmetic (logic) iii. Memory (Storage) iv. Control, and v. Output.

The input, which is the beginning of computer operation. is in coded form. This code consists of two numbers o and 1, called the binary numbers. This is so because the computer works on the ON/OFF, or YES NO or o/1 principle. It is an arithmetic similar to counting with two hands with no fingers. Whatever be the method of input and memory, be it in punched cards, punched tapes, magnetic tapes, magnetic discs, magnetic drums, vacuum tubes, magnetic cores, or magnetized films, the operation is on the principle of binary numbers.

The coded information which goes into the computer is called the programme which is a set of instructions to the computer on what it should perform out of these data. From here the control unit takes over. It determines what bits of information should be taken out of the memory unit and when, what operation ought to ensue, and the whole sequence of steps towards the resulting output. This, of course, is done in accordance with the programme. Memory is the place where information is stored until it is used. The arithmetic unit performs all the mathematical operations, and can also be termed as the logic unit. The arithmetic unit follows the orders of memory and so is dependent on the information stored in memory. The resulting solution to the problem through all these operations is the answer which the computer turns out, or the output.

Need for Computerisation

It could be said that computerisation emerged as a consequence of the modern concepts of management. The objective of management is to optimize all resources—fiscal, material, manual and mechanical. In this process of optimization, management makes decisions based on control information on the availability and utilisation thereto of these resources. Modern decision making in business demands two prime requirements:

(i) A processing and information providing unit which receives, analyses, and integrates voluminous and repetitive data, and provides the required information on related management functions;

(ii) A similarly centralised system for the utilisation of modern techniques like Operations Research.

The two demands made above are incorporated in the computer which alone can perform these operations. The processing of similar data in a manual information system would be time consuming and inaccurate. And decisions based on these results are likely to be sub-optimal and because of the time lag, anachronistic. A machine like the computer helps analyse dynamic situations and projects decisions towards the organization's objectives. In a well-designed computer system, along with its routine handling of routine operations, **the system extracts and digests information for the precise requirements of the management.** Such a management information system enables control by exception.

Another complexity in management is the need for correlation and collection of variegated data pertaining to a particular management function. In a conventional manual system, data and activities in processing them remain departmentalised and are transmitted through communications, but are never or scarcely integrated. This results, on the one hand in duplication, and lack of feed back on the other, owing to difficulties in ensuring prompt and effective interdepartmental communications. In other words, there is no central pooling o

information and the management is thus denied the advantage of an over-all picture. This anomaly is eliminated in a computerised information system, because the centrifugal point is the computer which remains in one place, and therefore receives and emits information from one source.

Management techniques like Operations Research make the computer imperative because **the human mind cannot correlate the various parameters involved in these calculations with similar fecundity.** Many of the techniques are a by-product of computer science itself, and cannot be applied without it.

Pre-requisites

The main pre-requisite of computerisation is the need for it. This need is established by the determination of whether the whole or a part of the manual data processing system in an organization could profitably be converted into a computerised one. This study of the feasibility to computerise starts with the collection of information regarding the procedures, data volumes and forms. The information gathered is then analysed and presented on charts to indicate information flowing from one direction or another. The decision to computerise or not is based on this study which ought to have proved that the volume of communication of data is too large, too repetitive and difficult to be efficiently processed manually and so warrants a computer. **Oftentimes, at least in the case of small organizations, the necessity is for streamlining the information system, its procedures, activities, forms etc., than for computerisation.**

Phases in Installation

The first phase which follows the feasibility study is systems design. As the feasibility study would have revealed and made available the set-up of the current information system, systems design deals with how it should be recast, and eliminated or supplemented to meet the management's objectives.

The results of the feasibility study are further analysed with a view to **spotting circumlocutous procedures.** Processing activities and paper work which are duplicatory, superfluous or vestigal are discarded, and a streamlined, integrated and simplified system is evolved. The potentialities of the computer whose purchase or hiring and installation are considered, are thoroughly studied and a befitting system is designed to meet the objectives of computerisation. This is done by determining the output data that would be required of the system and by working backwards to establish a sequence of input and processing leading on again to the output.

The importance of the systems design cannot be overemphasized for, in its absence, **a computer which can better a good system could also worsen an already bad one. Wrong data fed into the computer could produce catastrophic results and could be corrected only with considerable dislocation and expense.**

The next phase is the codification of input data for identification in computer language. The main consideration in the evolution of these codes is the nature of data and the type of processing of the code.

Equally important is the preparation for the new system. The first task lies in selecting and training the staff for the computer The second is programming or the translation of instructions into computer language. Sets of instructions for computer processing, called programmes, are written and tested for corrections. This is followed by the creation of the master-files of information-memory in the form of punched cards, magnetic tapes, discs etc. The last task is the preparation of and for the equipment itself—like site, power, climate and storage area.

The final phase is the changeover to the new system. This consists in closely monitoring the computer system until a full processing cycle is established.

Accruing Benefit and Productivity

The benefits which accrue can be illustrated from specific instances. The computer has been used for routine operations in inventory

control, production scheduling, bonus and payrolls, cost and management accounting, financing and realisation of outstandings in banking operations, income tax returns and insurance policy calculations, and even in the tabulation of examination results. It has made possible controls by exception for stocking, PERT for project planning and cost control, linear programming for product mix problems and so on. Thus the productivity of the computer lies in that it helps carry out the means for sophisticated management which, in its absence, would have been difficult.

As a scientific device, it has contributed to better aircraft designs, flight and radar control, evaluation of satellite orbits and telecommunication and experimentation in medicines and chemicals.

It is also being increasingly applied for macro-economic, socio-anthropological and demographic studies.

Need for Flexibility and Critical Analysis

It must be noted that **management systems are dependent on an exterior business pattern,** and are therefore dynamic. They have to be reviewed against obsolescence and towards redefined goals. Correspondingly, the computer system needs redesign and critical analysis when the objectives which brought it in change or the parameters for attaining these objectives become different.

Another form of change can come with the advent of more sophisticated computers themselves. Here too, the advantages of the change-over have to be analysed through a feasibility study.

Scope for Sophistication

Recent researches in the concept of computers have tended towards the creation of tailor-made computers for specific problems. We shall soon see more of these ready-fitting computers for production scheduling, inventory control, and the like, and hybrid computers for all specialised applications. If the efforts at conceiving and perfecting a computer to translate languages succeed, the world would get unified by a single source of information which not only binds, but transcends geometrical and language barriers.

ECONOMIC ASPECTS

What are the potentialities of computerisation in an economy like India's? Our economy is primarily agro-economic, labour-oriented, and at the point of take-off. Would computerisation create massive unemployment and retard take-off or obviate the problems it is likely to create by otherwise contributing to productivity?

It would be of interest for a student of developmental economics to inquire as to why computer development shou'd have been concentrated and significant only in some highly developed economies like the USA. Even Japan, France and the Soviet Union have taken to it only in small doses, despite their immense strides in electronics and automation. There could have been two possible reasons: firstly, these countries have not had the need for processing voluminous data; and secondly, they, like India, have been primarily agriculturally based, and have had to face the problem of unemployment.

The population of India is at loggerheads with its productivity. Further, its agricultural proportion is at a disequilibrium with its industrial proportion. In other words, the contribution of this sector to the latter is offset by the acuteness of population concentrated and dependent directly or indirectly on agriculture.

Employment *vs.* Computerisation

Because of this unproductive concentration of labour, our economy follows the Lewis model of development. There is no palpable fall in production with the withdrawal of labour upto a certain point. In the productive sense this is surplus labour or "disguised unemployment." From the point of view of distribution of wealth, it signifies gainful employment to labour which in the absence of such a set-up would be superfluous and therefore unutilised even partially. The direct displacement of

labour would in the first instance be the disguised dependence of this group on a smaller income of other groups, and in the long run, the reduction of general purchasing power and consequent retardation of industrialisation and take-off.

Massive computerisation in India may, therefore, be viewed in the context of the following facts:

(a) there is "disguised" and "undisguised" or open unemployment in agriculture, seeking vent into industry;

(b) there is the case of the educated and the skilled unemployed seeking employment in industry; and

(c) there will be the case of white-collar workers displaced because of the installation of the computer.

Why should India alone face this aggravation of the unemployment problem by the introduction of the computer, while despite massive computerisation and automation, the unemployment figure has been decreasing in the United States and has remained constant in the United Kingdom? These economies have attained the stage of full employment where every person who is able and willing to work is gainfully employed. Low population in terms of resources and the necessity for prosperity through productivity have veered towards making manual resources scarce in these countries. The case of India is the contrary because of its potentiality for unlimited supply of labour. Therefore **should computerisation swarm in to occupy every feasible area of clerical activity in India, like in the United States and the United Kingdom: would the displacement of this labour force be formidable?** One already hears of the introduction of computers in the petroleum industries in the country and the proposal for a large-scale computerisation in Government organisations like Life Insurance, Income-Tax, Accountant-General's Offices and the Electricity Boards. Could the displacement of the labour force be rehabilitated or obviated by the absorption of skilled labour in computer industry and its applications? The answer is in the negative if what we have in mind is a sudden revolution which would usher in the computer.

Other Problems

Besides the unemployment problem, the obstacle is the feasibility of computerisation itself. The incompleteness, unreliability and disrupted flow of information relating to agricultural and industrial productivity, income distribution and even the census do not make decision-making through a computerised system any more advantageous than through a manual system. Therefore, computerisation in these sectors would not be profitable unless methods of collection of primary data are improved by the use of statistical techniques and the like.

The next obstacle is the administrative set-up and mentality which may not be geared to exploit this sophistication. The prompt and accurate availability through the computer of the information required for decision-making would serve no purpose when the decision is going to be inordinately delayed or not made at all on account of bureaucracy, administrative constraints and lack of initiative. The ground should first be laid for effective decision making and control in the organisation. Or else computerisation in particular areas would be like installing automatic traffic lights at isolated places in a main thoroughfare when all the roads leading to it and away from it are narrow and corwded and where the traffic is ill-regulated. In other words, although some specific problems might have been overcome, the overall situation has not improved. In such cases **the computer would only be a showpiece.**

Selective Introduction

The problems confronted in massive computerisation do not undermine the fact that **the computer is an eventual necessity.** Even the industrial revolution which created widespread unemployment in its first phase, subsequently absorbed the displaced and additional labour force in new vocations of white collar workers and workers in overalls. It

would be pointless therefore to emulate the 'LUDDITES' and deny ourselves a valuable tool for higher productivity and progress. The basic issue is not whether to computerise or not, but how to introduce computerisation without adversely affecting the national interests. The solution, therefore, lies in not calling a halt to computerisation, but in discriminately introducing it in the light of national implications.

India ought to introduce computers immediately where there is no threat of unemployment, that is, in scientific research and design and in export-oriented industries which face international competition, or wherever the advantages outweigh its disadvantages. Its introduction in other larger complexes and service organisations ought to come in progressively as their requirements justify its utilisation in the light of socio-economic implications.

Computer Service

There are two empirical impediments to the successful introduction of computers in India. Modern computers are sophisticated equipments and their potentialities are likely to be left unexploited. This would take us then, to the problem of **computer underemployment.** The other one is the prohibitive cost of installation and operation of a computer. Many industries which require the aid of the computer are, therefore, left to do without it.

To meet both these contingencies, it would be in the interests of national productivity, if the Government and organizations in the private sector could establish computer centres with computers and computer expertise in the form of systems analysis, programming etc. These centres would cater to the needs of small and medium sized organizations, and amalgamate their findings, and pay themselves from the recovery of the cost of service rendered. They would also provide the forum for education in computer science and later for computer technology, and plan for self-sufficiency and development in the field of computers.

SOCIAL ASPECTS

Misconceptions

To the layman the computer is an inexplicable scientific device capable of performing all the functions as his imagination would tell him. Even to educated people, the computer represents an electronic brain capable of taking decisions by itself. These misconceptions are due to improper scientific education or attempts by newspapers at sensationalization. A clear understanding of its capabilities and its limitations would remove both the shroud of mystery about it, and the uncalled-for fear of having to face its after effects. It is fundamental to realise the fact that it is not a substitute for the human mind or intelligence.

Computer *vs.* the Human Mind

When the days come when we would have grown used to the computer, like at present to electricity, would our mental processes be deadened? The indications hitherto have been to the contrary. For one, it systematizes human thinking, helps reanalyse existing situations and to critically examine new ones and opens up much greater fields for skill and to put one's wits against the oddities and challenges of problems.

On the contrary, there are some instances of executives in the computer industries abroad developing stress illness after a few years of active service. This is probably due to the continuous and exacting demands the complexities of data processing and the competitiveness of the industry could make on the mental alertness and resourcefulness of the systems analysts and the programmers. Although India might not be beset with this problem for some more years to come, this might eventually require attention as a vocational illness and also require social therapy.

Socio-economically, as stated earlier, the benefits of computerisation are, in the end, themselves imperceptible and taken for granted.

National Approach

If our industries have to become competitive in the local and world markets, and if we

have to exploit all our resources in order to become a self-sufficient and self-alimenting economy, **we cannot afford not to computerise over a time.**

It is, of course, true that indiscriminate introduction of computers would entail difficult consequences. Both the Government and private industries ought to consider the important social consequences of computerisation. For instance, in personal service organizations, if there is a threat of massive sequen tial unemployment, unless the results of computerisation are likely to dwarf the disturbances caused, it would be prudent to make this a part of a long metamorphosis, than a sudden revolution.

It is also essential to take corrective measures for rehabilitation of the unemployed. These would mean the creation of a planned basis of additional employment opportunities, retraining of the displaced in new trades, compensatory payment for redundancy or unemployment insurance benefits, and a positive policy oriented towards the country's needs. It would be more constructive to control rather than call a halt to the spate of modern advancement. It would be a step backwards if we went iconoclastic or luddite. **What India ought to do is not to fight shy of the computer, but fight its problems by computerising in a selective and phased manner.●●●**



Numerical Control System

AV Athani*

Though the author has worked out the mechanics of the application of a numerical Control System to the machine tool industry, actually this is of wide application; and we have printed it here, as readers would naturally like to know how machine working gets automated in a Computerised System.

NUMERICAL CONTROL SYSTEM SETS THE positions of the slides of a machine tool accurately. The position of the part is clearly defined in terms of numbers. So also the relative position of the tool is defined in terms of numbers. The data regarding the position of the part and that of the tool are in the form of punched tape or cards, or are recorded on a magnetic tape. For that reason these machines are also called Tape Controlled Machines.

There are two distinct types of controls for the two types of machine tools. In point to point control systems the work is stationary and the tool is given the cutting motion. This is the case when a drilling machine is fitted with numerical control—abbreviated N/C. The second type is the contouring control system in which the workpiece and the tool, both, move simultaneously to give the required shape. This system is more complicated than the former, and more costlier. Milling, routing are the examples of this type of control system.

N/C is now generally fitted to most of the types of machine tools. Of late, even drafting machines, for making intricate drawings, have numerical control.

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The basic system (Fig. 1) includes the data handling unit and a servosystem which drives the slides. Naturally one servosystem is needed for each axis of control. The servosystem also includes some type of measuring unit to see that the slides occupy the required position. The error signal is generated in the comparator unit, amplified for accuracy, and then supplied to the servomotor which in turn drives the slides, and thus control is incorporated.

Codes

Throughout the process, information is recorded on the tapes and cards in a coded form. The codes are so selected that the numerical data can be handled by the control unit easily. Nowadays binary code, with 2 as base, is mostly used.

The number 1 1 1 1 1 under the binary code will mean $2^4+2^3+2^2+2^1+2^0=31$. An improvement in the binary is the decimal binary code, in which fractions can also be expressed.

The tapes used for the purpose of storing the information may be a five-hole tape or an eight-hole tape. In binary code, a five-hole can be used for the movement of slides to the maximum extent of $2^4+2^3+2^2+2^1+2^0=31$, while in an eight-hole tape maximum infor-

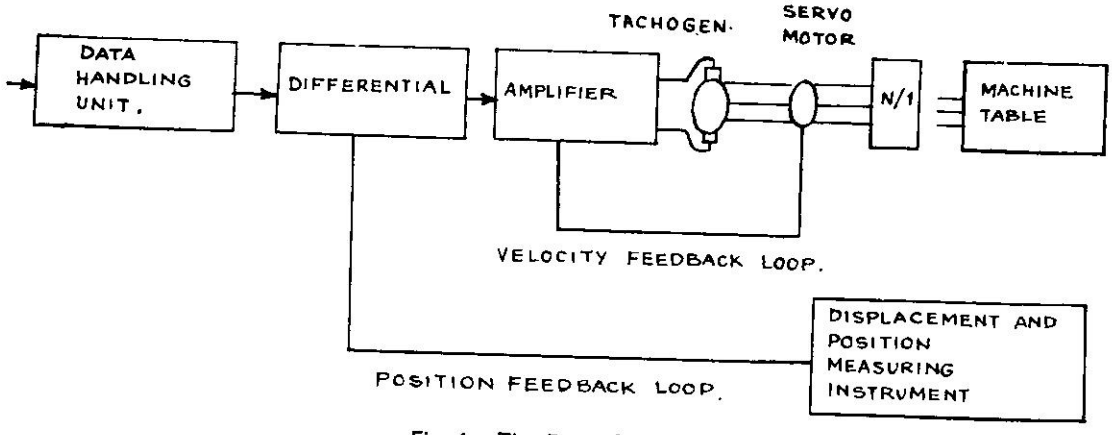

Fig. 1. The Basic System

mation that can be stored will be $2^7+2^6+2^5+2^4+2^3+2^2+2^1+2^0=255$. Thus the information stored is about eight times that storable on a five-hole tape. Separate codes are used to indicate miscellaneous functions such as starting, stopping and the like.

The appearance of a punched tape is shown in Figure 2. On this tape, dimensions are coded in the decimal form. Since each value is represented by one hole, two rows of holes are needed for one digit. The tape shown is a Ferranty point-to-point control system tape, with five holes. The values punched are X (00.750) and Y (03.503). The maximum value that can be obtained is 99.999. Each system has its own codes. Management instructions follow the bare values.

Machine Accuracy

These machines have a position-measuring device incorporating the use of transducers, designed to compare the achieved signal with the ordered signal in a comparator, followed by an amplifier, which can detect the minutest error signal.

For driving the machine, and for control purposes, mechanical power is necessary. This power can be obtained by electric, hydraulic or pneumatic means or a suitable combination of them.

Servosystem

The servosystem consists of at least one feedback loop (see Fig. 1) containing servo-

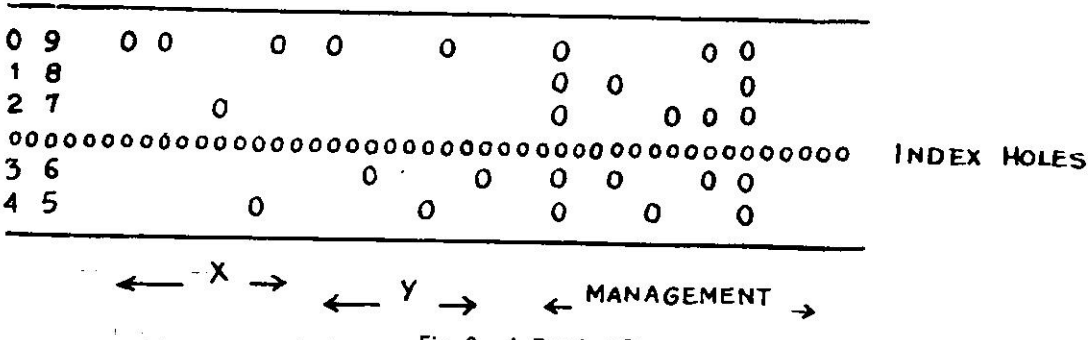

Fig. 2. A Punched Tape

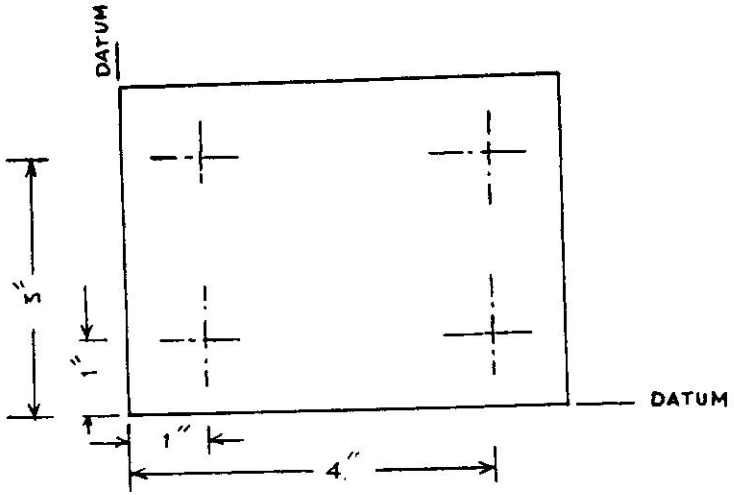

Fig. 3. Point to Point Control

motor, position-measuring device, and a differential. For stabilising purposes, additional feedback loop containing tachogenerator is used.

After collecting the data, it is processed to suit the particular unit. For point to point unit, this task is easy. The distances X and Y from certain datum, as shown in Figure 3, have to be specified.

For contouring control this is a difficult task, since it involves simultaneous motions of tool and the workpiece. A contour is first divided into a number of elements. Each element can be expressed as a straight line (in linear interpolator) or as an arc of a circle or parabola (circular of parabolic interpolator). The technique of finding out equations of a contour is shown in Figure 4. When X and Y steps are drawn, these are smoothed out. In the same way the cutter path is specified as shown in Fig. 5. When the cutter is worn out slightly cutter dimension compensation is allowed.

Figure 4 shows how the equations are to be found. First, the equation of the line AB is found out, then that of line CD is found out. The curve BC is an arc of a circle, and hence its equation can be found out. Figure 5 shows how the cutter path is smoothed out. These steps of X and Y are very small.

Advantages

If properly used, N/C can have several advantages. A single machine can be used for different purposes. Only a single tool i

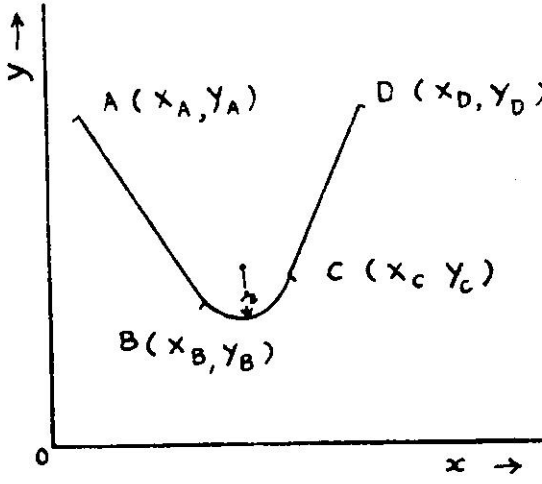

Fig. 4. Contouring Control

needed, with no templets or any other toolings. The use of these machines is, however, restricted to batch production. The use of N/C with templets will make it suitable for mass production. N/C is now being used for the production of cans, gears, turbine blades, tools, jigs, aircraft wings etc.

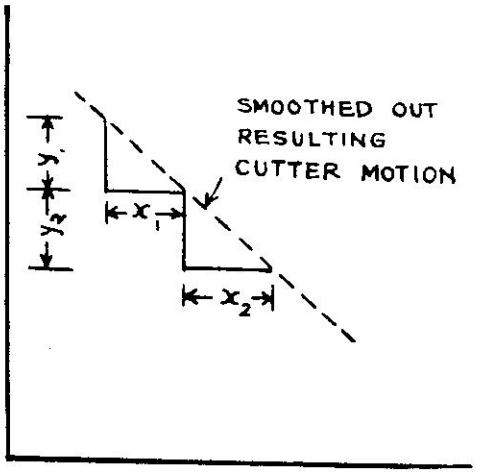

Fig. 5. Cutter Path

The most important point to note is the productivity of these machines. **A productivity of 450 per cent can be achieved with only 120 per cent running costs.** High accuracy and extensive savings on toolings are the main advantages. Repeatability is another feature of these machines; the same tape can be stored, and used for the production of the same part with the same accuracy.

In Indian industry, N/C is still in its experimental stages. However, one can say with confidence that it is almost a **must** if we have to compete in highly sophisticated foreign markets, which enjoy the high economies of the Numerical System. ●●●



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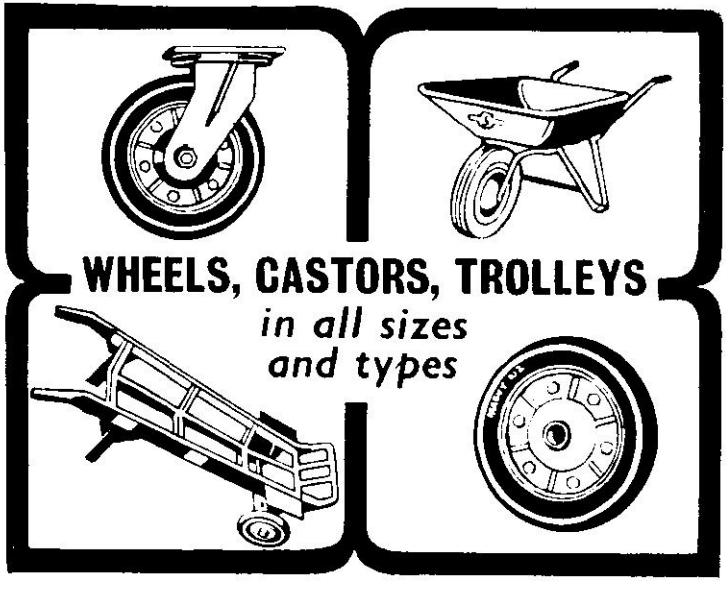

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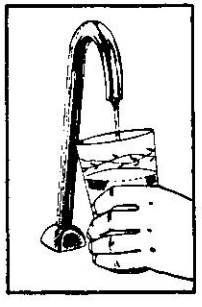

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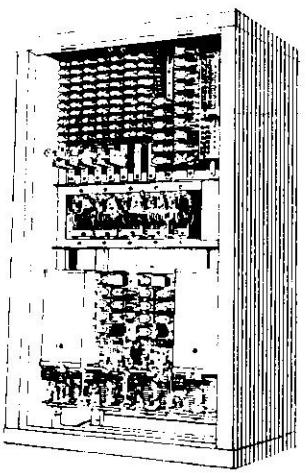

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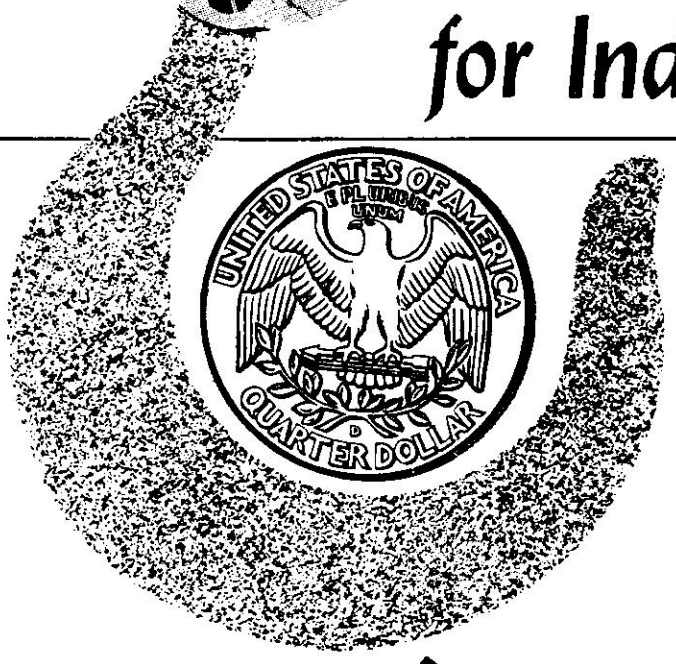

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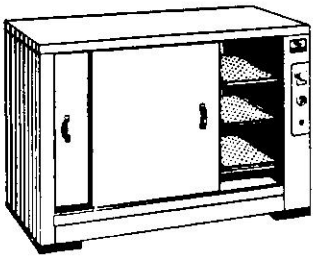

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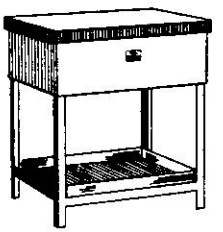

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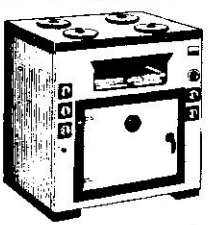

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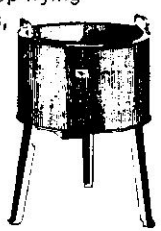

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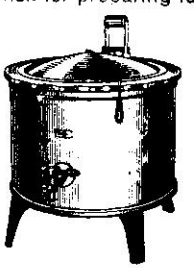

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Computer Control Systems for Cement Plants*

By the courtesy of the Westinghouse, we have been able to secure the right of publishing their specialised write-up on Computer Control Systems for particular industries. This is for Cement and has, by the very nature of the case, explosive possibilities for an underdeveloped country like India which requires cement by billions of tons.

ON LINE DIGITAL CONTROL OF A CEMENT mill can minimise raw material costs and produce more on-specification product. Computers can be used in the modernization of existing mills or as the primary control system for new plants. They can be applied to the kiln, raw material blending, raw and finish grinding, and control of silo storage. In addition, the same computer used for on-line control, can be useful in providing correlated data logging, monitoring and alarming, running time and maintenance scheduling.

An Engineering Approach

Through the use of an engineering approach to computer control, on line operation can be quickly achieved. It is not necessary to spend months on data accumulation and reduction in order to determine a mathematical model. Westinghouse has proven conclusively in a large number of process control computer applications that good sound engineering equations can be derived to provide the necessary information for an accurate control model.

Designed for Growth

By the use of these advanced techniques for computer control, Westinghouse modular hardware concepts permit cement plant automation on a plant-wide, integrated system or on a step by step approach. In either case, there is no risk that the system you buy today will need to be replaced because you have outgrown it. It can merely be expanded to meet any future requirements.

Complete Systems

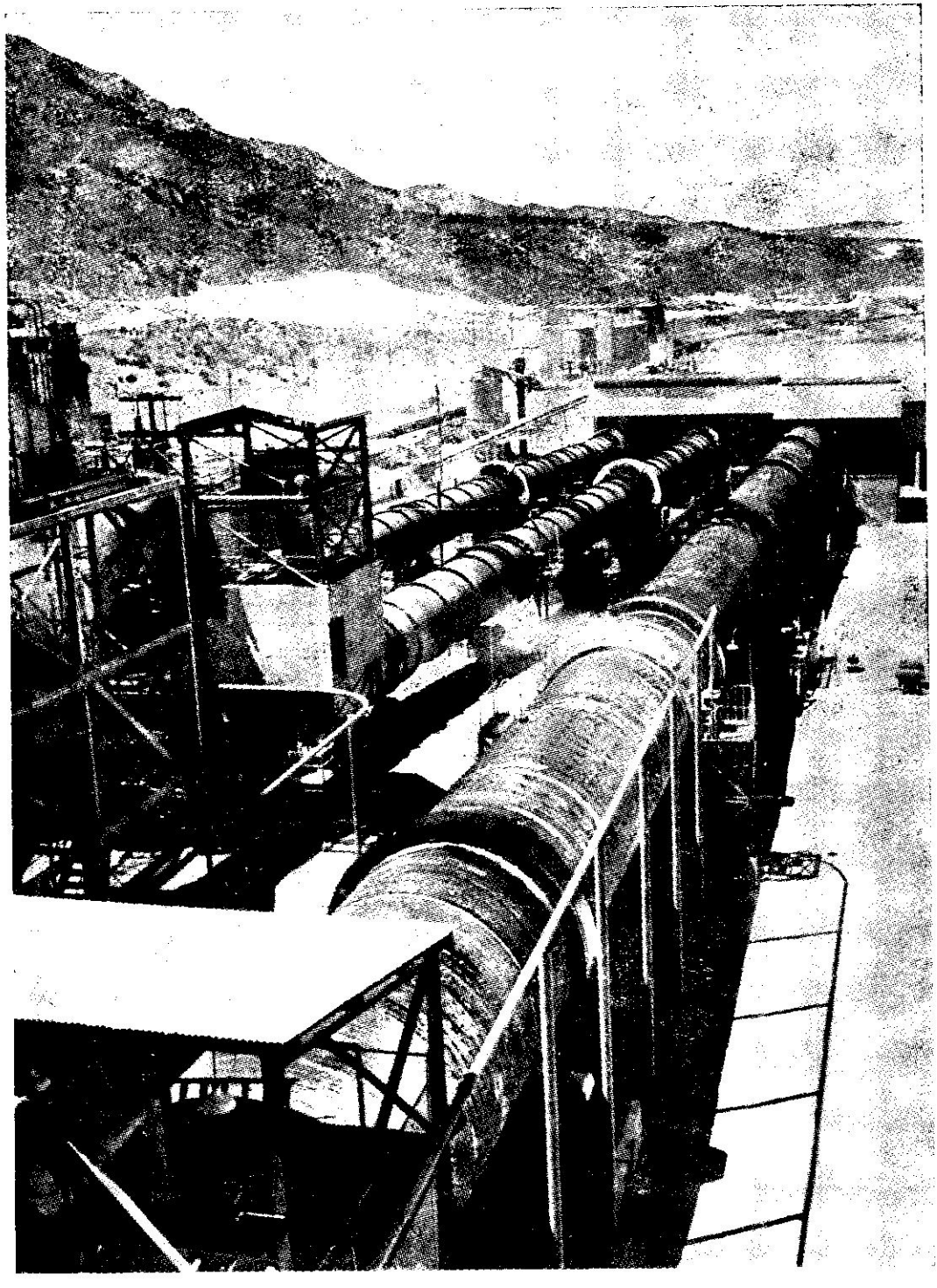
You can buy from Westinghouse just what you need, ranging from computer hardware only, all the way to a complete system including the software, the instrumentation, and systems engineering to meet a functional specification. When the system is installed Westinghouse will train your programmers and maintenance men and/or if you prefer has complete maintenance services available throughout the world.

Digital control of a cement mill with on line process control computer systems can give an excellent return on investment and Westinghouse can provide the exact system that you need to obtain it.

Kiln Control

Computer control of a kiln is based on heat and mass balances. Conventional instrumentation can be used to obtain most of the necessary information including the flow of

*Westinghouse Electric Corpn. Computer Systems Division, Pittsburgh, Pa., U.S.A.



Cement mill with on-line process control computer system

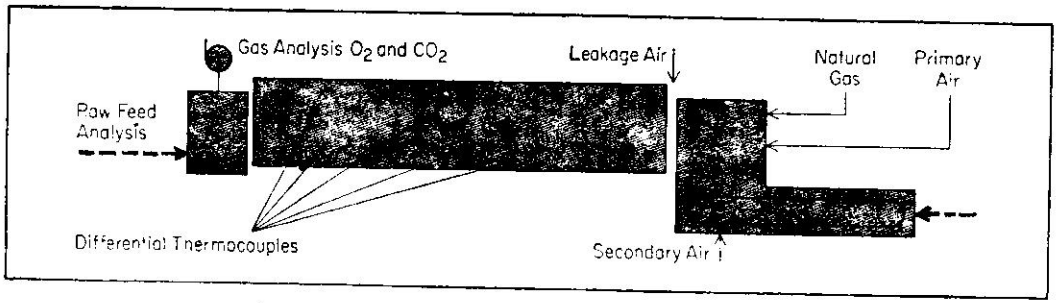


Figure 1 — Principal computer inputs for kiln control

fuel, primary and secondary air, insulflated air, together with feed and gas analysis. These are shown in Figure 1. This does not take into consideration however, the exothermic reactions in the burning zone. For this, Westinghouse uses a unique technique utilizing differential thermo-couples. From them the computer can determine the heat flux profile throughout the kiln, especially in the burning zone. Not only does this technique complete the heat balance equations, it also helps provide far more accurate control of the process to both improve product quality and lower lining wear. This reduction in lining wear can mean one less shut down per year which could mean a savings of $ 60,000 on increased production alone.

Another advantage of computer control is that trends in the kiln can be used as a control parameter as well as absolute values at any time. This is of chief benefit in maintaining a consistent product since it prevents wide excursions from the optimum conditions.

Grinding Control

The objective in grinding control is to obtain ıe highest throughput possible with the ıipment and to produce a particular and ıiform particle size. Since the total output a ball mill is the new material plus the ecycle, the computer controls feed rate in dance with recycle to provide maximum hroughput. Recycle ratio is constantly changing e of mill wear and variations in raw erial hardness.

In a wet mill a small cyclone separator sampling the main slurry stream can be operated under computer control to give particle size distribution. This is shown in Figure 2. The

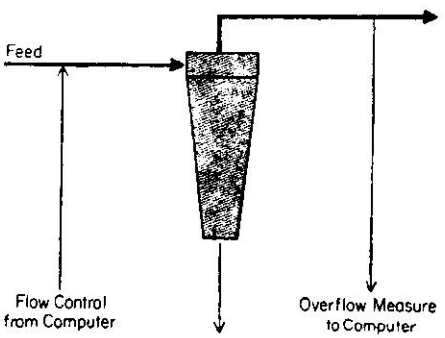


Figure 2 – Particle size distribution equipment.

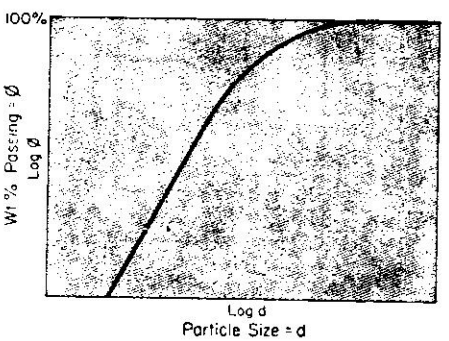


Figure 3 – Particle size versus percent passing determination.

separation in a cyclone is a function of the inlet velocity. Under computer control the inlet velocity is increased in small controlled steps and the resulting change in overflow and underflow is measured. The result of the test is a curve as shown in Figure 3 of particle size versus percent passing.

Raw Blending

While a few mills are fortunate enough to operate on a raw feed which is of uniform composition, most quarries produce a constantly changing material. Figure 4 shows a typical plant with four raw materials, any or all of which will change from time to time.

If the composition of each raw material is known, the lowest cost blend can be calculated by solving four simultaneous equations. The feeders on each product line can then be set to give the desired composition. The sample of the slurry in the silo is also put through the on-line analyzer and the composition is verified. When the quarry material changes, the X-ray will detect the change in overall composition and the computer, by working the equations backwards, can modify the initial composition of the raw feeds. The X-ray analysis is made as frequently as possible to prevent major upsets in the raw blend. The transport delays through the conveyors and through the grinding system are factored into the calculations.

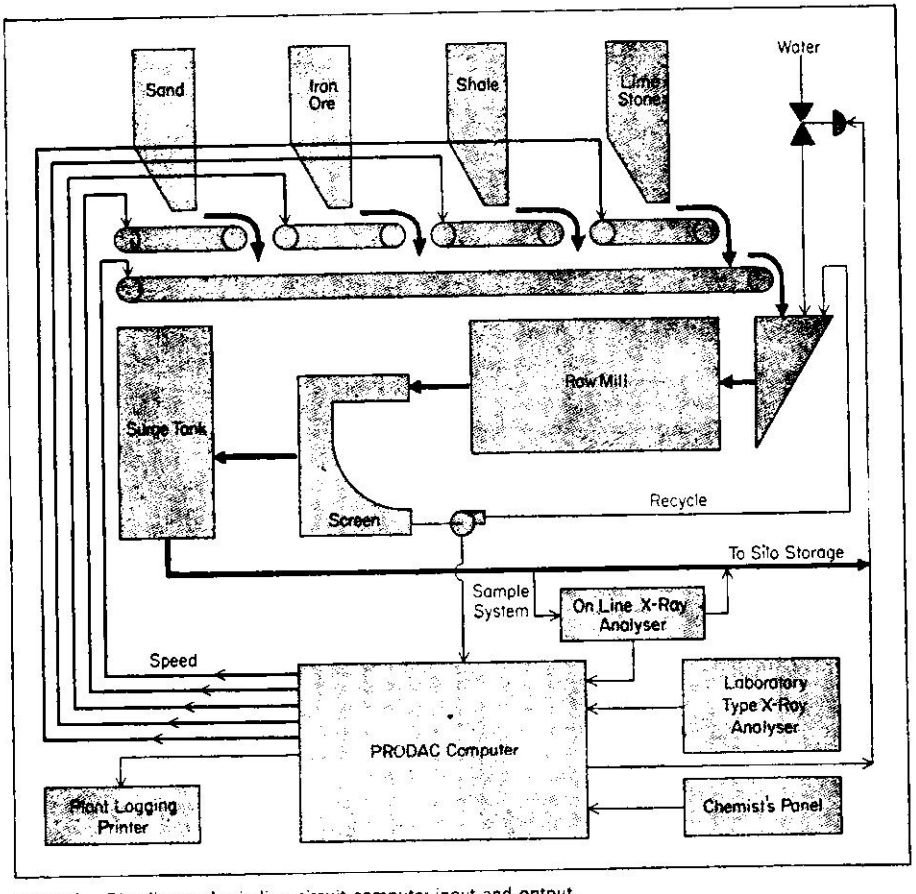


Figure 4 – Blending and grinding circuit computer input and output.

If the dust from the precipitators is recirculated this adds one more element to the blending calculations but presents no problem to the computer.

Figure 4 also shows the computer directly controlling the speed of the individual conveyors on the feeders. This can be done by direct digital control with the computer constantly monitoring and adjusting the drive motor speeds or provides a speed reference to a self regulated drive. The more functions assigned to the computer the more comprehensive the system becomes. For example, the recycle in the grinding stage must be considered in determining the water added to the raw mill. Under a comprehensive system the computer is provided with information on the water in the recycle line and then computes the water which must be added to the feed to achieve the desired density.

In the case of a directly controlled blending system, if the raw material is such that the blend cannot be brought within specifications the computer will alarm to the operator and can provide alternative suggestions including changing the type of cement being produced to one which can be made with the material available.

Data Accumulation

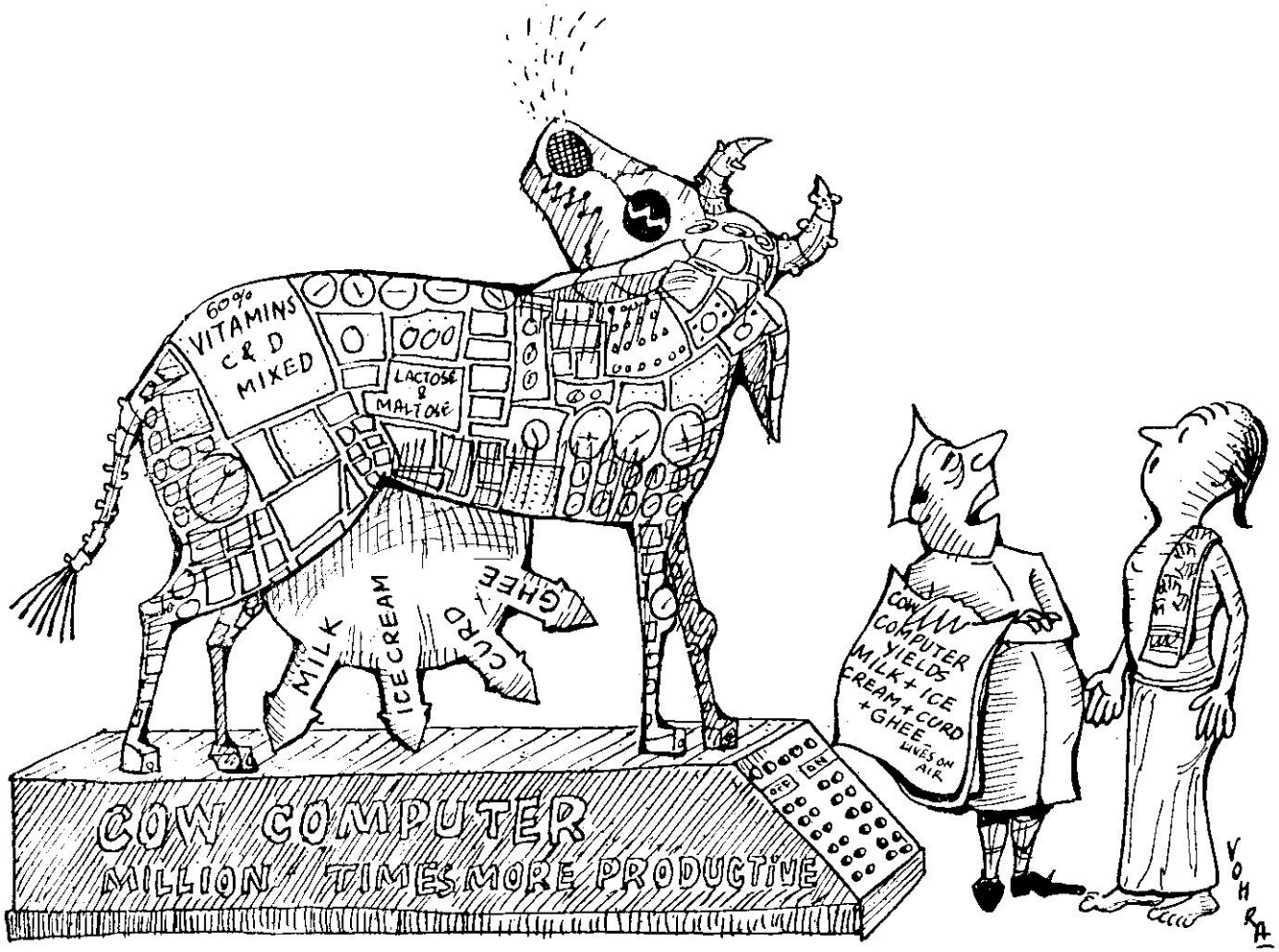
While the emphasis is on control by computer, the importance of data accumulation should not be overlooked. Hourly and demand logs are important to plant operators and a daily summary log is a valuable management tool. The information obtained by the computer is time correlated and has been found to be more accurate than other data logging systems. Alarms and out of limit conditions are recorded on the log sheet. In addition calculations within the computer can produce information for the log sheet which must otherwise be calculated long after the fact.

Part of the data accumulation programme is inventory control. Because flows and weights are used in the controlled calculations the computer already has much of the necessary information. Additional data can be obtained either directly from scale values or from human observations such as stadia readings from a stock pile survey. Again these raw data can be processed into a more convenient form by the computer.

Data accumulation can also include such information as the running times on equipment and maintenance information. By incorporating a convenient means of giving the computer the maintenance performed, preventive maintenance schedules can be produced and automatically typed out for each shift. A clock programme within the computer makes this feasible.

Summary

Computer control of a cement mill includes heat and material balance equations for more accurate control of the kiln which will produce a more uniform product, give increased control of burning zone temperature profiles and location, minimize fuel consumption and greatly increase lining life. In the grinding circuits the computer can determine particle size distribution and optimize recycle rates to give the highest ball mill throughput. In the blending of raw feed, where this is necessary, the computer can calculate the lowest cost feed for given product and automatically control the individual feeders. Direct reading of an X-ray analyzer permits running changes to be made to the individual feed rates to obtain far closer control of the slurry to the silo storage. When silo blending is possible the computer can assure a uniform feed to the kiln. At the same time the control is being performed, data accumulation systems can produce management information which is concise, accurate and quickly understood. ●●●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Computer Control for Arc Furnace*

SINCE ELECTRICAL ENERGY IS THE LARGEST operating expense for most arc furnace shops, it is the most likely place for major cost reductions. Westinghouse has developed a demand and load factor control system with a base price of $70,000 which can pay for itself in 6 months or less.

In a power bill two factors must be considered. First is the maximum rate at which electricity is used, (demand charge) and second is the total energy consumed during the billing period. It is this second factor, (energy charge) energy measured in kilowatt hours, which produces steel. The rate of using electricity (demand) does not melt scrap, but is a major factor in determining the total power bill.

For example, in a shop with a 20,000 KW furnace load, if all furnaces were turned on full for just half an hour and then shut off for the rest of the month, the demand charge would be more than $20,000. The energy charge would only be about $50 but only 20 tons of steel would have been produced at a cost of $1000 per ton. If the furnaces had been operated at full load for the entire month, the demand charge would have been the same and the energy charge would be around $70,000. However, about 28,000 tons of steel could have been produced at a cost of $4 per ton. While both these cases are unlikely, they show how the demand charge is not directly related to production and how a high average load gives low cost operation.

Load factor, the ratio of the actual average load to the maximum possible load, is as important in cost control as demand limiting. Load factor can be improved by reducing the demand by increasing the number of kilowatt hours burned at the same demand rate. The best approach is a combination of both. The Westinghouse arc furnace demand and load factor control system constantly measures the rate of using power and the total energy consumed. It automatically adjusts the furnaces to take full advantage of power company rate structures and to produce hot metal at lowest cost. Experience with systems already in operation shows that a load factor of 85% can be maintained when using load tap changing transformers and that the system will pay for itself in approximately 6 months in shops of 15,000 KW or larger.

Additions to the base demand and load factor control system can be made either at the time of installation or at a later date. Typical additions include a heat log produced automatically from the actual control information, putting more furnaces under control, changing from no-load to load tap changing, and automatic control of chemical composition.

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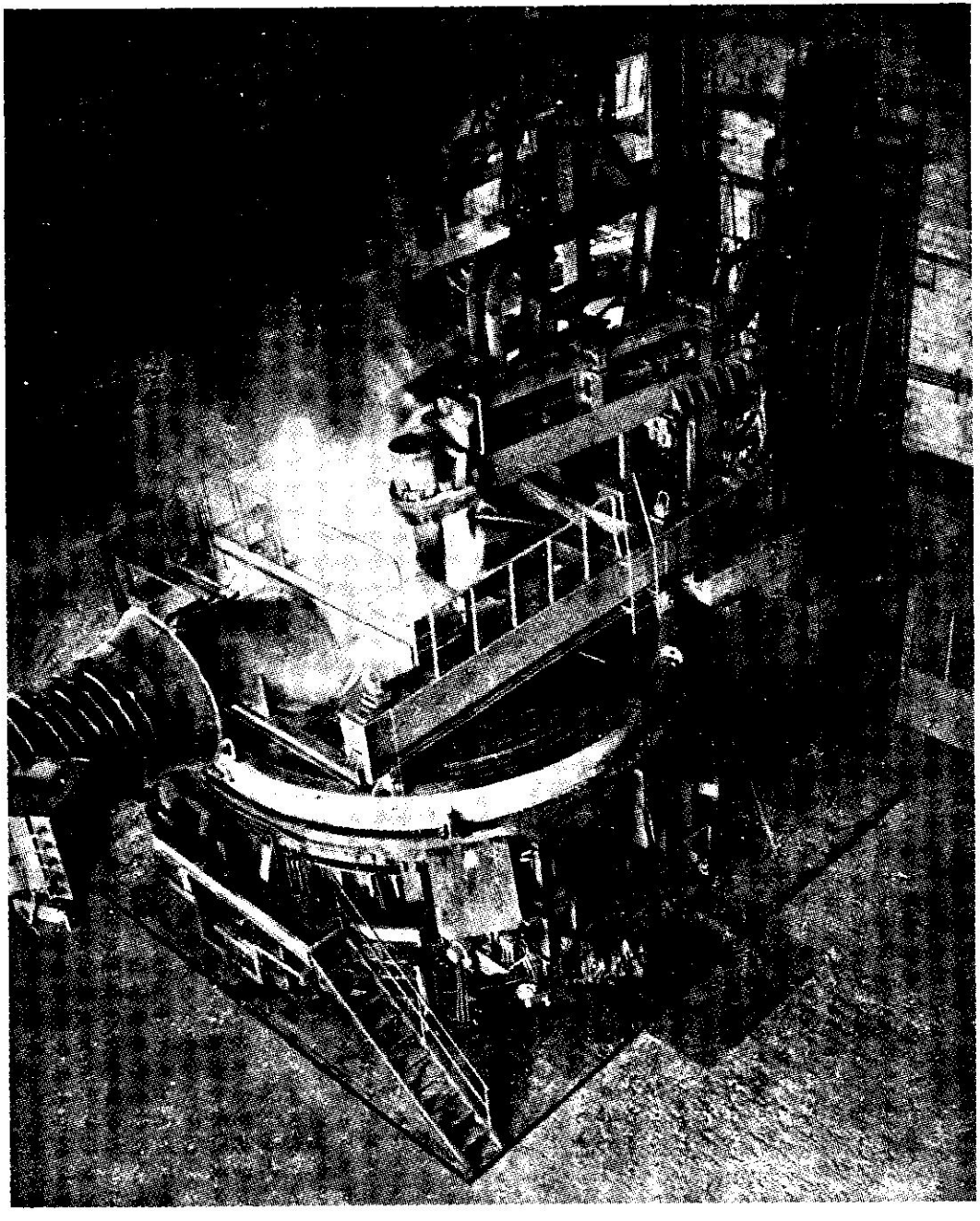


20,000 KW Arc Furnace

The heart of the system is the Westinghouse PRODAC 50 process control computer--a solid-state, all silicon component system designed especially for industrial control applications. In over 60 installations the P-50 has been proven reliable, rugged and extremely capable. The P-50 is also far more versatile than wired logic systems which have been used for demand control. Demand is the rate of using electricity, usually measured over a 15-minute period. If a 20,000 KW shop operates at full load for half the period, the meter will register 10,000 KW. At the end of the period, the tell-tale hand on the demand meter will remain at 10,000 KW, and the actual hand will start from zero again. Shutting off half the furnaces during another demand period and operating the others at half load would establish a demand of only 5,000, and the tell-tale would never move. Turning all furnaces on full for the whole period would establish a new demand peak of 20,000 KW which would be used for billing.

The energy charge is based on the actual KWH for the entire month. Utility companies give a quantity discount on these kilowatt hours, the discount quantity depending on the demand. This means that reducing demand produces direct saving in demand charge and reduces the number of kwh on the higher steps of the rate; a double saving, as can be seen in this example:

Typical industrial power contract :

Demand charge: $1.15 per KW of peak billing demand over 15 minute period

First 300 hours use of billing demand at $ 0.0065/KWH

Next 200 hours use of billing demand at 0.005/KWH

Additional use of billing demand at 0.004/KWH

Assume that the maximum demand was 20,000 KW (for one demand period during the month everything was on full load) but that the average load for the month was 60 per cent, represented by Figure 1. The total KWH are 8,760,000. According to the schedule the bill will be :

Demand Charge 20,000 at $1.15	=	$22,300
Energy charge 300 hrs × 20,000 KW = 6,000,000 KWH at $0.0065	=	39,000
Balance (2,760,000) at $0.005	=	13,800
Total billing (demand plus power)	=	$75,100

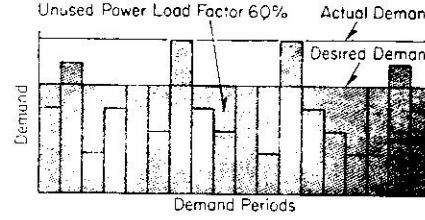


Figure 1: Without Demand Control

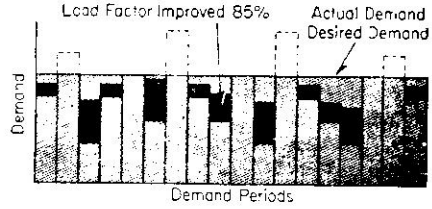


Figure 2: With Demand Control

Since there are about 730 hours per month, the same 8,760,000 KWH and the same amount of heat could have been obtained with a demand of 12,000 KW The total bill then would have been :

Demand charge 12,000 at $ 1.15	=	$13,800
Energy charge 300 hrs × 12,000KW = 3,600,000 KWH at $0.0065	=	23,400
200 hrs × 12,000 kw=2,400,000 KWH at $0.005	=	12,000
Balance (2,760,000) at $0.004	=	11,040
Total billing	=	$60,240

This provides a saving of $ 14,860 and would still have melted the same amount

of steel, but represents a 100 per cent load factor. In actual practice, a load factor over 85 per cent is unlikely. The charging and pouring time must be considered, there are times when the power cannot be increased, the refractory must be changed, etc. At an 85 per cent load factor as indicated in Figure 2, the monthly billing would be $ 64,782 and the savings would be $ 10,318, still a very worthwhile amount.

In this example the demand was reduced while holding energy consumption constant. An alternative is to keep demand at a higher level, increase usage through improved load factor control and melt additional metal with the added electrical energy. The approach taken must be determined not from a control standpoint but strictly the economics of the plant and the industry.

One of the great advantages of a computer controlled system is the ease with which the entire philosophy of control can be changed to meet changing plant operating requirements and technical innovations. Simple wired logic systems are available which will turn off load to keep demand within a set value. They cannot consider alternate approaches or increase load on furnaces to make the most efficient use of the overall plant facilities.

Some utilities have a variable demand schedule, dependent on the time of day and their peak load. This permits even greater savings if the control system is capable of handling the more complex calculations. It must have the rate information stored in memory, and know the time of day in the outside world.

The P-50 power controller system can give better and more flexible control because it receives from the power meter a signal each time a fixed quantity of kilowatt hours is consumed. Since the computer control knows the exact time of day, it can plot a curve for each demand period showing the rise of the demand. The ideal line is shown in Figure 3.

The controller stores high and low limits shown in Figure 4. If the actual curve

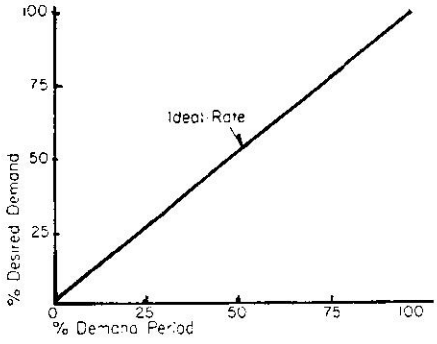


Figure 3

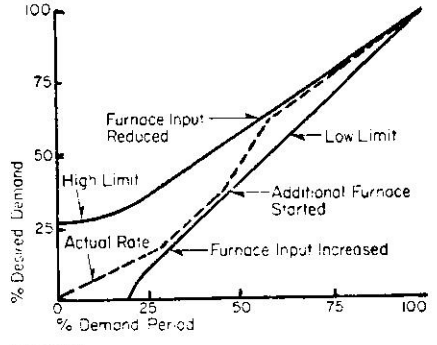


Figure 4.

falls outside the limits, a tap change is made to raise or reduce load. When the furnace has load tap changing, the computer calculates what tap is required to make the actual demand reach the desired demand by the end of the period. The computer-control changes the transformer to that tap. Should the load change again, and it most likely will, the computer will determine if it is going out of limits and will again change the tap to bring it in on target.

Only by keeping track of both the power consumed and the passage of time can the control system keep the demand within the desired limit and keep the load factor high.

Should the transformer have no-load tap changing, the controller can change the taps by lifting the electrodes, opening the breaker, changing the tap, closing the breaker and restriking the arc; or it can advise the operator

through his console and have him do the actual work.

While the charge is in the early stages of meltdown, changes in power will have little effect on the metallurgy. Large changes in the heat would, however, adversely effect the molten metal. Therefore, the computer keeps track of where each furnace is in the melting process, and changes taps up or down on the furnace most recently started. If a greater change is required than can be obtained on a single furnace, the next to last one started is changed.

There is nothing experimental about a Westinghouse P-50 furnace control system. Several have been in operation for long enough to provide actual, meaningful information on what they can accomplish. In one shop with two furnaces rated 53,000 KW, the average power bill was reduced between $ 10,000 and $13,000 per month.

One reason for this kind of performance is that Westinghouse takes full responsibility for the system. You don't have to buy hardware and install it yourself. The system is built from standard hardware modules which have been thoroughly tested. Then checked-out programmes are read into memory. The entire control system is then tested together, using another computer to simulate the dynamic operation of an arc furnace shop. When the system is shipped, Westinghouse provides technical direction of the installation and gives it a thorough check-out. There is no one to pass the buck.

At present most Westinghouse computer demand and load control systems are installed in existing arc furnace shops and use existing weighting equipment. An operator's panel (shown in Figure 6) is provided with which he can give information to the computer and receive instructions from it. The operator reads the weight of scrap from the scale and uses his console to give this information to the computer. In the same way he can set the highest and lowest taps which the control can use, and, of course, set the demand limit.

From the melter's panel the summary of each furnace can be read, such as the actual demand, which step it is on, the transformer tap being used, etc.: this panel is shown in Figure 7.

In a new installation, or in the case of a major revamp the weight scales will usually

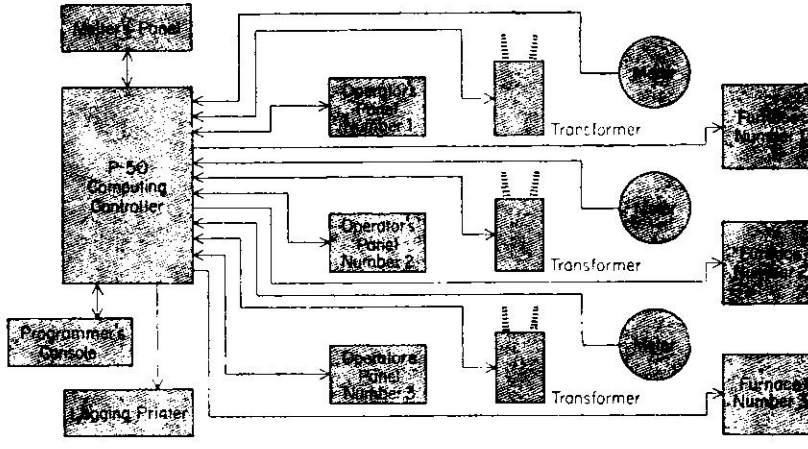


Figure 5: Block Diagram of Information Signals for Demand and Load Factor Control System

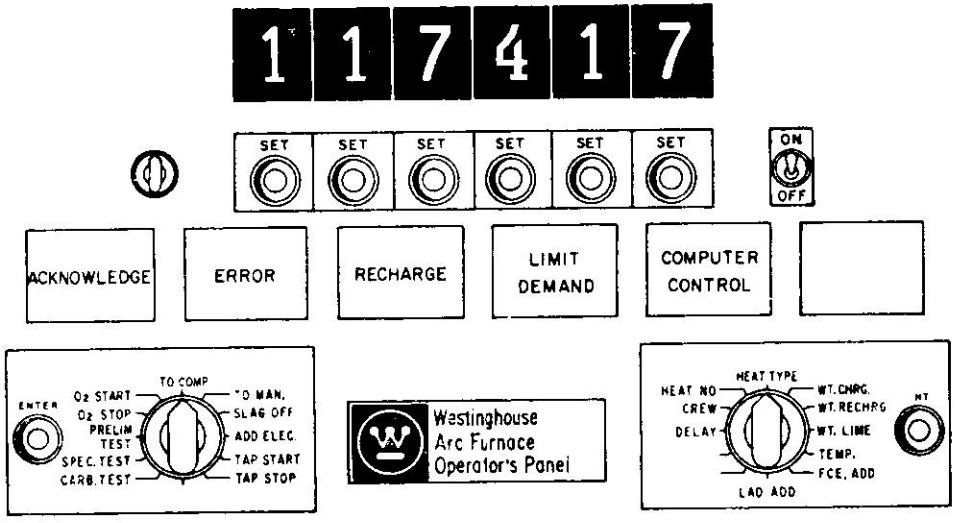
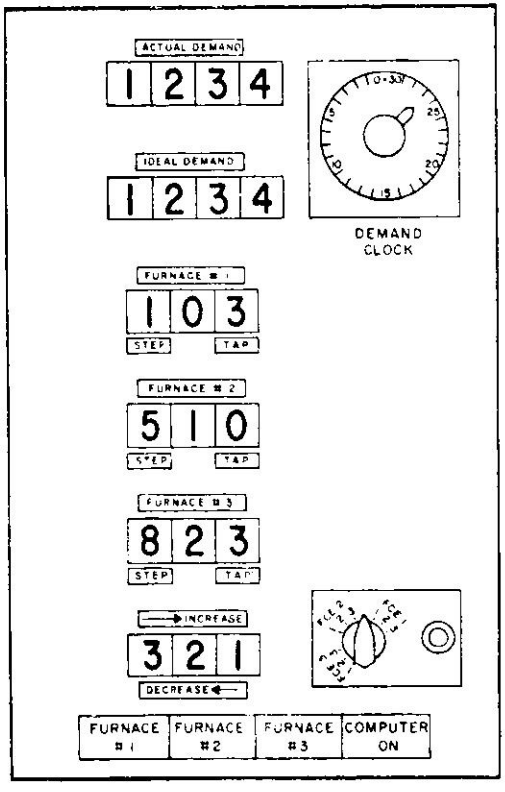


Figure 6 : Arc Furnace Operator's Panel



← Figure 7 : Melter's Panel Assembly

be fed directly into the computer, and the operator is relieved of this task.

The heat log is an extra which can be supplied. It is a typewritten record produced automatically by the control computer which lists the charge, the time and the crew, the energy consumed, the taps on which the furnace operated and the time the heat was finished It is a permanent log of operations and eliminates the time-consuming and frequently inaccurate logs commonly found.

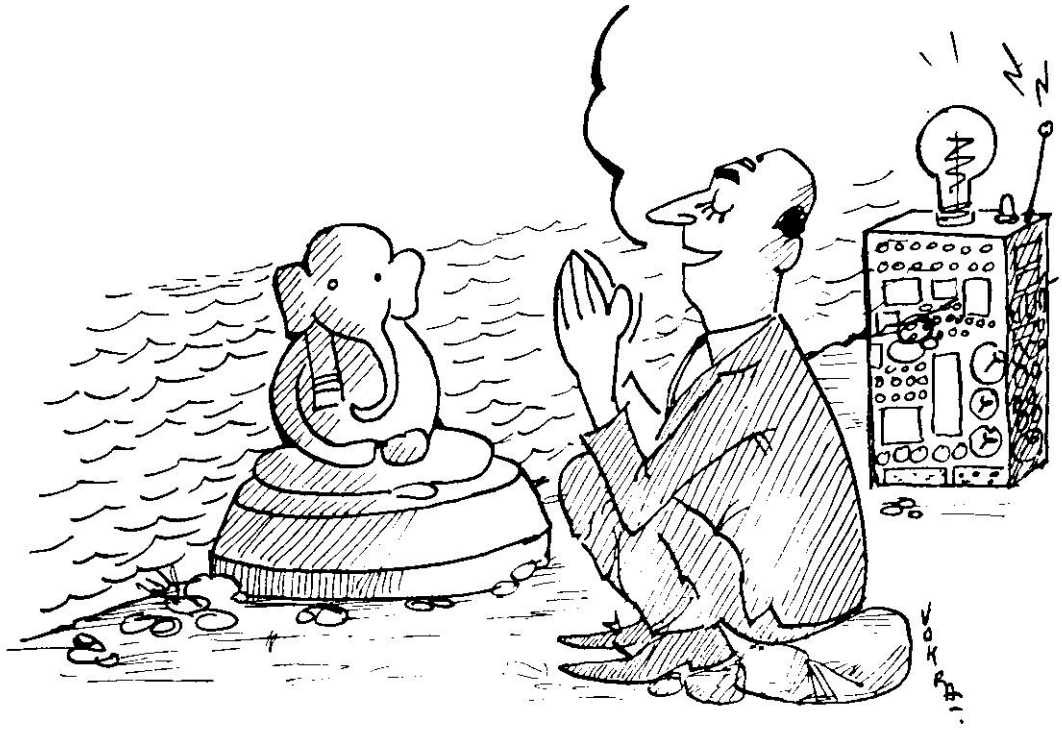
Either at the time of the original installation or at any later date a "chemistry package" can be added. In a high alloy shop the additive savings which the computer can produce are even greater than the power savings. A chemist's console is used to feed actual composition from quantitative or spectrographic analysis. The desired alloy data is fed in, and the computer calculates the optimum additions which will produce the end result, incorporating such considerations as oxygen blow, reduction of FeO in the slag, ladle efficiency and so on. Because of the modular construction of both the hardware and programming, there is little

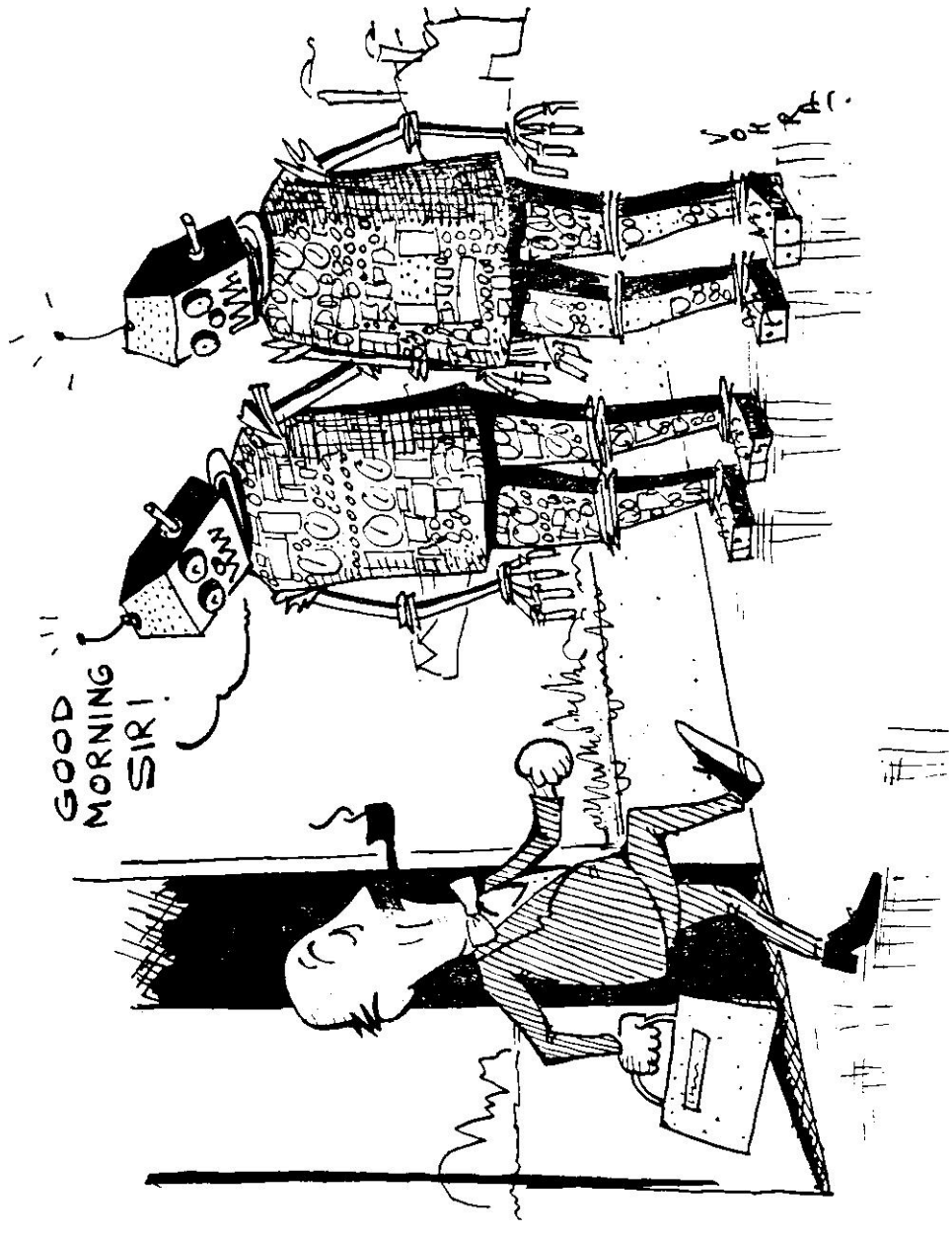
difficulty adding the chemistry package in the field.

The machine that makes all this possible is the Westinghouse PRODAC 50 computing control system. It is a general-purpose digital computer, designed especially to give the reliability and ruggedness necessary for industrial control applications. It is solid-state silicon so that it can stand temperatures of 120°F and has built-in filters which keep out mill grime. Air conditioned rooms are not necessary.

Memory can be provided up to 32,000 words. The word length is 14 bits. This retains the accuracy of available instrumentation. It can communicate with analog instruments that produce a continuously variable signal (such as pressures and temperatures) or it can look at 14 contacts at a time, and determine whether they are open or closed. It can read tape or cards, rotary switches, push-buttons or typewriters.

While the P-50 was designed as a small computer, the number of plant sensing devices which can be connected is huge. No installation has even approached its total communications ability. Unlike most data processing computers that work on a single job at a time, a P-50 system time-shares itself, watching the whole plant, conversing with the operator and producing management information.




GOOD MORNING SIR!

Data Processing in A Continuous Tube Rolling Mill

Horst Brock, Aurel Romascan & George Veberschar

Electronic data processing systems are being employed to an increasing extent for production scheduling and control. The requirements to be met in such applications are quite different to those imposed on the systems used to solve problems in the economic and administrative fields. What is needed here is a wealth of organisational experience, a thorough study of the process and an analysis of the relationships between technology, plant organisation and electronic data processing. Siemens, who have been dealing intensively with these problems for a long time, installed two data processing systems, in addition to conventional electric systems, some time ago in the Thyssen Rohrenwerke AG for their new continuous tube mill train.

A LOOK AT THE MANUFACTURE OF SEAMLESS tubes makes it easier to understand the problems that the data processing systems are required to deal with in the continuous tube rolling mill. The raw material for tube manufacture consists of solid, cylindrical steel billets. After these billets have been checked for conformance to fixed weight limits, they are heated in a rotating hearth furnace. At a temperature of approximately 1200 °C the billets are fed into the rotary piercing mill between two profiled rolls whose axes are at an angle to each other. The centre cavity which is formed during the rolling process is enlarged by forcing the billet over a piercer plug. Short compact shells with a considerable wall thickness are thus obtained.

In the continuous rolling mill these shells are rolled down over a piercer plug rod. Several 2"-high sizing stands arranged in series and displaced by 90 degrees greatly reduce the wall-thickness. When passing through the stands, the rolling stock initially has an oval cross section. The last mill stand gives the shell its round cross section, thus allowing the piercer plug rod to be drawn out easily. The desired tube shape is then obtained in the following stretch-reducing mill train. Afterwards the tubes are cooled on a cooling bank. Finally, the tube bundles are cut according to a pre-determined programme, gathered in slings, weighed and transported to the finishing shop for dressing and testing. The continuous tube mill train in the Thyssen Rohrenwerke AG is designed for the high production rate of four tubes per minute. The manufacturing programme is very extensive. It embraces tubes with an OD of 26 to 114 mm and wall thickness of 2.6 to 12.5 mm. To use the mill train to full advantage a system had to be found which would compile economic production lots from the incoming orders and ensure continuous supervision and efficient control of the whole production line.

Data Processing Systems

Two Siemens 3003 data processing systems perform the production scheduling, supervision and control functions at the continuous tube mill train. During normal operation the two computer systems are assigned different jobs. One system, the scheduling computer, compiles optimum production programmes and detailed operating instructions from the orders on hand while the other system, the operations computer, controls and supervises production according to these instructions.

The Scheduling Computer

The scheduling computer establishes optimum production schedules on the basis of the orders received, taking into consideration the available capacity, the materials on hand and the specified delivery dates and supervises the processing of orders. Everyday the incoming orders are fed into the computer via punched tape and checked for conformance with the delivery programme of the plant. Various data including the original order are converted into an intra-plant code. In the main these data cover dimensions (in inches), domestic and foreign steel grades, domestic and foreign tolerance requirements, types of tube and a few other characteristics. The orders are scheduled according to delivery date and available plant capacity, sorted according to dimensions and steel grade and stored on magnetic tape. Any subsequent wishes the customers may have with respect to the orders are allowed for daily, and the ordering data stored on tape are updated accordingly.

Making allowance for the raw material procurement time and the delivery dates, the orders for the same steel grade and size, which can include varying tube lengths are combined weekly in such a manner that relatively few, but large-size lots are obtained: **production lot optimisation.** The required lengths are calculated per lot and the shorts are duly considered so as to keep the amount of scrap at a minimum: **waste minimisation.** The computer also determines the raw material requirements for ordering steel and allocates existing stocks of raw materials and finished products to the lots: **stock minimisation.**

If the delivery dates of orders fall before those of the raw material, the computer must examine not only the plant capacity, but also whether the required raw material is on hand in sufficient quantities. Only if adequate capacity and raw material are available, can the order be scheduled in accordance with the requested delivery dead-line. Any stock of finished products is taken into account here. The lots are then apportioned and arranged in a sequence most suitable for processing: **rolling programme optimisation.** Specifically the lots are sorted according to four main criteria :

i. Diameters of the tubes in ascending order.

ii. Wall thicknesses either in ascending or descending order so that the transition to the next diameter will entail a minimum change in wall-thickness.

iii. Steel grades in descending order; however, if the tube diameter or the tube wall-thickness changes in a lot with a lower grade this is processed in advance wherever possible.

iv. Tube lengths in ascending or descending order, so that the change from one length to the next remains as small as possible.

The operations sheets are read out daily via high-speed printers in the form of shift rolling programmes and saw-cutting programmes for periods of 24 hours and made available to the various operating points. The rolling and cutting programmes are also passed in condensed form to the operations computer via a data channel.

The operating instructions for the finishing shop are read out in a manner similar to those for the rolling programme: **finishing programme.** When this programme is being prepared, the loading capacity of the dressing machine lines and the work not yet processed are taken into account: **finishing programme optimisation.**

The scheduling computer receives in accordance with the issued operations sheets a series of status reports (actual values) both from the operations computer and via punched tape from the finishing shop. The various data are compiled according to lot and order and stored on magnetic tape for evaluation at a later date. Data of immediate interest received from certain operating points are read out on high-speed printers for preparing shift reports and production surveys for the management. Production supervision includes a scheduled value/actual value comparison based on the allowances made in the operations sheets and the status reports received. Any deviation will be duly considered during optimisation of the next production schedule.

The Operations Computer

The operations computer in the Thyssen Rohrenwerke AG controls and supervises the production flow, collects the resulting production data and modifies the production scheduling data with the aid of the saw-cutting programme supplied by the scheduling computer and the status reports received. To this end, the Siemens data processing system 3003 must **keep track of each piece of rolling stock** in the continuous tube mill train. At any instant the system must know the status of the waiting and processing stations along the mill train.

Product tracking begins at the entry to the mill train. The identity data and lot numbers of the billets awaiting processing on a maximum of five supporting grids are fed into the operations computer via a keyboard. Using the pre-determined rolling programme and the grid status information, the computer supplies a grid recommendation which shows the operator which grid stock should be drawn on next. This keeps together billets of the same lot and charge, which are distributed over several supporting grids. The grid recommendation is accompanied by information on the number of billets to be drawn off successively. As soon as these billets have been dealt with, the computer determines the next grid recommendation. At the beginning of every new lot the computer reads out the limit weights and the number of billets which have to be weighed. Any billets drawn off in excess or any weighing too much or too little are removed at this point.

To facilitate the tracking of the rolling stock, the mill train is divided into zones, in each of which only one piece of rolling stock can be present during normal operation. Signals are transmitted to the operations computer when rolling stock enters and leaves such a zone. This means that at any instant real-time information is available on the location of rolling stock in the mill train.

Each zone of the mill train is allocated a storage cell in the operations computer. This cell contains the identity data of the billet which happens to be in this zone. The billet identity data in the magnetic-core memory are moved from one storage cell to the other by the billet tracking programme as a function of the tracking signals. Due to the great number of waiting and processing stations along the mill train, allowance has to be made for the fact that disturbances and deviations from the normal sequence may occur. **The computer is, therefore, required to track the rolling stock correctly, even if a tracking signal fails to arrive;** a tracking signal arrives although rolling stock has not been moved. The operators bypass the automatic control and place two pieces of rolling stock in one waiting station; the crane removes rolling stock from the production line.

If information of this type is missing, the computer itself must determine the required information from the incoming tracking signals and the data stored in the magnetic-core memory.

The metered data which arrive from the process supervision points are allocated to the individual products and stored. Working instructions for the saws and for post-treatment in the finishing shop are derived from the measured tube lengths and the temperature of tubes leaving the stretch-reducing mill. If the requested tube lengths permit, the tubes are cut in bundles in accordance with the cutting programme. After the cutting operation,

the bundles are tracked by the operations computer along the run-out table following the saw. At this point the computer selects the most favourable strapping sling for the various bundles. When a sling has been filled and weighed, the operations computer prepares a paper-tape card which holds the relevant data of the filled sling. This concludes the last product-tracking function of the operations computer.

Another important task allotted to the operations computer consists in the collection and storage of the production data generated during product tracking along the rolling mill train. These data are evaluated in the scheduling computer and the results compiled in reports.

The **input report** covers the rolling stock entering the mill train from the weigh scales. The **production report** covers the tubes produced, the running time of the lots and the down time. The **trouble report** contains the beginning, end and location of trouble conditions.

The **reject report** covers each product which has been rejected along the mill train. This includes the lot number, the point of rejection and the reason for rejection.

The reports and the tracking data are fed into both computers. Consequently the scheduling computer can assume the functions of the process-linked operations computer, should the latter fail. **An electronic switch ensures that the scheduling computer will be cut in automatically as soon as a fault is detected in the operations computer.** The tasks of the scheduling computer can be set aside in this case until the fault has been eliminated, because the rolling programme is in any case made available for the following shifts as a precaution. The production data are, however, recorded on punched tape so that they can be taken into account later for preparing new shift schedules when both computers are operating again.

Efficient and economical tube manufacture largely depends on the quality of the product and the extent to which the mill train is utilised. The characteristic features of this mill train which operates under the control of two data processing systems are : **high and uniform quality of the rolling stock** as well as **efficient and,** in particular, **uniform utilisation of the rolling mill plant up to its maximum capacity.**●●●

"It would take 50 people working day and night for 20 years to make the same mistake that an electronic computer could make in only two seconds."


THUG
Who am I ?
GREAT-MAN :
MR. TOLAMO
LONDON
NEW YORK
SYDNEY
NOW IN INDIA

Production Control in Iron and Steel Works

Adolf Haubruck*

The engineering progress achieved in the iron and steel making industry, the erection of large-scale production plants and the consumer demands for products of better and better quality resulted in the adoption of new and more efficient methods in steel works, especially in the field of production control and data acquisition. Above all, the requirement for high-quality steel calls for strict supervision of plant operations. Hand-written notes in memo-books or forms and time-consuming yield determination are no longer sufficient. It is often necessary to process large quantities of data in order to arrive at reliable and pertinent values. Nevertheless, these values must be up-to-date and instantly available. These requirements as well as the demand for more efficient production control entailed the installation of a comprehensive SIEMENS SELEX(R) Data Acquisition Network and a Siemens Data Processing System in the Ruhrort Works of the August Thyssen-Hutee AG. This paper has been prepared by Adolf Haubruck, department Chief in the Ruhrort Works, who is responsible for data acquisition and programming as well as for the computer center.

STRICT SUPERVISION OF THE PRODUCTION flow calls for the acquisition of data from beginning to end at certain process-dependent intervals; quantity and time values, quality data as well as coded gradings and other information. These data are required in the manufacturing process and must therefore accompany each product on its way. Furthermore, the data gathered during many production stages permit conclusions to be drawn in respect of the subsequent treatment of the products and of the future manufacture of similar products. To solve these and other problems a comprehensive SIEMENS SELEX System and a Siemens Data Processing System were set up in the Ruhrort Works. The following are the most important applications of these systems:

Order Recording: The orders placed by the customers are recorded, sorted according to similar steel grades and dimensions in order to obtain economical production lots and stored in the data processing system. Data originating from the production flow can be assigned directly to the associated orders so that the order volume and the progress achieved in filling the orders are known at all times.

Production Planning: The quantities to be produced and processed daily or monthly are scheduled on the basis of the orders on

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hand, taking into account economical considerations, delivery dates and existing plant conditions.

Yield Determination: The quantities produced are summed up and issued as totals for one day, ten days or a month so as to give a detailed survey of the state of production. These quantity data are supplemented by information on the yield achieved and the costs incurred. A comparison with the planning figures, i.e. a comparison between actual and scheduled values, serves as a working basis for the preparation of the next production schedule.

Stock Keeping: Efficient production planning and filling of customer orders on schedule call for close supervision of the raw material, the semi-finished products and the finished products on stock. The stock records which are broken down according to steel grades, sizes and storing place, are updated on the basis of the products received and delivered.

Cost Calculation: To calculate the production costs, the cost of materials used, processing time, etc. are ascertained for each production lot. From these figures the actual costs and, finally, the profit are calculated.

Quality Control and R & D: The multifaceted problems encountered here are handled on the data processing system, partly using the information gethered with the aid of the SIEMENS SELEX System. In addition, preparatory work is done in connection with the change-over to computer process control.

Data Evaluation: In many departments, it is often necessary to evaluate the collected data according to the most varied points of view. Depending on the aims to be achieved, a new programme must be frequently prepared.

Critical Path Analysis: Critical path analysis permits the supervision of the progress of building projects. The construction department makes use of the data processing system to ensure that the individual projects, which are mostly very complex, are carried out on schedule.

Data Acquisition

Data acquisition begins with the receipt of the customer order and ends with the delivery of the finished goods to the customer. Fig. 1 shows that, in parallel with the material flow, a data network has been set up in which each operating point is assigned a SIEMENS SELEX station (S) for data acquisition. The layout of such a station (at the slab shear) and the data bearing media processed and produced there are shown in Figs. 2 to 7. Fig. 1 illustrates how the individual stations are interconnected and linked with the computer center. At all operating points, the most important data are collected and then passed on partly to the data processing system for direct evaluation and partly to the subsequent operating point. In this way, no superfluous information has to be passed on from one operating point to another. Tracking data accompany the rolling stock from beginning to end. These data comprise the order and item numbers of the customer order, the charge number and the quality grade of the produced steel as well as the number of the teemed ingot. Identifying code numbers of this type are used at all processing stages.

The material flow starts when the raw materials such as iron ore, coke etc. are supplied and the blast furnaces are charged with these materials (Fig. 1). The molten pig iron is conveyed to the steel plants in rail-bound transfer ladles which pass a weigh bridge to determine the yield of the blast furnaces. When the furnace or steel converter is charged with the hot metal, the charge number is registered to identify the steel during the following production flow. A sample of the hot pig iron is analyzed in the laboratories to determine the steel grade which is communicated to the steel plant by means of SIEMENS SELEX equipment. From the information gathered up to this point, a SIEMENS SELEX System selects the data which are required for evaluation in the data processing system as well as the data which are required for controlling the subsequent production flow.

The weighing scales ascertain the ingot weight from which the tonnage of the charge

produced is obtained. Together with the data furnished by the steel plant in the form of punched tapes, the weight of each ingot and the associated ingot number are transmitted to the soaking pits of the slab mill train again by means of the SIEMENS SELEX System. In the soaking pits, the ingots are heated to rolling temperature, before they enter the rolling mill. The heating period and the start-of-rolling time are added to the data which are already available. The material is then cut clearly at the slab shear stand. The SIEMENS SELEX station installed at this stand registers the weight of each piece and the scrap (Fig. 2).

Without any intermediate reheating, the slabs enter the billet mill train. The shear cuts the rolled stock to the ordered length and removes scrap. With the aid of the SIEMENS SELEX System, the product is now assigned to a customer order. All orders placed by the customers are processed in a SIEMENS SELEX System as soon as they are received. In this process, an LSK card (center punched tape card) for the order file and a punched tape for the maintenance of the order file in the data processing system are generated. As soon as a piece of rolling stock has reached the slab shear, the respective order data card is taken out of the order file cabinet and the relevant data are transmitted to the slab shear stand. These data contain both cutting instructions and product tracking information. The data on the slab identity card accompanying the material flow and on the order card are compiled to form a uniform message which is transmitted both to the data processing system and the shipping department.

The LSK cards serve as direct working records. For this purpose, they are provided with entry fields for hand-written notes (Figs. 3 and 7). The cards have been so designed that they can be exposed to humidity and dirt without machine-processing being adversely affected. This eliminates the necessity of making notes on scrap-paper or in memo-books.

If the product is scheduled for post-treatment the kind of treatment, the required time and the quantity of rejects are recorded on the LSK card. When the finished product is shipped, a complete shipping report is made out with the aid of the LSK cards. The shipping information reaches both the shipping department—for making out the despatch note and the invoice and the data processing system. This completes the tracking of the order from its receipt to the delivery of the finished product.

Data Protection is of Paramount Importance

All data going to the data processing system are recorded on punched tapes. The tapes produced during one shift or day are then read into the system for processing. This method (off-line operation) has so far been preferred to direct input into the computer (on-line operation). One of the reasons for this has been that, during the changeover from manual to machine-operated data acquisition, input errors are liable to occur because the personnel must first become familiar with the operation of the machines. Such errors can be better corrected in the punched tape. Another reason for the adoption of the off-line method is that the data processing system is used for a variety of applications. However, the Siemens System 2002 which was installed several years ago does not yet permit simultaneous operation. Therefore, direct input was not possible without using the entire system exculsively for this purpose.

Off-line operation also requires that the read-in data be free from errors as far as possible. For this reason, the SIEMENS SELEX Systems have been equipped with checking devices. Since the data transmitted consist almost exclusively of figures, the operating reliability could be further improved by the use of the number protection code. The message length is fixed in each case and each message is terminated by a check character which is not typed in by the operator until he has checked the input data on his page-printer. If he detects an error, he types a question mark instead of the check character which otherwise characterises an error-free message. Any error which is detected at a later date is corrected by means of a new message

which contains a different check character. The data processing system then replaces the erring message by the correct one which follows. This procedure ensures error-free data input.

The data acquisition system has been so designed that change-over to on-line operation is readily possible. This changeover will be accomplished step by step on the successor to the Siemens System 2002—a Siemens Data Processing System 4004/45.

Data Evaluation

At the end of a production shift or day, the data received from the workshops are evaluated in the Siemens data processing system. The data stored on tape are read directly into the system and checked for completeness, illegal characters and check criteria. Incomplete messages are printed out on a page-printer, errored signals are not accepted and corrections are made automatically. After some coded input data have been supplemented by texts, checking calculations carried out and errors indicated, the shift result is printed out on the basis of the read-in data. As early as about 30 minutes after the termination of the last production shift, the printed lists are passed on as a working record to the workshops and to the job planning department. For daily data analyses, all data originating from the punched tapes are stored on a magnetic tape (day's tape). The daily performance lists obtained from the day's tape are also sent to the various production shops. The balance of production per day, deliveries and old order volume results in the new order volume which is also made known to all shops and departments by means of high-speed printer lists.

The day's tapes are condensed to form a library tape which contains all the data for the current month. These data are used for management information, cost finding and production output calculations.

Results and New Aims

In conjunction with the changeover from a manual to a machine-operated method, the entire data acquisition procedure had to be revised. It was necessary to standardize the large number of records, many multiple records were discarded and the amount of forms and hand-written notes was reduced.

Next, a uniform symbolic code was agreed upon which met two important requirements: it had to be self-explanatory and easy to memorize. Codes which can only be read after consulting code books are usually unfit for practical use in production plants.

Before the data acquisition and data processing systems were installed, the available personnel had to record the operational data by hand — a fact which greatly facilitated the changeover to data logging by means of SIEMENS SELEX Systems. Bottlenecks occurred only at some places because the 50-baud machines used there were too slow. These difficulties were, however, soon overcome by using 75-baud machines.

The installation of the new systems permitted the range of data acquisition to be expanded considerably so that other administrative departments could be incorporated. In spite of this expansion, less personnel was required for data acquisition. It was only a short time after the installation of the system that it became quite evident that data acquistion and data processing had become considerably faster and more reliable. Recording errors, which had formerly not been noticed, were now recognized and corrected. Furthermore, it was possible to carry out evaluation which could not have been accomplished without a data processing system because of the large quantities of data involved.

In the course of time, the number of data analysis and evaluation programmes increased steadily. While some of these programmes have to be run only once, the major part is repeated at regular intervals. The performance calculations which have to be carried out at the end of each of the three shifts and also the great many daily and monthly evaluations and the ever-increasing number of special requests soon exceeded the capacity of the 2002 System.

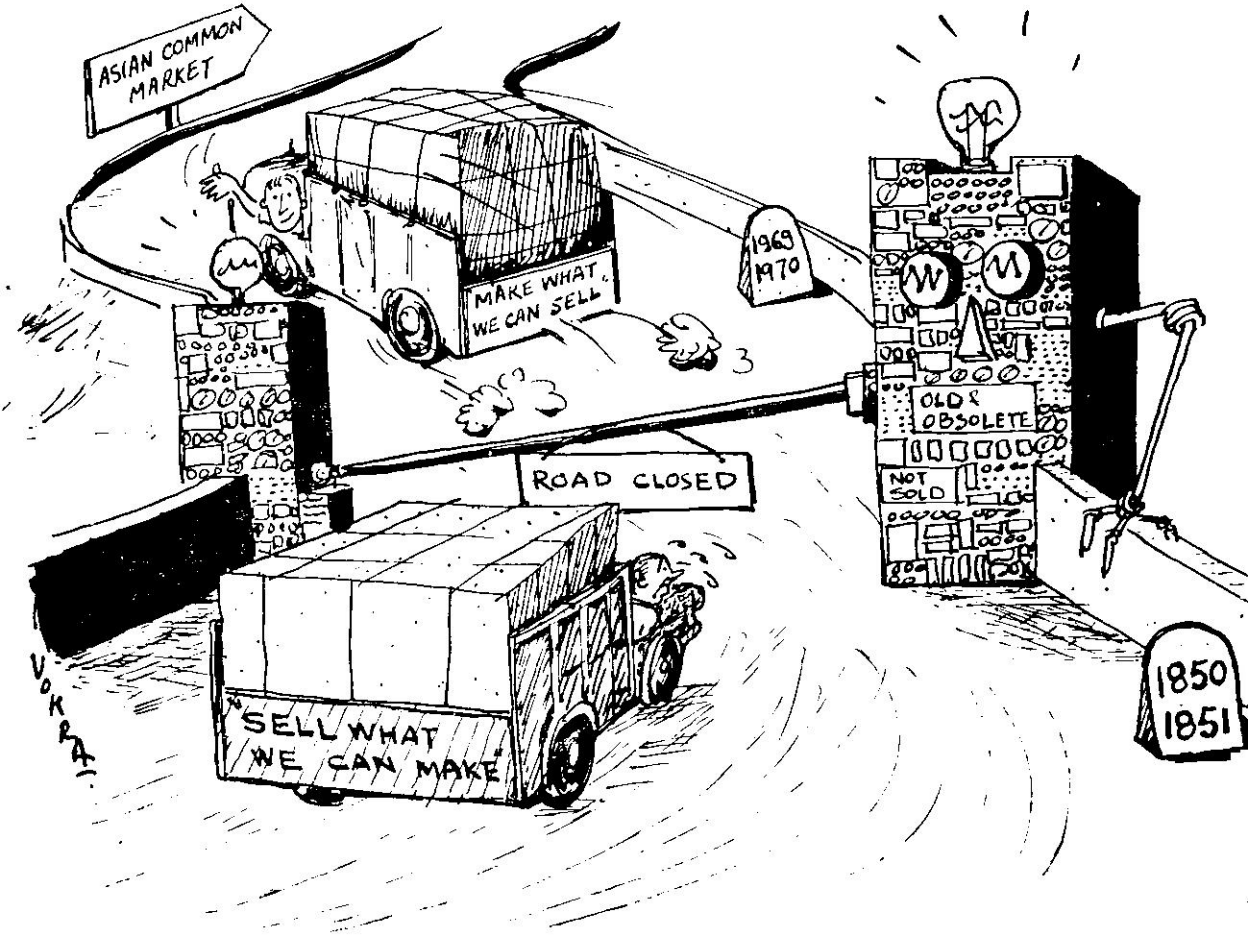
There are, in addition, other problems which have so far not been dealt with. As some of

these call for on-line processing, a system which permits simultaneous operation is required. For this reason the Data Processing System 2002 was replaced by a Siemans System 4004/45.

It is to be expected that an ever-increasing amount of data will be read directly into a process computer. For the control of processes by computers, many data have to be gathered by permanently installed measuring devices and processed in the process control computer. These data can then be read into the data processing system without the necessity of further manual inputs.

The smooth changeover to the new organization and the successful introduction of the data acquisition and transmission system are mainly due to the fact that all departments and shops concerned from the management down to the foremen, cooperated eagerly in the effective solution of the problems described above.

This development in the Ruhrort Works is still in full swing. The first reorganization stage has already been completed. Improved efficiency in data acquisition and data processing, optimization of plant operations and reduction of costs are the noteworthy achievements. ●●●



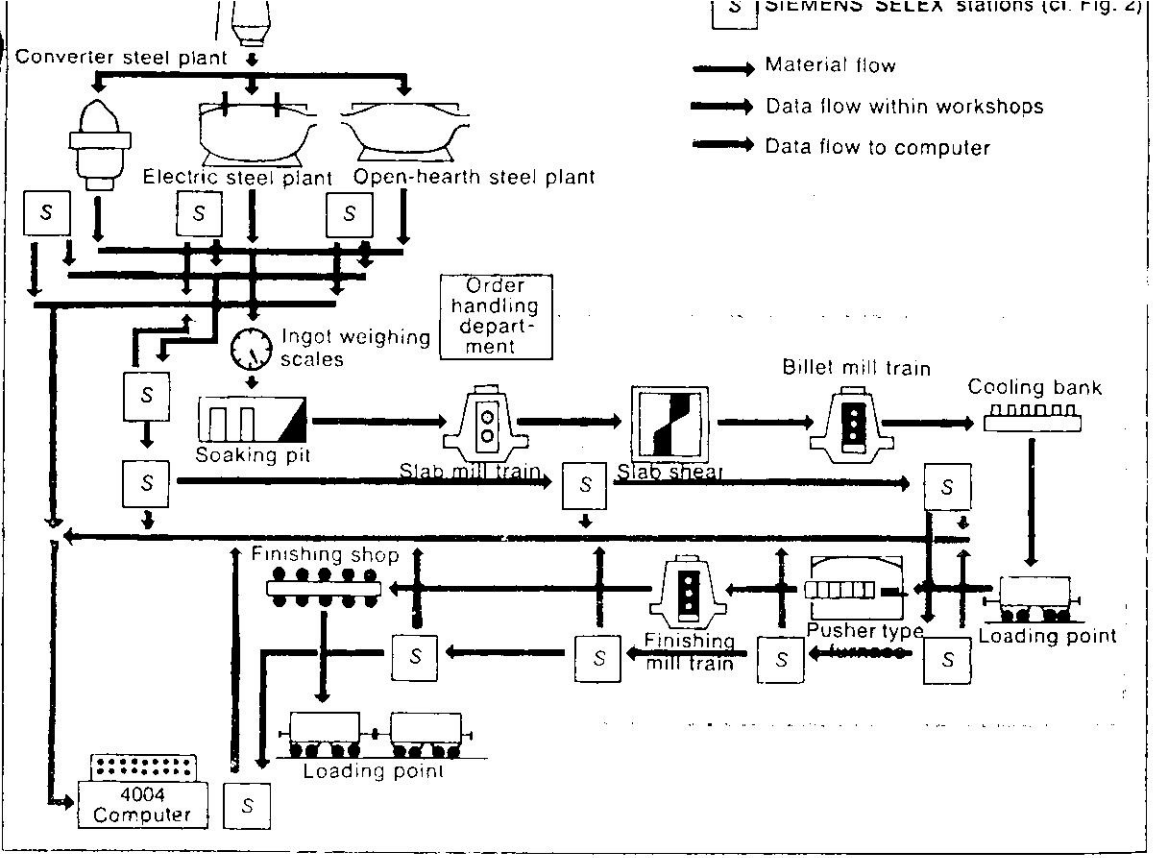


Fig. 1. FLOW OF PRODUCTION : Each important operating point is assigned a SIEMENS SELEX Station (s) which is used for the input and output of data essential for production flow. In addition, each station transmits data to the computer centre directly (A further SELEX station is located in the shipping department. It is connected with the computer and the two loading points.)

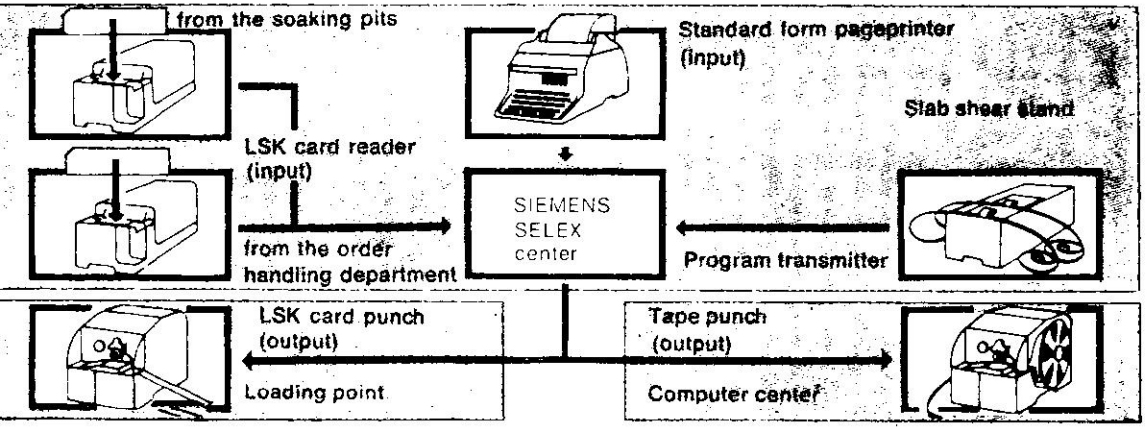
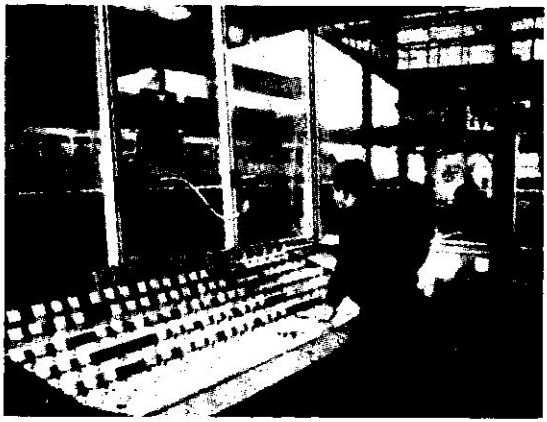


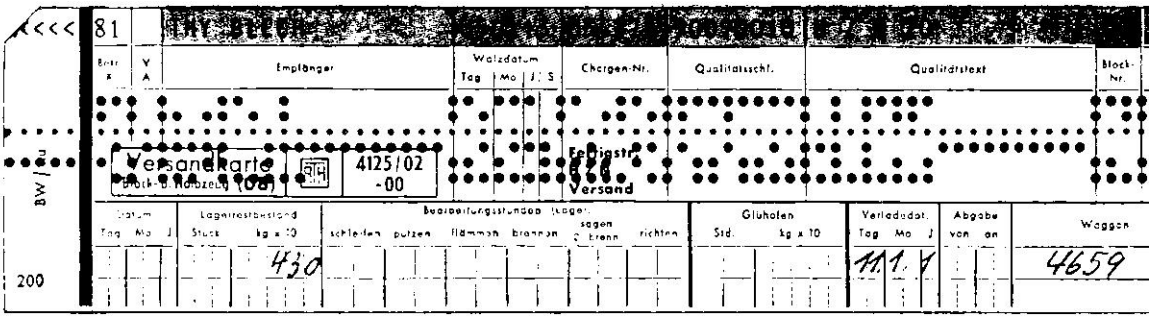
Fig. 2. One of the SIEMENS SELEX Stations, shown in Fig. 1, is located at the slab shear stand. It receives data from the stations at the soaking pits (as in Fig. 3) and the order handling department (as in Fig. 4). These data are selected and entered in a form by means of an input page-printer and are supplemented by yield and scrap tonnage (as in Fig. 5). At the same time, shipping data cards are produced at the loading point (as in Fig. 6). All data required for evaluation with the aid of the data processing system are recorded by a tape punch in the computer centre (as in Fig. 7).

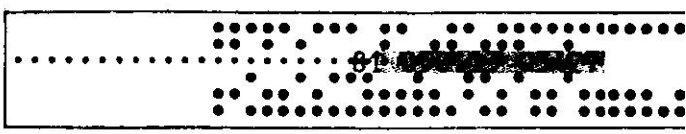


Soaking Pit



Orde







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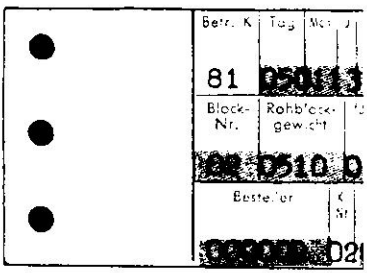
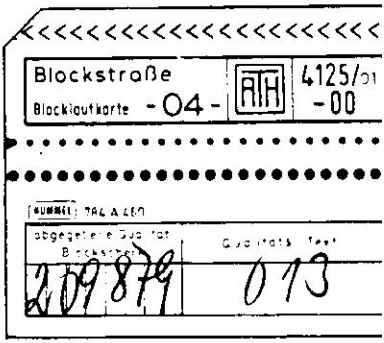




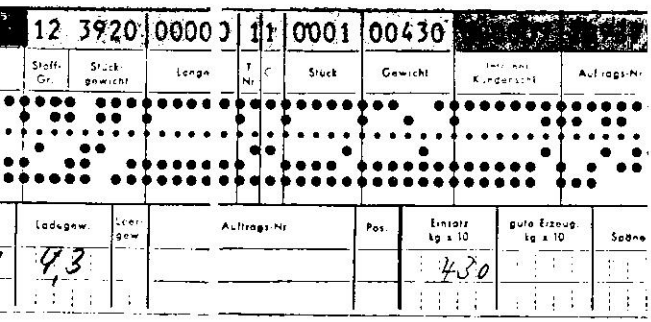
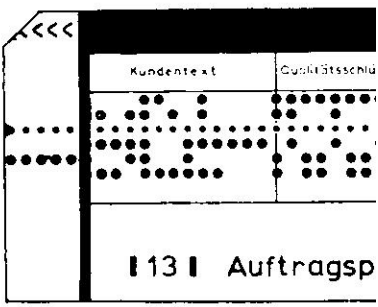
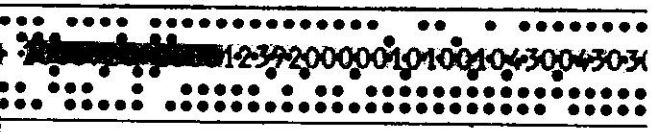


Fig. 6. Shipping Data Card





7. Tape Punch in Computer Centre

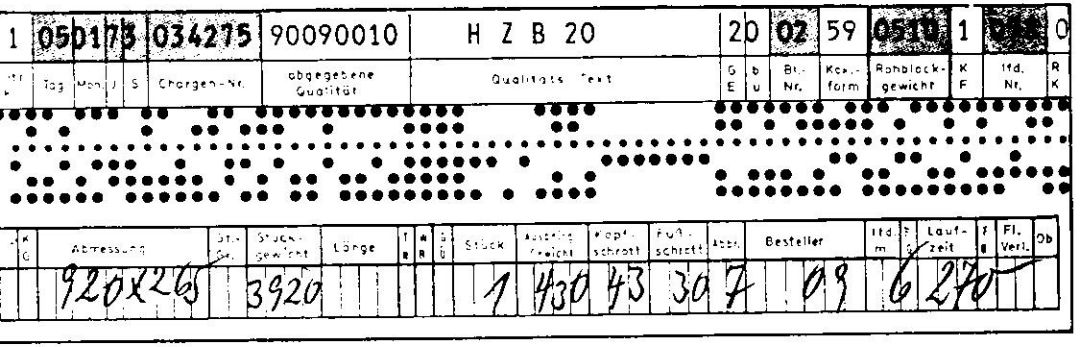

1 05 01 75 034275 90090010 H Z B 20 20 02 59 0510 1 0
Tag Chargen-Nr. abgegebene Qualität Qualitäts-Text Bl.-Nr. Rohblock-gewicht
Abmessung Stück-gewicht Länge Stück Kopf-schrott Fuß-schrott Besteller lfd. m Lauf-zeit
920x260 3920 1 430 43 30 7 09 6 270

Fig. 3

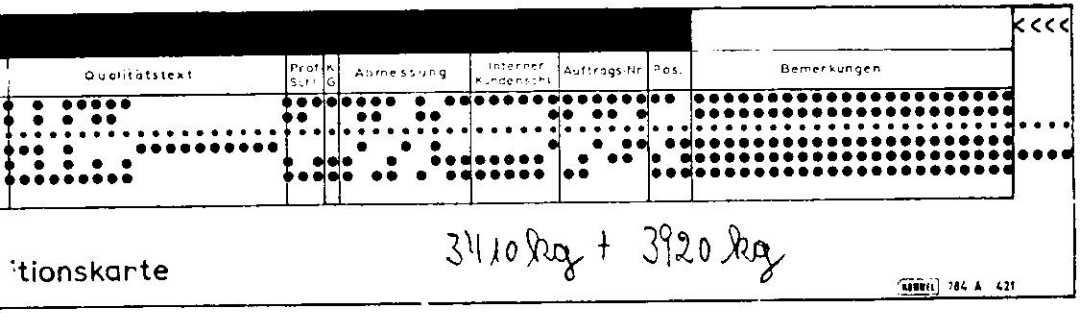
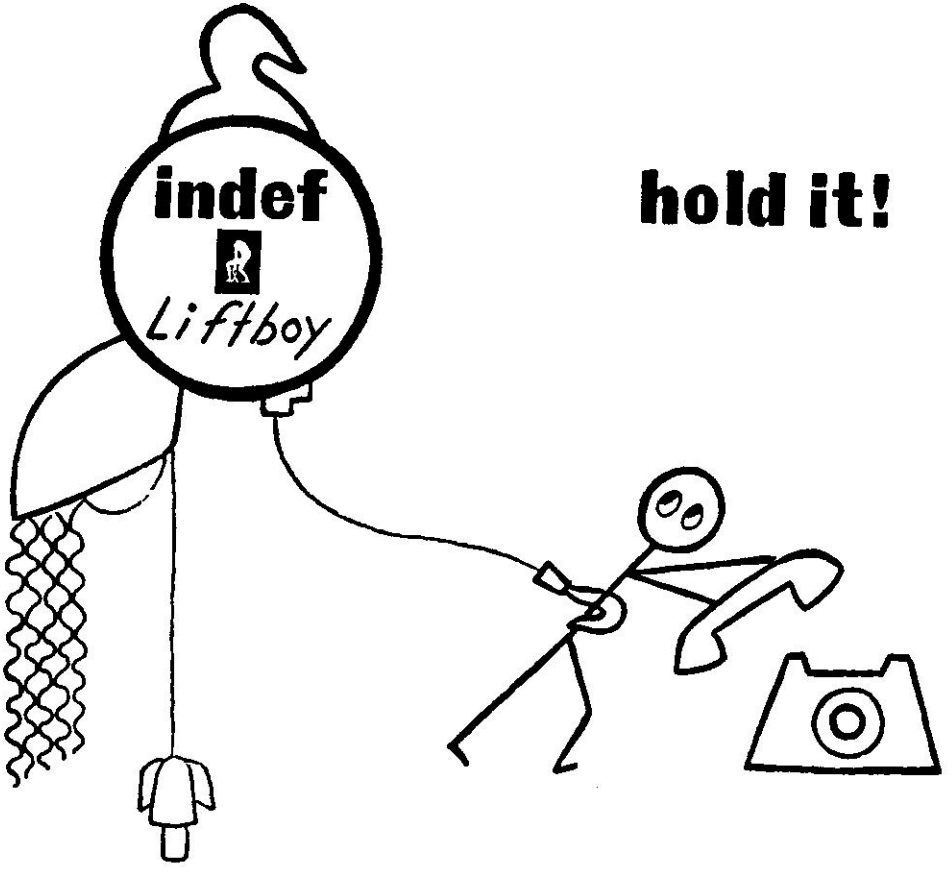

Qualitätstext
Abmessung
Auftrags-Nr.
Pos.
Bemerkungen
tionskarte
3410 kg + 3920 kg

Fig. 4



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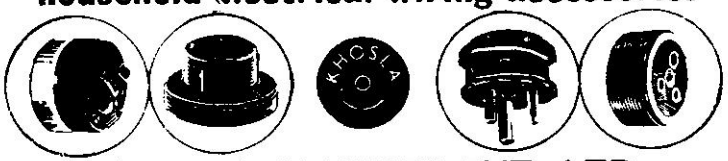

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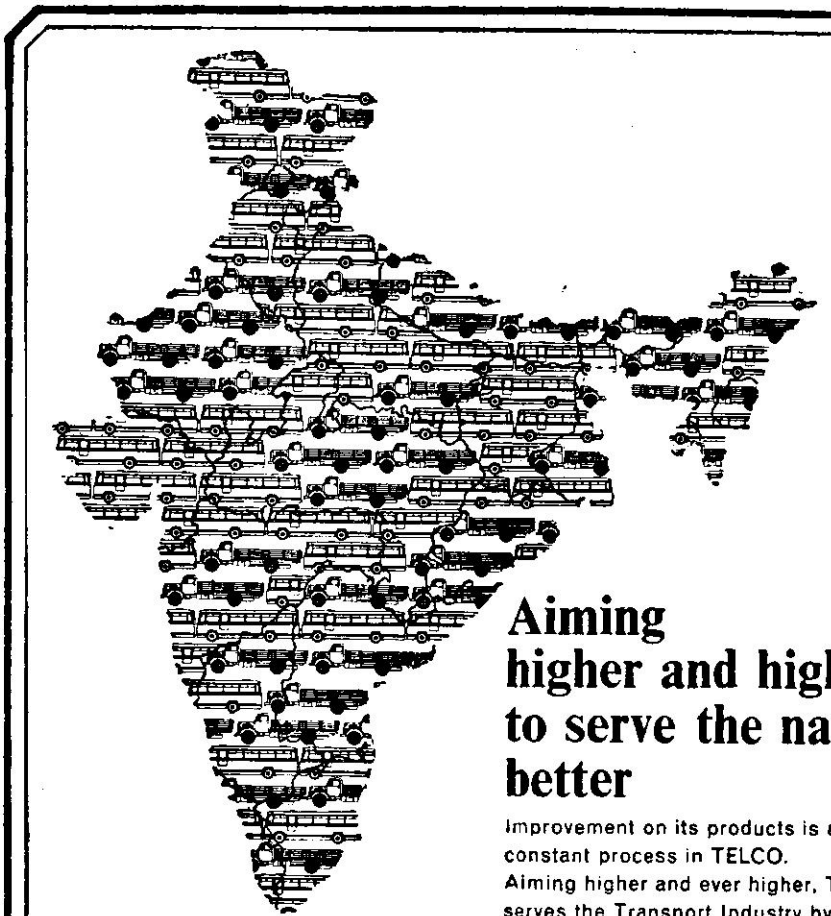

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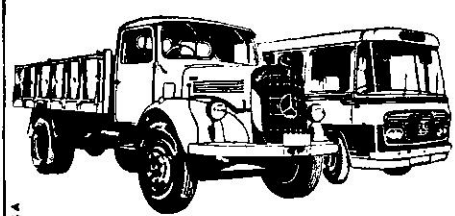

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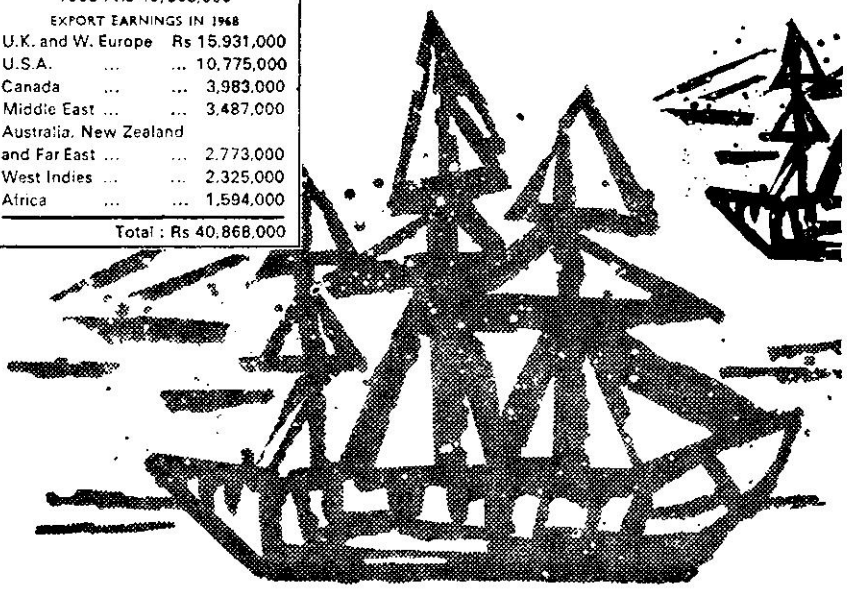
FIGURES AT A GLANCE

1967 : Rs 35,245,000

1968 : Rs 40,868,000

EXPORT EARNINGS IN 1968

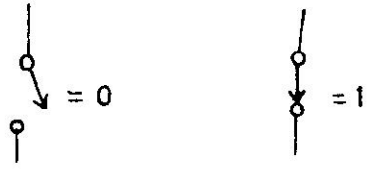
U.K. and W. Europe	Rs 15,931,000
U.S.A.	10,775,000
Canada	3,983,000
Middle East	3,487,000
Australia, New Zealand and Far East	2,773,000
West Indies	2,325,000
Africa	1,594,000
Total :	Rs 40,868,000



Boolean Algebra

BOOLEAN ALGEBRA WAS INTRODUCED IN 1847 by an English mathematician, George Boole. The purpose of the algebra was to find a shorthand notation for the system of logic originally set forth by Aristotle. Aristotle's system dealt with statements which were considered to be either true or false, but never partially true or false. Boole's algebra was based on a single valued function with two discrete possible states.

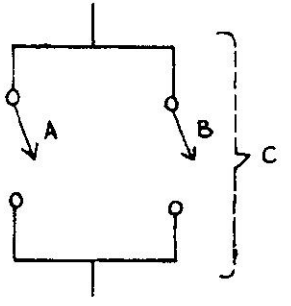
Boolean algebra lay almost dormant until recent times. Today, however, it is gaining widespread recognition as an efficient method for handling any single valued function with only two possible states. When it is applied to binary arithmetic, the two states are 0 and 1. When discussing a switch, the two values are open and closed.



Switch Analogy

The convention used will be that the open state corresponds to the 0 state, while the closed state corresponds to the 1 state.

OR Function

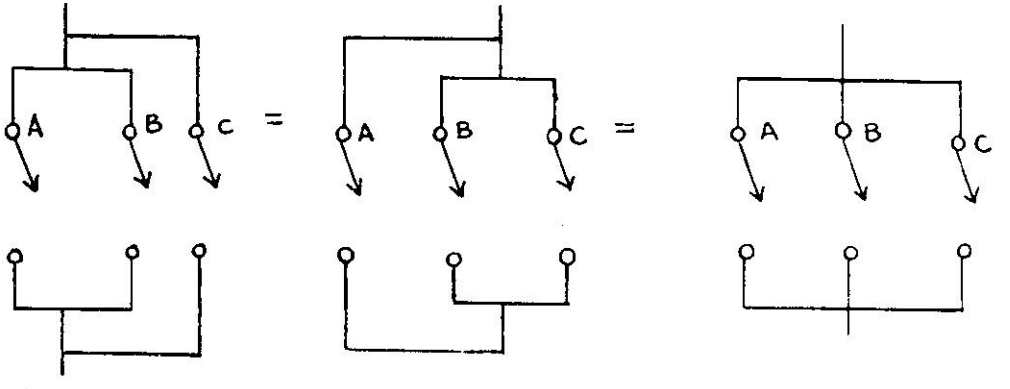


A+B=C
0+0=0
0+1=1
1+0=1
1+1=1

If two switches, A and B, are connected in parallel to form a gate, inspection shows that the gate can only transmit information if A and B or both are in the transmitting state, i.e. closed. This is written in equation form as

A+B=C

(A or B equals C)



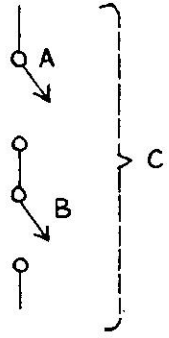
Compound OR Functions

By adding a third gate in parallel, as in the above figure, it becomes obvious how the OR function may be extended to any number of variables. This figure also serves to illustrate that the communicative and associative laws are valid for the OR function, i.e.

$$A+B=B+A$$

$$(A+B)+C\equiv A+(B+C)\equiv A+B+C$$

AND Function

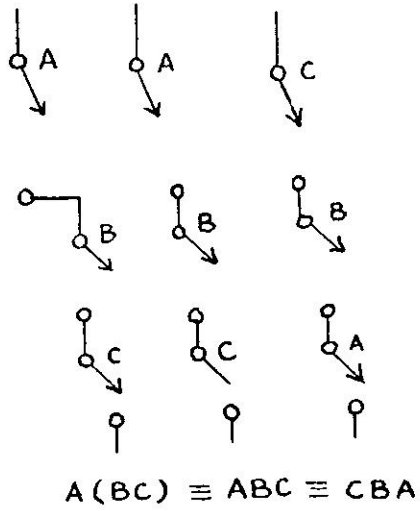


AB = C
00 = 0
01 = 0
10 = 0
11 = 1

If two or more gates are placed in series, the result is known as an AND gate. Inspection of the arrangement in the above Figure shows that the resulting gate will transmit only if both A and B are closed, i.e., equal to 1. The equivalent equation in Boolean form is

$$AB = C$$

(A and B equals C)



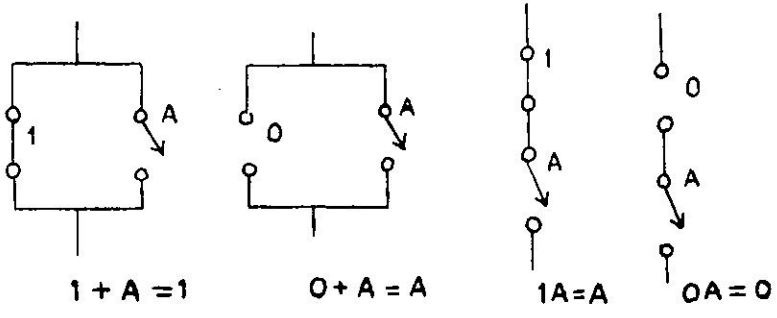
Compound AND Functions

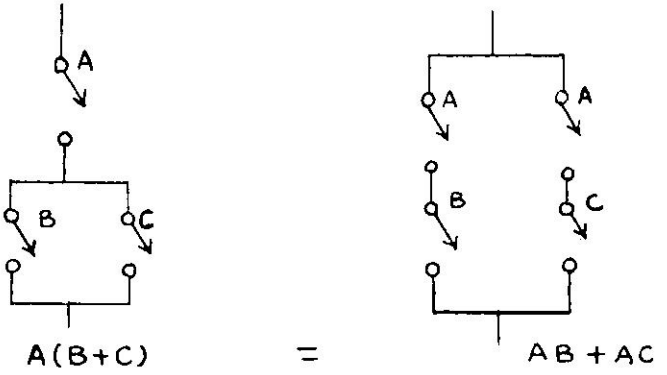
The above figure demonstrates how the AN function is applied to more than one variabl The cummulative and associative laws also hol

$$AB = BA$$

$$A(BC) \equiv (AB)C \equiv ABC$$

Identities





To enable the simplification of Boolean functions, there are many identities which are helpful. In the Figure above the combination of switches and corresponding equations demonstrate these identities.

Complement

If two gates are connected so that the same signal will open both of them or close both of them simultaneously, the switches are given the same symbol. If two gates are connected so that a single signal will open one gate while closing the other gate, and *vice versa*, these gates are said to be the complement of each other. Thus, if one gate is labeled A, the other gate will be labeled $\bar{A}$ (read "not A" or "A not"). An entire function may also be complemented. For example,

if $D=A(B+C)$

then $D=\overline{A(B+C)}$

The use of one label for more than one gate makes the following identities helpful:

$$A+A=A \quad A+\bar{A}=1 \quad A=A$$

$$AA=A \quad A\bar{A}=0$$

De Morgan's Laws

Two unique laws which can be applied only to Boolean algebra are known as De Morgan's laws.

$$\overline{A+B+C+\ldots+N}=\bar{A}\bar{B}\bar{C}\ldots\bar{N}$$

$$\overline{ABC\ldots N}=\bar{A}+\bar{B}+C\ldots+\bar{N}$$

These laws may be verified by constructing a table of various possible values. ●●●

How Large is Home?

With means of rapid comunication and transportation incrcasing daily, some have commented that, in a relative sense, the 'earth is getting smaller each day'. But how does earth compare with her sister planets? With a diameter of 7,927 miles, earth is smaller than four of the nine planets in our solar system and larger than the other four. The smaller planet, Mercury, is about one-sixteenth of the size of our earth. But Jupiter is over 1,300 times as large as our home, Earth.

Basic Analogue Computing Elements

THE FIRST COMMERCIALLY AVAILABLE GENERAL-purpose electronic analog computers appeared on the market in the 1940's. These early machines were an outgrowth of an emerging electronics technology and a critical need for automatic computing machines that could solve complex dynamic problems. Slide Rule and manual equation solving could no longer be relied upon as a practical approach to seeking engineering solutions. Therefore, analog computers became important tools in the design of aircraft, jet engines, atomic reactors, oil refineries, chemical plants, etc.

Many types of analog computers have evolved over the years. The family has included the mechanical differential analyzer, electromechanical differential analyzer, and most recently, the iterative differential analyzer.

The analog computer has always had several advantages compared to a digital computer. These are primarily speed, more simulation capability per dollar, an ability to integrate, and an excellent man-machine interface.

The main feature of the analog computer is that it can integrate time-varying voltages. There is no easy way to differentiate. Consequently a mathematical model of a physical system which is expressed in terms of differential equations cannot be solved with the machine directly. It is necessary to reformulate the mathematical model in terms of integral equations, either implicitly or explicitly.

The analog computer can integrate only with respect to time. Thus, a mathematical model which contains partial integrals (corresponding to partial derivatives) with respect to several variables must be approximated by a set of ordinary integral equations with respect to time. Of course, computer time need not correspond to time in the physical world, although it usually does.

Before 1959 the analog computer was a synchronous machine; all its integrators operated in unison. In 1959 the DYSTAC* was introduced. The name was an acronym for 'dynamic storage analog computer'. This machine was the forerunner of the iterative differential analyzer which appeared in 1960. The iterative differential analyzer is an asynchronous computer; the integrators need not be controlled in unison. They can operate independently either in groups or singly.

In 1962 the analog computer was augmented with digital logic. This innovation first appeared in a machine called the HYDAC.† The HYDAC had a very large quantity o synchronous digital logic. Since that time the inclusion of a smaller complement o asynchronous digital logic has become accepted practice.

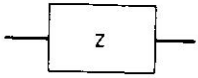
*DYSTAC is a registered trademark of CSI

†Hydac is a Registered trademark of EAI

HOW ELECTRONIC EQUIPMENT AND CIRCUITS ARE USED to implement mathematical relationships in an analog computer is described here.

OHM'S LAW

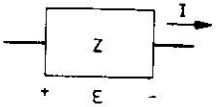
Ohm's law describes the relationship between the current through, and the voltage across a passive impedance. A passive impedance is a collection of passive elements such as resistors and capacitors connected together in an arbitrary way. Such an impedance is generally considered (in analog computing) to be a two-terminal network which can be denoted by



where Z is the dynamic impedance of the element. Ohm's law states

$$E = ZI$$

for



where I is the time-varying current (in the direction indicated) through the passive element generated by the impressed time-varying voltage, E (with the polarity indicated).

In order to simplify what follows, transform notation will be used where

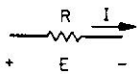
$$s\,f(t) = \frac{d}{dt} f(t)$$

and

$$\frac{1}{s} f = \int f(t)dt.$$

For a resistor Z = R and Ohm's law is

$$E = R\,I$$



For a capacitor

$$C\,\frac{dE}{dt} = I$$

so that Ohm's law is

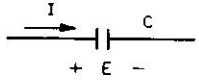
$$E = \frac{1}{Cs} I$$

or

$$E = ZI$$

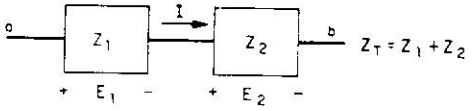
where

$$Z = \frac{1}{Cs}$$



SERIES and PARALLEL IMPEDANCE

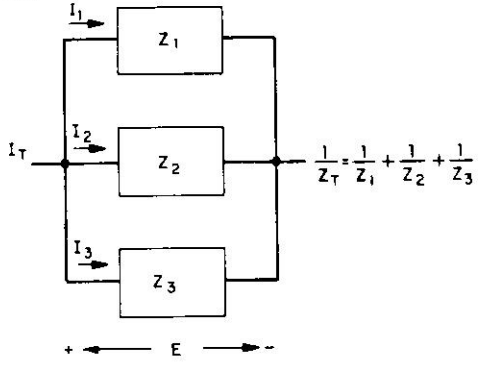
Impedances are additive in series:



This can be proved in a simple way. The total voltage from point a to point b is $E_T = E_1 + E_2$ and by Ohm's law

$$E_T = Z_1 I + Z_2 I = (Z_1 + Z_2)\, I = Z_T I.$$

When impedances are connected in parallel the total impedance can be found as the reciprocal of the sum of the reciprocals:



This again can be proved by simple application of Ohm's law:

$$I_T = I_1 + I_2 + I_3$$

$$I_T = \frac{E}{Z_1} + \frac{E}{Z_2} + \frac{E}{Z_3}$$

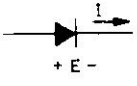
$$\frac{I_T}{E} = \frac{1}{Z_T} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}$$

The total impedance of two parallel impedances has the simple formula:

$$Z_T = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}} = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

DIODE

A diode is a non-linear resistor. Its resistance or impedance depends on the direction of the current flowing through it. It is denoted by



where

$$E = ZI$$

$$Z = R_1, \quad E > 0$$

$$= R_2, \quad E < 0$$

and generally

$$R_2 \gg R_1 .$$

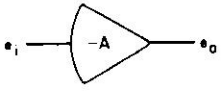
Typically, R_1 ranges between 1 ohm and 100 ohms; and R_2 between 100,000 ohms (100KΩ) and 1,000,000 ohms (1MΩ). Thus the diode is an approximation to a switch for which

$$R_1 = 0$$

$$R_2 = \infty$$

OPERATIONAL AMPLIFIER

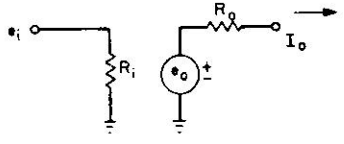
An operational amplifier is of the type that is called a d-c amplifier; it amplifies not only time-varying voltages, but also d-c or constant voltages. It is characterized by its excellent stability and extremely high low-frequency gain (amplification). It is denoted by



where

$$e_o = -A\, e_i$$

These voltages are measured with respect to ground (zero reference). The gain, A, is usually frequency dependent and will decrease with increasing frequency. As will be seen presently, this becomes a limiting factor in the use of a computer at high speeds. An equivalent circuit for the amplifier is



where, generally, R_i is greater than 10^6 ohms and R_o less than 10^{-4} ohms (closed-loop) at zero frequency. However, the amplifier is current limited. That is, it will only perform satisfactorily if the output current, I_o, is less than some value. The current limit for the S-D[1] amplifier is ±25 milliamperes at ±100 volt output. The amplifier is also voltage limited; it will not function satisfactorily if the output voltage, e_o, is greater, in absolute value, than some upper limit. The limit for the S-D solid-state 100 volt amplifier is 105 volts. Since the output of these amplifiers contains unwanted noise whose magnitude typically can be 10^{-2} volts, their effective useful range is about three and one-half decades (5×10^{-2} to 10^2 volts).

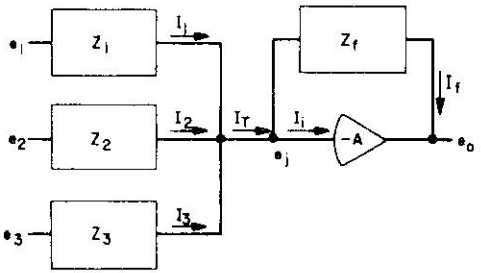
GENERATION OF TRANSFER FUNCTIONS

In what follows, it will be assumed that the input impedance of the operational amplifier is infinite, the output impedance is zero, and the gain is infinite.

[1] Abbreviation for Systron-Donner.

These assumptions introduce negligible error at zero frequency and are a good approximation at mid-frequencies. At high frequency, the assumptions cannot be made (particularly for gain).

Consider an amplifier with input and feedback (from output to input) impedances and applied input voltages as shown.



From Ohm's law

$$I_T = \frac{(e_1 - e_j)}{Z_1} + \frac{(e_2 - e_j)}{Z_2} + \frac{(e_3 - e_j)}{Z_3}$$

$$I_f = \frac{e_j - e_o}{Z_f}$$

$$I_T = I_f + I_i$$

Now if the input impedance, R_i, of the amplifier is assumed to be infinite

$$I_i = \frac{e_j}{R_i} = 0$$

for finite e_j. Thus

$$I_T = I_f$$

and

$$\frac{(e_1 - e_j)}{Z_1} + \frac{(e_2 - e_j)}{Z_2} + \frac{(e_3 - e_j)}{Z_3} = \frac{e_j - e_o}{Z_f} \quad \text{----(1)}$$

Further, if the gain, A, of the amplifier is assumed to be infinite, then

$$e_j = \frac{e_o}{-A} = 0$$

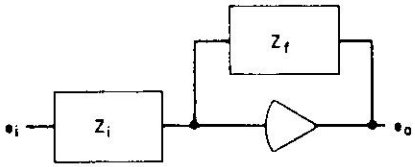
This is a reasonable assumption at low frequencies since as noted above e_o, at most, will be in the neighborhood of 100 volts in absolute value. Thus, equation (1) becomes

$$\frac{e_1}{Z_1} + \frac{e_2}{Z_2} + \frac{e_3}{Z_3} = -\frac{e_o}{Z_f}$$

and

$$e_o = -\left[\frac{Z_f}{Z_1} e_1 + \frac{Z_f}{Z_2} e_2 + \frac{Z_f}{Z_3} e_3\right] . \quad \text{-----(2)}$$

The simplest case is



$$e_o = -\frac{Z_f}{Z_i} e_i$$

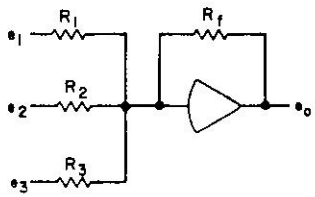
which can be expressed

$$\frac{e_o}{e_i} = -\frac{Z_f}{Z_i} . \quad \text{----------(3)}$$

By a suitable choice of impedances many desired transfer functions can be generated. (Henceforth, the units of megohm and microfarad will be used for resistance and capacitance respectively.)

SUMMER (ADDER)

Consider the configuration shown below, which is called a summer.



If, in equation (2), the substitutions

$$Z_1 = R_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_f = R_f$$

are made, then

$$e_o = -\frac{R_f}{R_1} e_1 - \frac{R_f}{R_2} e_2 - \frac{R_f}{R_3} e_3 .$$

A set of typical values (in megohms) for these resistors in a summer in a computer is

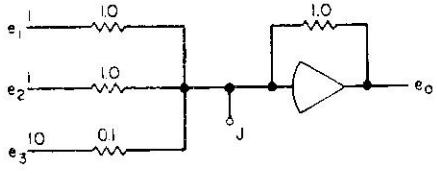
$$R_1 = R_2 = R_f = 1.0$$

$$R_3 = 0.1$$

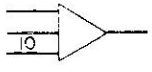
so that

$$e_o = -e_1 - e_2 - 10e_3 .$$

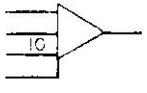
In a computer, access is usually provided to the input (summing) junction so that additional input resistors or feedback components can be added to the summer circuit externally. Thus, the summer circuit is



where the gains (multiplying factors) are indicated at each input, and the summing junction terminal by J. The program symbol for the summer is

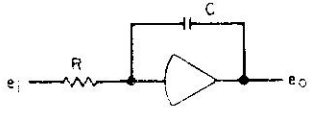


where the input gains are omitted if they are unity. If it is desired to indicate the junction or summing junction (high-gain input), the symbol becomes



INTEGRATOR

The high-gain input is labeled only if pertinent. Consider the configuration shown below, which is called an integrator



Substitution in equation (3) of

$$Z_i = R, \; Z_f = \frac{1}{Cs}$$

leads to the transfer function

$$\frac{e_o}{e_i} = -\frac{1}{RCs}$$

or

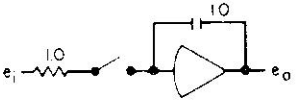
$$e_o = -\frac{1}{RCs}\, e_i = -\frac{1}{RC}\int e_i(t)dt$$

If R=1, C=1, then

$$e_o = -\int_0^t e_i(t)dt$$

so that the output voltage, e_o, of the amplifier will be the integral with respect to time of the time-varying input voltage, e_i.

If a switch is included as shown



and if

1) there is an initial charge stored on the capacitor which results in the voltage, $e_o(0)$

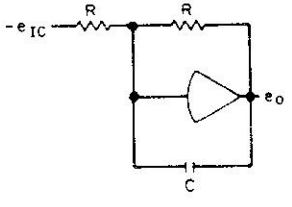
2) the switch closes at t=0,

then

$$e_o = e_o(0) - \int_0^t e_i(t)dt .$$

It is common practice to call this initial voltage the 'initial condition' for the integrator. The derivation of this terminology is obvious from mathematics.

It is necessary to find a practical way to establish the initial condition or initial voltage for the integrator. To accomplish this, the circuit below is used.



Here

$$\frac{1}{Z_f} = Cs + \frac{1}{R} = \frac{RCs + 1}{R}$$

$$Z_f = \frac{R}{RCs + 1}$$

$$Z_i = R$$

and substituting in equation (3)

$$e_o = \left(-\frac{1}{RCs + 1}\right)(-e_{IC}) = \frac{1}{RCs + 1} e_{IC}$$

or

$$RC \frac{de_o}{dt} + e_o = e_{IC}.$$

The solution of this differential equation is

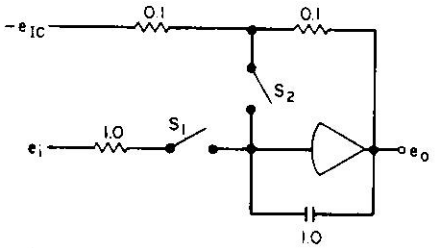
$$e_o = A \exp\left(\frac{-t}{RC}\right) + e_{IC},$$

where A is a constant depending on the initial voltage stored on the capacitor before e_{IC} was applied. Then

$$\lim_{t \to \infty} e_o = e_{IC},$$

For practical cases, it is only necessary that $t > 10RC$, since $e^{-10} < .0001$, which is compatible with the accuracy of the circuit. The result in simple terms is: to guarantee the establishment of the initial condition it is necessary to wait 10RC seconds after the voltage, $-e_{IC}$, has been applied to the circuit.

The two previous circuits, combined with appropriate switches as shown below, constitute a practical integrator



The operation is as follows:

With S_2 closed and S_1 open, $e_o = e_{IC}$ after 1.0 second (or 0.1 second if C = 0.1, etc.).

With S_2 open, e_o still equals e_{IC}, since the current through the capacitor is zero. (This must be true since both S_1 and S_2 are open and the input impedance of the amplifier is assumed to be infinite.)

With S_1 closed at, say, t=0, then

$$e_o(t) = e_{IC} - \int_0^t e_i(t)dt.$$

If at t = T, S_1 is again opened, e_o will stop changing and remain at the last value before S_1 opened, namely

$$e_o(T) = e_{IC} - \int_0^T e_i(t)dt.$$

If S_2 is closed again while S_1 is open, the output of the integrator will return to

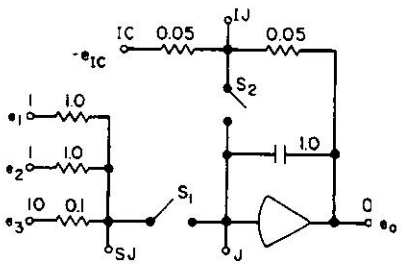
$$e_o = e_{IC}.$$

Each integrator in a computer has these switches as part of its circuit. They are open or closed depending on what the programmer wants the integrator to do. The state of these switches is called the integrator mode. If all the integrators are controlled in unison, the switch states are determined by the main computer mode.

The modes have simple names with obvious interpretations. During the R, or reset (IC) mode, initial voltages are impressed on the integrator capacitors. During the compute or C mode, the integrators integrate input voltages. During the hold or H mode, the integrator outputs remain constant at the last value achieved before entering the hold mode. Thus, the mode permits the programmer to stop the computation at any time, enabling him to evaluate what has happened thus far in the calculation. The table below shows the states of S_1 and S_2 in the various modes. The numeral 1 indicates the switch is closed (logical 1) while 0 indicates the switch is open (logical 0).

MODE	S_1	S_2
R(IC)	0	1
H	0	0
C	1	0

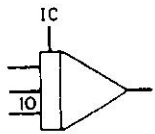
Finally, the general integrator circuit is shown below together with a definition of its transfer function for various modes.



MODE	TRANSFER FUNCTION
R	$e_o = e_{IC}$
C	$e_o(t) = e_{IC} - \int_o^t \left[e_1(t) + e_2(t) + 10\,e_3(t)\right] dt$
H	$e_o(T) = e_{IC} \int_o^T \left[e_1(t) + e_2(t) + 10\,e_3(t)\right] dt$

Note that the gain (multiplying factor) of the computing inputs is noted next to the terminals and is determined by the value of the input resistor. The SJ terminal is provided to allow the other external input resistors to be added. The IJ terminal provides the ability to generate an initial condition which is the sum of several voltages. The J terminal permits the connection of additional feedback elements around the amplifier (to be discussed in chapter 10). Also, these terminals provide an external connection for the use of solid-state switches in place of the mechanical switches (relays) S_1 and S_2. In this case S_1 and S_2 are constrained to be open regardless of integrator mode and the necessary switching is done by the external solid-state switches.

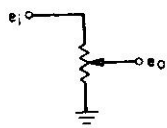
The program symbol for the integrator is



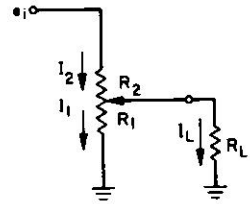
The input gains are usually omitted if they are unity.

POTENTIOMETERS

It is necessary to have a device for entering constant parameters in the computer program. This is accomplished with a potentiometer. The circuit for this element is shown below.



If the output voltage, e_o, of the potentiometer (pot) is applied to an input of another element of the computer, then the input impedance, R_L, of the other element is connected from the pot output to ground.



Then

$$I_2 = I_1 + I_L$$

so that

$$\frac{e_i - e_o}{R_2} = \frac{e_o}{R_1} + \frac{e_o}{R_L}$$

and

$$\frac{e_i}{R_2} = e_o \left[\frac{1}{R_1} + \frac{1}{R_L} + \frac{1}{R_2} \right].$$

Since

$$R_1 + R_2 = R_t$$

where R_t = total potentiometer resistance,

$$R_2 = R_t - R_1$$

and

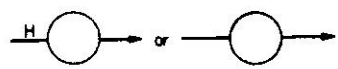
$$e_o = \left[\frac{1}{\frac{R_t}{R_L} + \frac{R_t}{R_L} - \frac{R_1}{R_L}} \right] e_i$$

$$e_o = \left[\frac{R_1 R_L}{R_t (R_L + R_1) - R_1^2} \right]$$

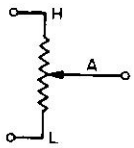
$$e_o = \alpha\, e_i.$$

Now, obviously, it would be time-consuming to determine R_1, with the knowledge of R_t, R_L for each new α. Consequently, in practice, the pot is set with the load connected, by reading the output voltage, e_o, with a meter, for a known input voltage, which is usually 100 volts.

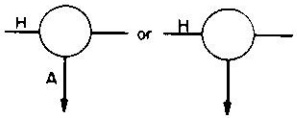
Thus the meter reading is equal to 100 α and the pot is changed until the desired value for α is obtained. The symbol for the potentiometer is



where H is the notation for the high end, or input. The H is usually omitted since it is obvious from the computer program which side is the input to the pot. The element discussed above is called a two-terminal pot since it has two available terminals (or connections) on the computer program board (patchboard). Sometimes it is desirable to connect the bottom (low) end of the pot to some computing-element instead of ground. In this case the low end is made available at the patchboard. The circuit is



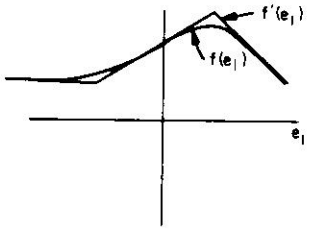
and the program symbol is



where notation for the arm, A, is omitted when it is obvious from the computer program.

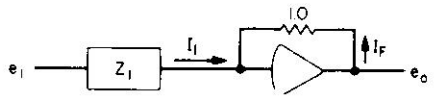
ARBITRARY FUNCTION GENERATOR

Many mathematical problems to be solved with a computer require the generation of an arbitrary function. This is accomplished with a device called an arbitrary function generator (or frequently, diode function generator, since the internal circuitry uses diodes). This device allows the programmer to approximate the desired function with straight line segments. An example is shown below



Here the function $f(e_1)$ is approximated by $f'(e_1)$ with three line segments. In general, each function generator, depending on how it is used, will provide either 10 or 11 line-segments with maximum slope changes of 2 or 2. 5:1. Several of these devices can be used together if more segments are required. The location of the slope discontinuity is called the breakpoint and is adjustable. Detailed instructions for the setup of this element appear in Chapter 6.

The principle of operation of the function generator depends on the use of a non-linear input impedance for an operational amplifier. That is, the impedance generates an input current proportional to the function which in turn constrains the output voltage to have this functional relationship to the input voltage. A simplified circuit is shown below.

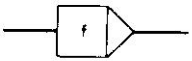


$$-I_1 = I_F$$

$$I_1 = - f'(e_1)$$

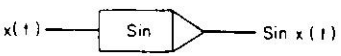
$$e_o = f'(e_1)$$

The program symbol for an arbitrary function generator is



FIXED FUNCTION GENERATOR

Fixed function generators are used to generate often-used functions such as sine, cosine, log, etc. These are similar to arbitrary function generators in operation, but do not permit the programmer to change the parameters within the device. Generally, a fixed function generator is more accurate and has better frequency and noise specifications than an arbitrary function generator. The program symbol for a sine generator, for example, is



MULTIPLIER

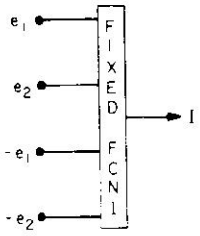
The multiplier used with the S-D computer is called a quarter-square multiplier. The name derives from the equation

$$XY = \frac{1}{4}\left[(X + Y)^2 - (X-Y)^2\right]$$

The actual equation to be implemented with hardware in order to provide multiplication is

$$e_1 e_2 = \frac{1}{400}\left[\left|e_1 + e_2\right|^2 - \left|e_1 - e_2\right|^2\right] \quad (4)$$

The multiplier module contains two fixed function generators. A block diagram for one of the generators is

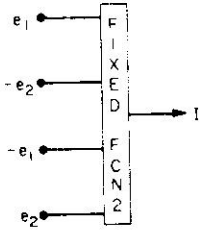


(Note that both polarities are required as inputs for both e_1 and e_2.) The transfer function is

$$I = K\frac{|e_1 - e_2|^2}{400} - .$$

where K is a constant that determines the feedback resistor of the output amplifier (to be shown below).

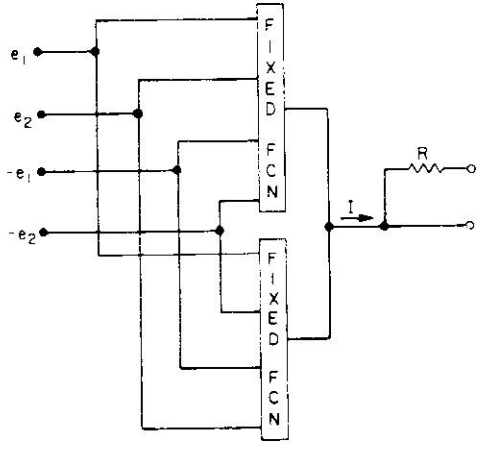
The block diagram for the other is



The transfer function is

$$I = -K\frac{|e_1 - e_2|^2}{400}$$

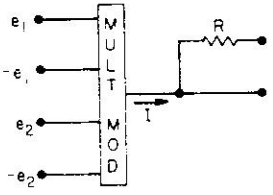
The multiplier module block diagram is



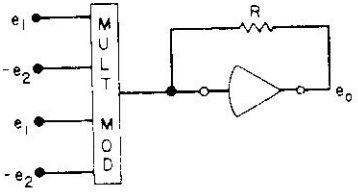
The transfer function is

$$I = \frac{K}{400}\left[|e_1 + e_2|^2 - |e_1 - e_2|^2\right] = K\frac{e_1 e_2}{100}$$

A simplified block diagram for the module is



If the module is connected to an output amplifier



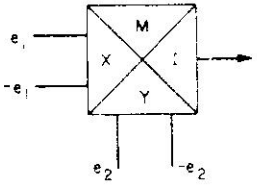
then

$$-\frac{e_o}{R} = \frac{K}{400}\left[|e_1 + e_2|^2 - |e_1 - e_2|^2\right] = K\frac{e_1 e_2}{100}$$

and if $K = \frac{1}{R}$

$$e_o = \frac{-e_1 e_2}{100}$$

The program symbol for the multiplier module (without the output amplifier) is

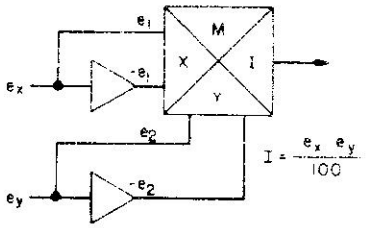


With the designations

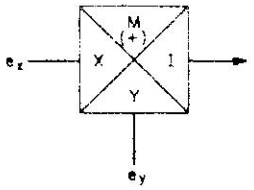
M: The module is used as a multiplier
I: The output is a current
X, Y: Bipolar inputs

If the bipolar inputs are not naturally available from the program (e.g. other variables) then summers can be used to generate them. This can be done in two ways.

Case I:



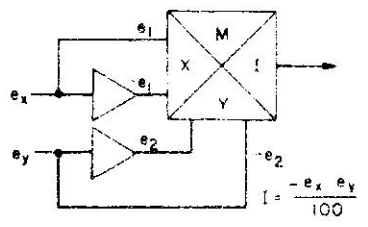
CIRCUIT



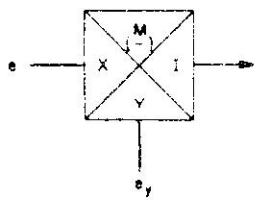
PROGRAM SYMBOL

Note that the "plus sign" associated with the "M" indicates a positive current is generated for a positive product, $e_x e_y$. The sign is generally omitted since this is the normal condition.

Case II:



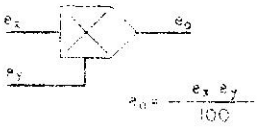
CIRCUIT



PROGRAM SYMBOL

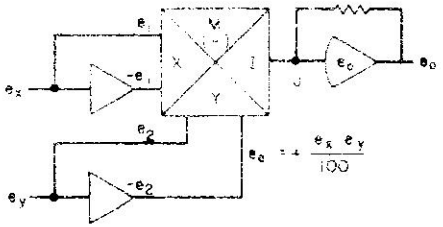
Note that the "minus sign" associated with the "M" indicates a negative current is generated for a positive product

The program symbol for the multiplier module together with an output amplifier is



An inverting amplifier can be used to generate the bipolar signals if they are not otherwise available.

Case I



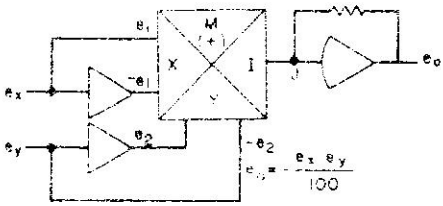
CIRCUIT



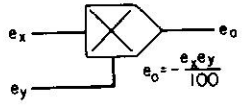
PROGRAM SYMBOL

Note that in the sign inversion is due to the output amplifier.)

Case II

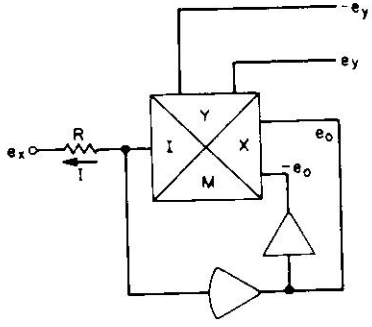


CIRCUIT



PROGRAM SYMBOL

A multiplier module can be used to make a divider with the same output amplifier. (This connection can be made conveniently at the patchboard.)



Here

$$I = K\frac{e_o e_y}{100} = -\frac{e_x}{R}$$

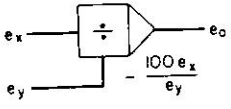
so that for $R = \frac{1}{K}$

$$e_x = -\frac{e_o e_y}{100}$$

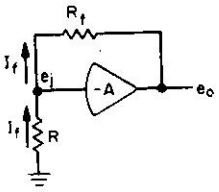
or

$$e_o = -\frac{100 e_x}{e_y}$$

The programmer's symbol is

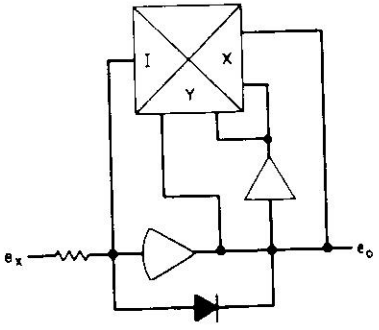


From the circuit it can be seen that the condition $e_y > 0$ must hold in order to avoid instability. This is easy to show. The multiplier module can be considered to be a non-linear feedback resister, R_f. The sign of R_f is the same as the polarity of e_y. Suppose in the circuit



$R_f < 0$. Then, I_f will be in the direction shown, for $e_o > 0$, and I_f will produce an $e_j < 0$. Since the gain of the amplifier is negative and large, the circuit will be unstable. An additional restriction, $|e_x| \leq |e_y|$, is necessary to ensure that the output amplifier not exceed the voltage limit.

The divider can be used to generate square root in a simple way. If $e_y = e_o$,



CIRCUIT

then

$$e_o = -100\frac{e_x}{e_o}$$

or

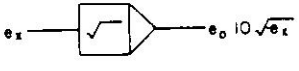
$$e_o^2 = -100\,e_x$$

so that

$$e_o = 10\sqrt{-e_x}, \quad e_x < 0.$$

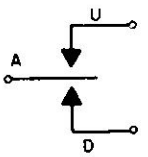
The diode insures that the system will not saturate in the wrong direction if e_x goes positive inadvertently.

This circuit has the program symbol



FUNCTION SWITCH

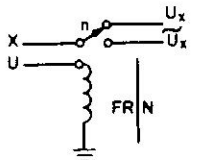
A function switch is a manual switch which can be operated from the control console. It is used to change the computer program during execution. The switch has three positions: up, down, and center (off). Its circuit is shown below.



This is the program symbol as well. The terminals of the switch are located at the patchboard.

FUNCTION RELAY

A function relay is used to make program changes automatically during execution. It is energized (logical 1) for an input equal to or greater than +28 volts and is de-energized (logical 0) for an input equal to or less than 0 volts. The circuit is shown below



$U_x = X$ if $U = 0$

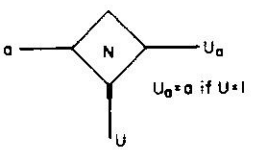
$\tilde{U}_x = X$ if $U = 1$

This is also the program symbol where N is the relay number.

ELECTRONIC SWITCH

An electronic switch is used in much the same way as a function relay; the only restriction being that it must be in series with the junction of an amplifier. Its speed of operation is much greater (10^{-5} sec) than a function relay (10^{-3} sec). It requires the same input voltages (logic levels) as the function relay (i.e. logical 1: $28 \le e_{in} \le 100$. logical 0: $-100 \le e_{in} \le 0$).

The program symbol is

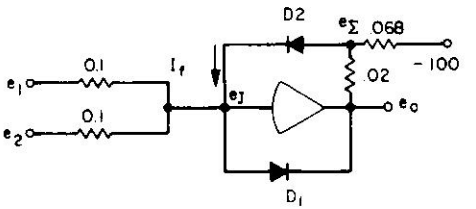


where N is the switch number.

COMPARATOR

Frequently, it is required to determine the sign of the sum of two variables.

A circuit which accomplishes this is

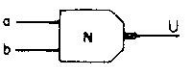


If $(e_1 + e_2) > 0$, then e_o is limited to approximately 0 volts by D_1 because of its low resistance when it conducts (logical 1). If $(e_1 + e_2) < 0$, then e_o is limited to approximately +28 volts by D_2 (logical 0). The latter is true since

1) I_F must be in the direction shown ($e_1 + e_2 > 0$) and $e_\Sigma > e_J$.

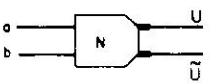
2) $e_o = 28$ volts since e_Σ must be approximately 0 volts due to the high gain of the amplifier.

The program symbol for the comparator is

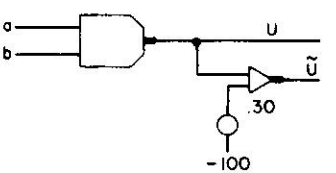


U=1 if (a+b)<0
U=0 if (a+b)>0

If both logical comparator outputs are required, then e_o is complemented with a biased analog inverter. The program symbol is



and the analog circuit is



Elementary Analog Programming

ALL DEPENDENT VARIABLES IN AN ANALOG COMPUTER are voltages. Consequently, it is necessary to equate these voltages to physical variables. Since the elements of the computer are voltage limited, scaling will be required. In this article, scaling is ignored since the necessary concepts can be developed without reference to scaling.

As pointed out earlier, it is necessary to remember that an analog computer cannot differentiate easily. It is a machine whose main feature is its ability to integrate. Consequently, problems which are defined by differential equations must be reformulated in terms of integral equations either explicitly or implicitly. Consider the problem

$$y = y(x)$$

$$\frac{dy}{dx} + By = 0$$

$$y(0) = A.$$

This can be rewritten as the integral equation

$$y + B\int y\,dx = 0$$

$$y(0) = A.$$

For this problem computer time will represent x, and

$$y(t) + B\int y\,dt = 0,\ t = x$$

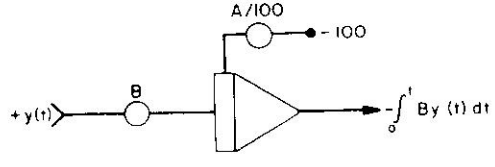
$$y(0) = A$$

An integrator, as shown in Chapter 2, integrates from $t = 0$ onward. It also requires an initial condition: namely the value of the integral at $t = 0$, which in this case is A. Thus, the problem is formulated for the computer as

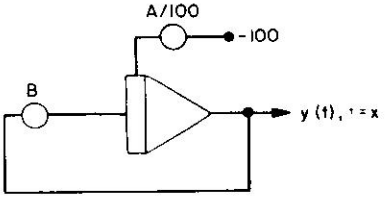
$$y(t) = -\int_0^t By(t)\,dt, \qquad (1)$$

$$y(0) = A$$

The right half of equation (1) can be generated by



where the constant B and the initial condition A are inserted by means of pots. Remember that the integrator inherently has a sign change. Equation (1) states that y(t) is equal to the negative integral. All that is needed, to complete the computer program for this problem, is to connect the output of the integrator to the input of the pot set to B. Hence, the computer program is



The independent variable, y, can be recorded from the output of the integrator.

In this example the differential equation was reformulated explicitly in terms of an integral equation. It is frequently possible to do this in an implicit way, as the next example will show.

Consider the problem

$$\ddot{y} + Ay + By = f(t),\ y = y(t) \qquad (2)$$

$$y(0) = C$$

$$\dot{y}(0) = D$$

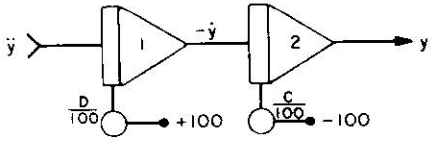
This is equivalent to

$$\ddot{y} = f(t) - A\dot{y} - By$$

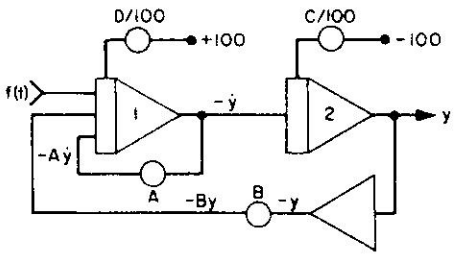
$$y(0) = C$$

$$\dot{y}(0) = D$$

First, y can be generated from $\ddot{y}$ by



(Note that again the pots are used to generate initial conditions.) Using this circuit, the complete program can be generated by



where equation (2) is satisfied by applying the correct inputs to integrator 1.

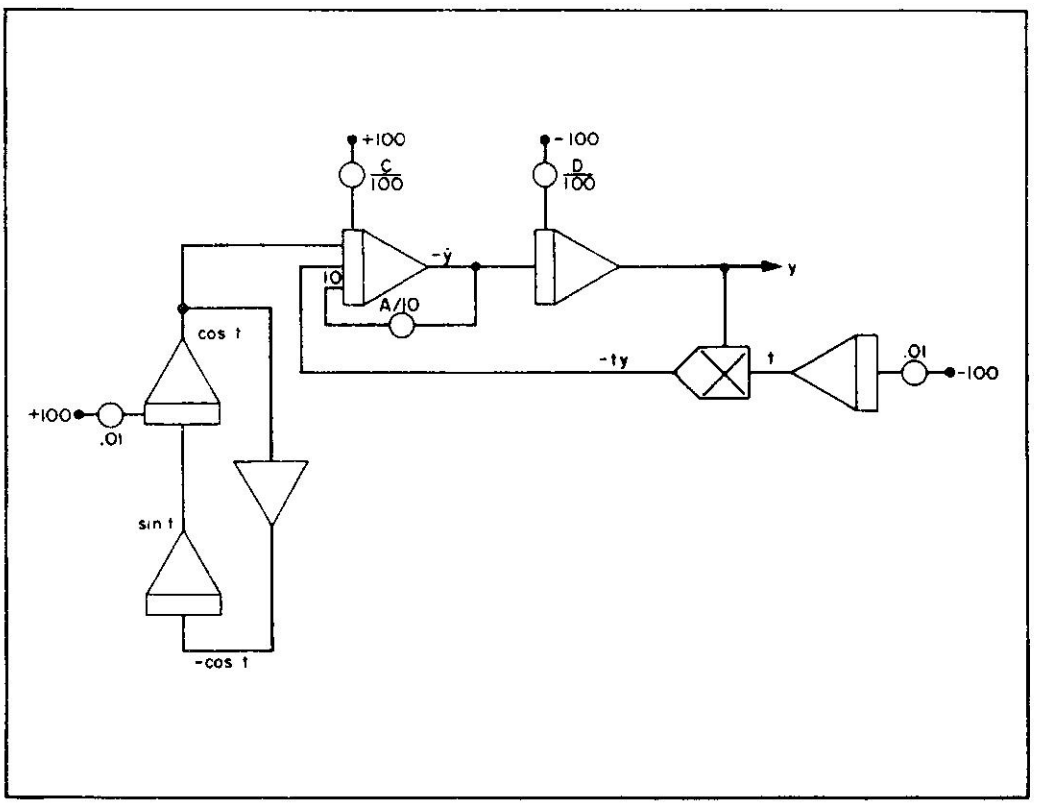
Next, the use of non-linear elements is demonstrated. Consider

$$\ddot{y} + A\dot{y} + ty = \cos t,\ 1 \le A \le 10,$$

$$\dot{y}(0) = C,$$

$$y(0) = D.$$

The computer program (except for scaling) is



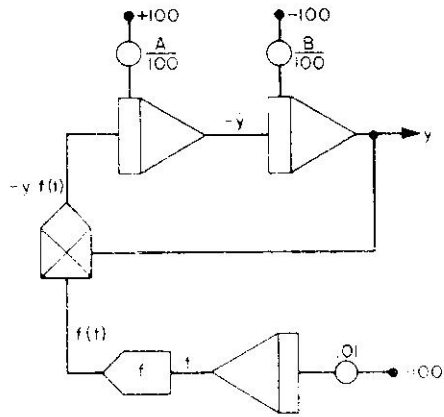
As another example, consider

$$\ddot{y} + f(t)y = 0$$

$$\dot{y}(0) = A$$

$$y(0) = B$$

The computer program is

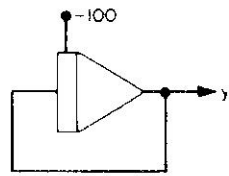


The next example shows how the DCU's (Chapter 8) can be used to determine the solution of a differential equation for a specified value of the independent variable. Suppose it is required to find y (.17) for

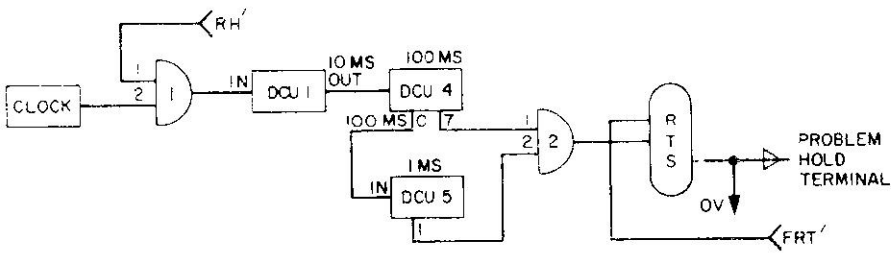
$$\ddot{y} - y = 0$$

$$y(0) = 100.$$

From above, the analog program which generates y is



In order to determine y(.17) the computer is allowed to compute for 0.17 seconds and then put into hold. The latter can be accomplished by applying +28 volts to the "problem hold" terminal at the patchboard after 0.17 seconds. This will halt the entire computer and in particular the computation carried out by the above program. The digital program which will do this is shown below:



The operation is as follows: The clock pulses are not applied to DCU 1 until the machine is in compute because the output of the RH' bus is a logical 0 in I C and this is an input to gate 1. The FF is initially in the R state when the machine is in compute having been reset by the FRT' Logic output. Divider 1 reduces the clock frequency of 1000 cycles/sec to 100 cycles/sec. The output of the 0 count of counter 4 is 10 cycles/sec and is connected to the input of counter 5. The 7 count output of counter 4 and the 1 count output of counter 5 are connected to gate 2. Thus, whenever t = 0.17 sec the output of gate 2 will change from 0 to 1, which will change the FF to the S state. At this time the computer will go to the hold mode due to the S output of the FF being connected to the problem hold terminal at the patchboard. Also, the clock and counters will be reset because of the logical 1 applied to the 0V terminal. As soon as the machine goes to the reset mode the FRT' logic output will cause the FF to return to the R state. Thus, the logic circuit is ready to be used again as the computer is manually put first in the reset mode and then the compute mode.

ALGEBRAIC EQUATIONS

The first examples were intended to illustrate the basic approach to programming. The following illustrates a more serious application of the analog computer. Suppose it is desired to solve a set of simultaneous algebraic equations which are expressed in matrix form by

$$AX = C \tag{3}$$

where the n x n matrix A and the column matrix C are known. For the purpose of illustration it will be assumed that A is of rank 2, although the derivation which follows is perfectly general. Consider

$$\dot{X} - AX = C \tag{3a}$$

When the system has reached steady-state (assuming there is one)

$$\dot{X} = 0$$

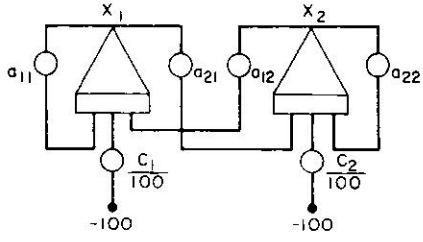
$$AX = C.$$

Thus the solution to equation (3) is obtained from the steady-state solution of equation (3a). The latter can be written

$$\dot{x}_1 + a_{11}x_1 + a_{12}x_2 = C_1$$

$$\dot{x}_2 + a_{21}x_1 + a_{22}x_2 = C_2 \qquad (4)$$

and the analog program is



Generally, integrator capacitors are chosen equal to 0.001 μfd to decrease the solution time. However, there is no guarantee that the system of differential equations, (4), is stable. A different approach will provide an unconditionally stable system of differential equations. If

$$AX = C$$

it follows that

$$A'AX = A'C \qquad (5)$$

where A' is the transpose of A. The solution of equation (5) is the same as that for equation (3). Again at steady-state the solution of

$$\dot{X} = A'AX = A'C \qquad (6)$$

will be the solution of equation (5) and therefore equation (3). The stability of equation (6) is determined by

$$\dot{X} = A'AX = 0. \qquad (7)$$

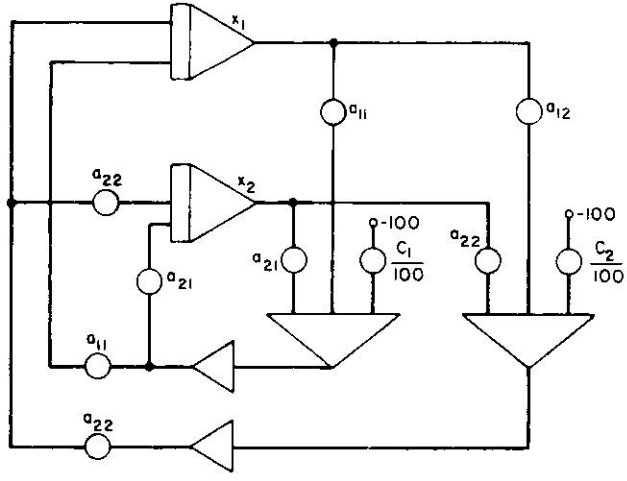
If equation (7) is multiplied by the row matrix X, then the result is

$$X\dot{X} + XA'AX = 0.$$

It is well known that XA'AX is positive definite (i.e. non-negative for all values of X). Unless X = 0,

$$X\dot{X} < 0$$

and stability is guaranteed. The computer program for equation (6) is



in this program it is easy to change individual coefficients because each pot is associated with only one coefficient. The program can be simplified so that it requires no more equipment than the previous program if the following coefficient changes are made.

OLD	NEW
a_{11}	$a_{11}^2 + a_{21}^2$
a_{12}	$a_{11}a_{12} + a_{21}a_{22}$
a_{21}	$a_{11}a_{12} + a_{21}a_{22}$
a_{22}	$a_{22}^2 + a_{12}^2$
C_1	$a_{11}C_1 + a_{21}C_1$
C_2	$a_{12}C_2 + a_{22}C_2$

This simplified program saves equipment but is inconvenient to use when the solution is required for several different values of the coefficients.

ARBITRARY CLOSED FUNCTIONS

Many analytic or closed functions can be generated by representing them in terms of their generating differential equations. The following examples illustrate the technique.

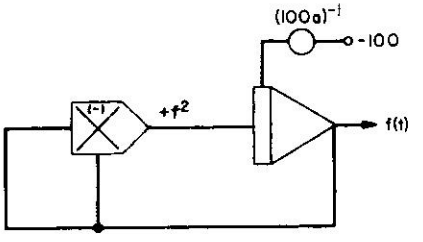
f(t) = 1/t, t>a:

This function has the generating equation

$$\frac{df}{dt} = -f^2$$

$$f(a) = \frac{1}{a}$$

The program which solves the generating equation is

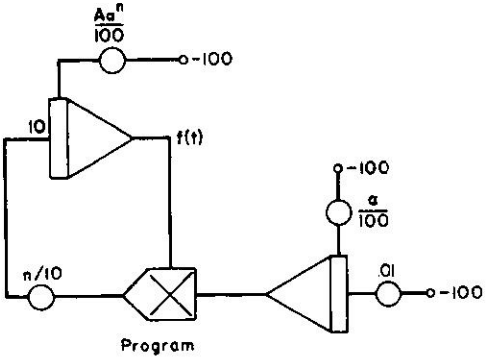


$f(t) = A(t + \alpha)^n, t > 0$:

$$\frac{df}{dt} = \frac{n}{t + \alpha} f$$

$$f(0) = A\alpha^n$$

Generating Equation

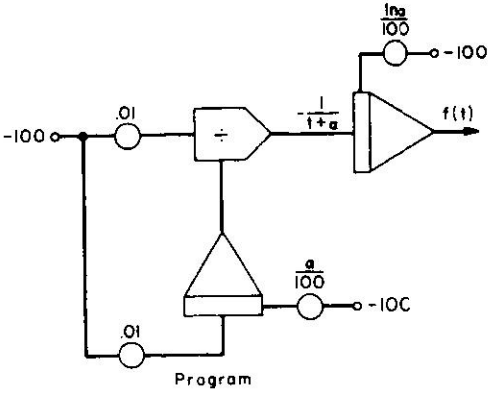


$f(t) = \ln(t + \alpha), t > 0$:

$$\frac{df}{dt} = \frac{1}{t + \alpha}$$

$$f(0) = \ln\alpha$$

Generating Equation

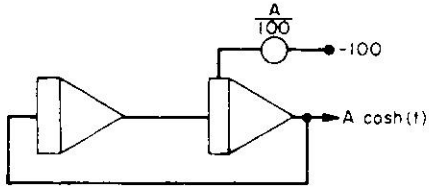


f(t) = A cosh(t), t>0:

$$\dot{f} = f$$

$$f(0) = A$$

Generating Equation



Program

Mean value:

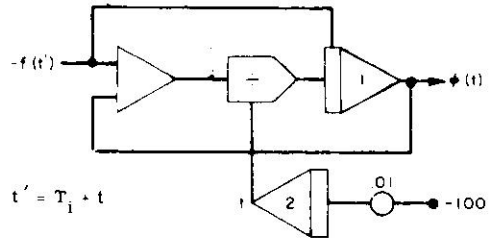
The mean value, $\phi(t)$, of a function, $f(t)$, over the interval $[T_1, T_1 + t]$ is defined by

$$\phi(t) = \frac{1}{t}\int_{T_1}^{T_1+t} f(\zeta)d\zeta, \quad t\geq 0. \tag{8}$$

The generating equation for ϕ can be obtained by differentiation:

$$\frac{d\phi}{dt} = \frac{1}{t}\{f(T_1 + t) - \phi(t)\} \tag{9}$$

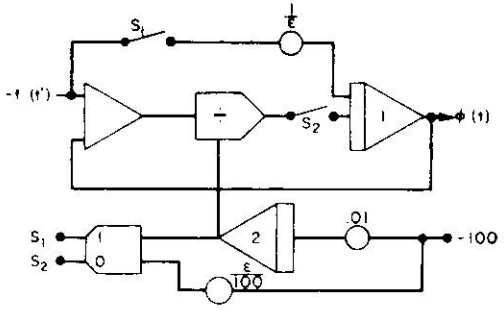
The program is



Suppose the integrators 1, 2 are in the initial condition mode until $t' = T_1$, at which time their mode is changed to compute. Then, theoretically, the program will generate the solution of equation (8). However, the program will not work because the right side of equation (9) is indeterminate for $t = 0$. Thus the divider, in the program will have an unstable output. Practical limitations require the Y-input to be at least 3 volts for useful operation. Consequently, it is necessary to choose a different initial condition:

$$\phi(\epsilon) = \frac{1}{\epsilon}\int_{T_1}^{T_1+\epsilon} f(\zeta)d\zeta,$$

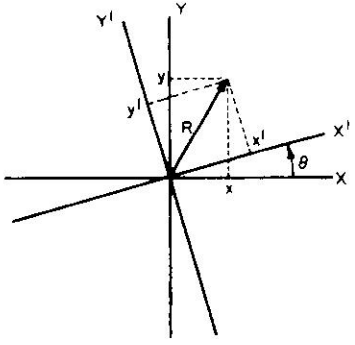
This program is



As before, when $t' = T_1$, the mode of integrators 1, 2 is changed from initial condition to compute. Initially S1 is closed and S2 is open. The output of integrator 1 will not be $\phi(t)$ until $t = \epsilon$. When $t = \epsilon$, the correct initial condition, namely $\phi(\epsilon)$, will have been established for integrator 1. At this time the comparator will be activated, which will open S1 and close S2. Also the output of integrator 2 will be ϵ. Thus, the generating equation is implemented by the program starting when $t = \epsilon$. The output of integrator 1 will be $\phi(t)$, $t>\epsilon$.

COORDINATE TRANSFORMATION

Suppose two coordinate systems have the same origin and are displaced by an angular rotation, θ:



An X-coordinate point, say x, will have the coordinates

$$x' = x\cos\theta$$

$$y' = -x\sin\theta$$

in the x', y'-coordinate system. Similarly, for a y-coordinate, say y,

$$x' = y\sin\theta$$

$$y' = y\cos\theta.$$

Thus, a vector, R, in the X, Y-system with components x, y, will have the components

$$x' = x \cos\theta + y \sin\theta$$

$$y' = -x \sin\theta + y \cos\theta$$

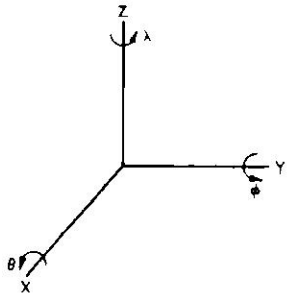
in the X', Y'-system. In matrix notation

$$R' = TR$$

where R, R' are the representations of the vector in the unprimed and primed coordinate systems respectively, and where

$$T = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}.$$

In the three-dimensional coordinate system



positive rotations θ, ϕ, λ respectively about the X, Y, Z axes correspond to the transformations

$$R^X_\theta \quad \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{bmatrix}$$

$$R^Y_\phi \quad \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix}$$

$$R^Z_\lambda \quad \begin{bmatrix} \cos\lambda & \sin\lambda & 0 \\ -\sin\lambda & \cos\lambda & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Any arbitrary three-dimensional rotation can be represented as a product of these three matrices. The superscripts refer to the axis about which the coordinate system is rotated and the subscripts to the name of the angle of rotation.

The transformation of a vector, V, by R^X is

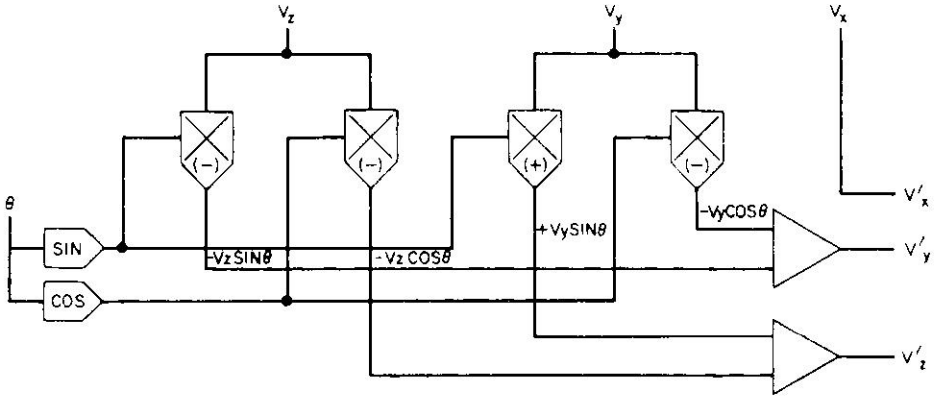
$$V' = RV$$

$$V'_x = V_x$$

$$V'_y = V_y \cos\theta + V_z \sin\theta$$

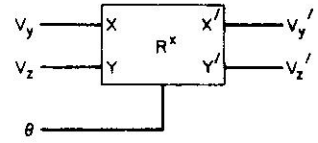
$$V'_z = -V_y \sin\theta + V_z \cos\theta.$$

The program is



Note that θ is limited by the range of the sine and cosine function generators.

The program symbol used frequently is



The transformations R^y, R^z have similar programs.

MATRICES

A matrix, A, is a collection of elements:

$$A = \{a_{ij}\} \begin{matrix} i = 1, \ldots, n \\ j = 1, \ldots, m. \end{matrix}$$

(in what follows it is assumed that n = m). Thus, if n = 3

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

Multiplication by a constant, α, follows the rule

$$\alpha A = \alpha \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} \alpha a_{11} & \alpha a_{12} & \alpha a_{13} \\ \alpha a_{21} & \alpha a_{22} & \alpha a_{23} \\ \alpha a_{31} & \alpha a_{32} & \alpha a_{33} \end{bmatrix}$$

which also can be denoted

$$\alpha A = \alpha a_{ij} \qquad \alpha A = \alpha [a_{ij}] = [\alpha a_{ij}]$$

when it is understood that the a_{ij} are the elements of A.

Addition follows the rule

$$A + B = a_{ij} + b_{ij} = (a + b)_{ij}$$

or for, say, n = 2

$$A + B = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}+b_{11} & a_{12}+b_{12} \\ a_{21}+b_{21} & a_{22}+b_{22} \end{bmatrix}.$$

Multiplication:

$$AB = \sum_{\alpha} a_{i\alpha} b_{\alpha j}$$

Thus for, say, n = 2

$$AB = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}.$$

Note that AB $\neq$ BA. The unit matrix, I, is

$$I = a_{ij} = I, \; i = j$$
$$= 0, \; i \neq j$$

Thus for, say, n = 3

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

I has the property

$$IA = AI = A$$

Differentiation:

$$\frac{d}{dx}A = \frac{d}{dx}(a_{ij}) = \frac{da}{dx}{}_{ij}$$

or for, say, n = 2

$$\frac{d}{dx}A = \frac{d}{dx}\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} \frac{da_{11}}{dx} & \frac{da_{12}}{dx} \\ \frac{da_{21}}{dx} & \frac{da_{22}}{dx} \end{bmatrix}$$

Transpose: The transpose, A', of A is

$$A' = a_{ji}.$$

or for, say, n = 2

$$A' = \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{bmatrix}$$

Submatrices: The submatrix, S_{ij}, corresponding to the element a_{ij} in A is obtained by deleting the i-th row and j-th column of A. Thus for, say, n = 3

$$S_{13} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} a_{21} & a_{22} \\ a_{31} & a_{32} \end{bmatrix}.$$

Determinant: The determinant, $|A|$, of A is a scalar quantity and can be found by induction. By definition

$$|A| = \sum_{j=1}^{N} (-1)^{i+j} a_{ij} |S_{ij}|, \text{ for any } i. \qquad (10)$$

(Note that some particular choice is made for i).

For n = 1

$$|A| = a_{11}.$$

Thus, for n = 2,

$$|A| = \sum_{j=1}^{2} (-1)^{1+j} a_{1j} |S_{1j}| = a_{11}S_{11} - a_{12}S_{12}$$

$$= a_{11}a_{22} - a_{12}a_{21}$$

or

$$|A| = \sum_{j=1}^{2} (-1)^{2-j} a_{2j} |S_{2j}| = -a_{21}S_{21} + a_{22}S_{22}$$

$$= -a_{21}a_{12} + a_{22}a_{11}$$

and either calculation leads to the same result. For n = 3,

$$|A| = \sum_{j=1}^{3} (-1)^{i+j} a_{ij} |S_{ij}|,$$

and in particular, any of the equations

$$|A| = \sum_{j=1}^{3} (-1)^{1+j} a_{1j} |S_{1j}|$$

$$|A| = \sum_{j=1}^{3} (-1)^{2-j} a_{2j} |S_{2j}|$$

$$|A| = \sum_{j=1}^{3} (-1)^{3+j} a_{3j} |S_{3j}|$$

will lead to the same $|A|$. If i = 1

$$|A| = a_{11}S_{11} - a_{12}S_{12} + a_{13}S_{13}$$

$$= a_{11}(a_{22}a_{33} - a_{23}a_{32}) - a_{12}(a_{21}a_{33} - a_{23}a_{31})$$

$$+ a_{13}(a_{21}a_{32} - a_{22}a_{31})$$

$$= a_{11}a_{22}a_{33} - a_{11}a_{23}a_{32} - a_{12}a_{21}a_{33} + a_{12}a_{23}a_{31}$$

$$- a_{13}a_{21}a_{32} + a_{13}a_{22}a_{31}$$

Alternatively, $|A|$ can be determined from

$$|A| = \sum_{i=1}^{n} (-1)^{i+j} a_{ij} |S_{ij}|, \text{ for any } j. \qquad (11)$$

A determinant can be multiplied by a constant, α, in a simple way:

$$|\alpha A| = \alpha |A|.$$

From equations (10) and (11) it can be seen that if a matrix B can be generated by m adjacent row interchanges and p adjacent column interchanges starting with matrix A, then

$$|B| = (-1)^{m+p} |A|.$$

Cofactor: The cofactor, C_{ij}, corresponding to the element a_{ij}, in A is

$$C_{ij} = (-1)^{i+j} |S_{ij}|,$$

or for, say, n = 3

$$C_{13} = \begin{vmatrix} a_{21} & a_{22} \\ a_{31} & a_{32} \end{vmatrix}$$

and

$$C_{23} = -\begin{vmatrix} a_{11} & a_{12} \\ a_{31} & a_{32} \end{vmatrix}.$$

Inverse: The inverse, A^{-1}, of matrix, A, is

$$A^{-1} = \frac{C_{ji}}{|A|}$$

For example, if n = 2

$$A^{-1} = \frac{1}{a_{11}a_{22} - a_{12}a_{21}} \begin{bmatrix} a_{22} & -a_{21} \\ -a_{12} & a_{11} \end{bmatrix}.$$

Orthogonality: A matrix, A, is said to be orthogonal if

$$A' = A^{-1}.$$

Note that R^X, R^Y, R^Z are orthogonal matrices. The geometric interpretation of orthogonality is rotation.

Logical Matrix Operations:

$$(AB)' = B'A'$$

$$(AB)^{-1} = B^{-1}A^{-1}$$

DECOMPOSITION OF ORTHOGONAL MATRICES

Frequently the programmer is presented with a composite orthogonal (rotation) matrix which is a function of several angular variables. Usually these angular variables represent successive rotations about coordinate axes. The simplest way to generate the computer program is to decompose the matrix into a product of the R^X, R^Y, R^Z matrices and then generate subprograms for each of these matrices. This can be accomplished by following a simple set of rules. These are stated without proof and examples are given. R^X, R^Y, R^Z are said to be type 1, 2, 3 matrices respectively. Suppose the composite matrix, M, can be represented

$$M = A_1 A_2 \cdots A_N.$$

The outer matrices are A_1, A_N and the inner matrix M_I, is defined by

$$M_I = A_2 A_3 \cdots A_{N-1} .$$

Now suppose the simplest element (lowest degree homogeneity) of M is located in row i and column j. Then A_1 is of type i and A_N is of type j. The angular variables corresponding to A_1, A_N will appear in the products of columns j, i respectively. The sense of the rotation, A_1, (positive or negative) can be found by setting all the variables corresponding to $A_2 \ldots$, A_N equal to zero. The sense of the rotation, A_N, is similarly found by setting the variables corresponding to A, ..., A_{N-1} equal to zero. If the simplest element of M is zero, then M has the representation

$$M = A_1 \; A_2$$

and there is no inner matrix. If the simplest element of M is not zero, then there is an inner matrix and M_I can be found by setting the variables corresponding to A_1, A_N equal to zero. The further decomposition of M_I is carried out with the same procedure as for M.

Example:

$$M = \begin{bmatrix} \text{Cos } \Psi & \text{Sin } \Psi & 0 \\ -\text{Cos } \theta \text{ Sin } \Psi & \text{Cos } \theta \text{ Cos } \Psi & \text{Sin } \theta \\ \text{Sin } \theta \text{ Sin } \Psi & -\text{Sin } \theta \text{ Cos } \Psi & \text{Cos } \theta \end{bmatrix}$$

The simplest element is zero and is in row 1 and column 3. Therefore there is no inner matrix and A_1, A_2, are of types 1, 3 respectively. The products of column 3 contain the variable θ and the products of row 1 contain the variable for Ψ. Therefore, the variable for A_1 is θ and the variable for A_2 is Ψ. If $\Psi = 0$

$$M = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \text{Cos } \theta & -\text{Sin } \theta \\ 0 & -\text{Sin } \theta & \text{Cos } \theta \end{bmatrix}$$

If $\theta = 0$

$$M = \begin{bmatrix} \text{Cos } \Psi & \text{Sin } \Psi & 0 \\ -\text{Sin } \Psi & \text{Cos } \Psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Finally,

$$M = R^X_\theta R^Z_\Psi$$

Example:

$$M = \begin{bmatrix} \text{Cos}\phi \text{ Cos}\Psi + \text{Sin}\theta \text{ Sin}\phi \text{ Sin}\Psi & & \\ -\text{Cos}\theta \text{ Sin}\phi & & \\ \text{Cos}\phi \text{ Sin}\Psi + \text{Sin}\theta \text{ Sin}\phi \text{ Cos}\Psi & & \end{bmatrix}$$

$$\begin{bmatrix} \text{Sin}\phi \text{ Cos}\Psi - \text{Sin}\theta \text{ Cos}\phi \text{ Sin}\Psi & -\text{Cos}\theta \text{ Sin}\Psi \\ \text{Cos}\theta \text{ Cos}\phi & \text{Sin}\theta \\ \text{Sin}\phi \text{ Sin}\Psi - \text{Sin}\theta \text{ Cos}\phi \text{ Cos}\Psi & \text{Cos}\theta \text{ Cos}\Psi \end{bmatrix}$$

The simplest element of M is $\text{Sin}\,\theta$ and is in row 2 and column 3. The products of column 3 contain the variable Ψ and those of row 2 the variable ϕ. Therefore A_1, A_3 are of types 2, 3 with variables Ψ, ϕ, respectively.

If $\theta = \phi = 0$, then

$$A_1 = \begin{bmatrix} \text{Cos } \Psi & 0 & -\text{Sin } \Psi \\ 0 & 1 & 0 \\ \text{Sin } \Psi & 0 & \text{Cos } \Psi \end{bmatrix} .$$

If $\Psi = \theta = 0$, then

$$A_3 = \begin{bmatrix} \text{Cos } \phi & \text{Sin } \phi & 0 \\ -\text{Sin } \phi & \text{Cos } \phi & 0 \\ 0 & 0 & 1 \end{bmatrix} .$$

If $\phi = \Psi = 0$, then

$$A_2 = M_I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \text{Cos } \theta & \text{Sin } \theta \\ 0 & -\text{Sin } \theta & \text{Cos } \theta \end{bmatrix} .$$

Finally,

$$M = R^Y_{-\Psi} \; R^X_\theta \, R^Z_\phi .$$

As can be seen from the previous example, it is not necessary to find all the elements of A_1 to determine the sense of Ψ. Since it is known that A_1 is of type 2 it is only required to evaluate the element in row 1 and column 3 with $\theta = \phi = 0$. Similarly, if the element in row 1 and column 2 is found for $\Psi = \theta = 0$, then the sense of ϕ is determined.

Example: (Here we use the abbreviations: $C_\alpha = \text{Cos}\alpha$, $S_\alpha = \text{Sin}\alpha$)

$$M = \begin{bmatrix} C_\phi C_\theta C_\Psi + C_\phi S_\theta S_\lambda S_\Psi + S_\phi S_\theta C_\lambda \\ C_\phi S_\theta C_\Psi - C_\phi C_\theta S_\lambda S_\Psi - S_\phi C_\theta C_\lambda \\ -C_\phi C_\lambda S_\Psi + S_\phi S_\lambda \end{bmatrix}$$

$$\begin{bmatrix} S_\phi C_\theta C_\Psi + S_\phi S_\theta S_\lambda S_\Psi - C_\phi S_\theta C_\lambda & C_\theta S_\Psi - S_\theta S_\lambda C_\Psi \\ S_\phi S_\theta C_\Psi - S_\phi C_\theta S_\lambda S_\Psi + C_\phi C_\theta C_\lambda & S_\theta S_\Psi + C_\theta S_\lambda C_\Psi \\ -S_\phi C_\lambda S_\Psi - C_\phi S_\lambda & C_\lambda C_\Psi \end{bmatrix}$$

The simplest element of M is $C_\lambda C_\Psi$ which is in row 3 and column 3. The products of column 3 contain θ and those of row 3 contain ϕ. Thus, A_1 is type 3 and A_N is also type 3. θ, ϕ are the variables for A_1, A_N respectively. Consider the element in row 1 and column 2. For $\lambda = \Psi = \phi = 0$ its value is $\text{Sin}\theta$ and consequently

$$A_1 = R^Z_{-\theta} .$$

For $\theta = \lambda = \Psi = 0$ its value is $\text{Sin}\phi$ and consequently

$$A_N = R^Z_\phi .$$

To determine the inner matrix, set $\theta = \phi = 0$ so that

$$M_I = \begin{bmatrix} C_\Psi & 0 & S_\Psi \\ -S_\lambda S_\Psi & C_\lambda & S_\lambda C_\Psi \\ C_\lambda S_\Psi & -S_\lambda & C_\lambda C_\Psi \end{bmatrix}$$

The simplest element of M_I is a zero in row 1 and column 2. Also for $\Psi = 0$ the element in row 2 and column 3 is $\mathrm{Sin}\lambda$. The products of column 2 and row 1 contain the variables λ, Ψ, respectively. Thus

$$M_I = R_\lambda^X R_\Psi^Y .$$

Finally,

$$A = R_\theta^Z R_\lambda^X R_\Psi^Y R_\phi^Z .$$

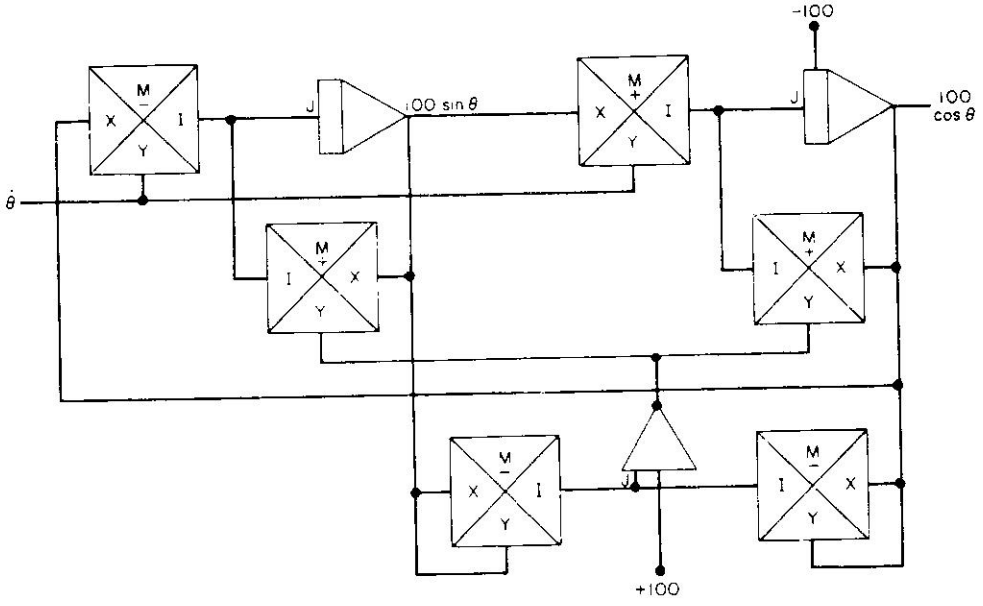
COORDINATE TRANSFORMATIONS WITH UNRESTRICTED ANGLES

The coordinate transformation program is the same as before, except for the use of Sine and Cosine function generators. For unrestricted range we use the variable θ and the equations

$$\mathrm{Sin}\theta = \int \dot{\theta}\,\mathrm{Cos}\theta\,dt$$

$$\mathrm{Cos}\theta = -\int \dot{\theta}\,\mathrm{Sin}\theta\,dt$$

The program is:



The lower two multipliers and summer generate

$$E = -(100 - \mathrm{Sin}^2\theta - \mathrm{Cos}^2\theta).$$

This error is used to change the damping of the integrators to ensure orthonormality of $\mathrm{Sin}\theta$, $\mathrm{Cos}\theta$.

Logical Algebra

It is necessary to have a rudimentary understanding of logical algebra in order to use logic elements. The fundamentals of logical algebra are presented for this reason.

LOGICAL VARIABLES

A logical variable, L, has two values:

1 (true)

0 (false)

ADDITION (OR)

The logical sum, $L_3 = L_1 + L_2$, is defined by the following table:

L_1	L_2	L_3
0	0	0
0	1	1
1	0	1
1	1	1

This is commonly called the OR function and has the alternative symbology

$$L_3 = L_1 \cup L_2 .$$

MULTIPLICATION (AND)

The logical product, $L_3 = L_1 \cdot L_2$ is defined by the following table:

L_1	L_2	L_3
0	0	0
0	1	0
1	0	0
1	1	1

This is commonly called the AND function and has the alternative symbology

$$L_3 = L_1 \cap L_2$$

COMPLEMENT

The complement of L is denoted by $\overline{L}$. Loosely speaking, $\overline{L}$ is the inverse of L. That is, whenever L = 1 or 0, then $\overline{L}$ = 0 or 1, respectively. In manipulating logical formulas, the two obvious relations below are often useful.

$$L + \overline{L} = 1$$

$$L \cdot \overline{L} = 0$$

COMMUTATIVE LAWS

$$L_1 + L_2 \qquad L_2 + L_1$$

$$L_1 \cdot L_2 \qquad L_2 \cdot L_1$$

ASSOCIATIVE LAWS

$$L_1 + (L_2 + L_3) \qquad (L_1 + L_2) + L_3$$

$$L_1 \cdot (L_2 \cdot L_3) \qquad (L_1 \cdot L_2) \cdot L_3$$

DISTRIBUTIVE LAW

$$L_1 \cdot (L_2 + L_3) = L_1 \cdot L_2 + L_1 \cdot L_3$$

COMPLEMENTED SUM

$$\overline{L_1 + L_2} = \overline{L}_1 \cdot \overline{L}_2$$

This relationship can be seen from the following table:

L_1	L_2	$L_1 + L_2$	$\overline{L_1 + L_2}$	$\overline{L}_1$	$\overline{L}_2$	$\overline{L}_1 \cdot \overline{L}_2$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

COMPLEMENTED PRODUCT

$$\overline{L_1 \cdot L_2} \qquad \overline{L}_1 + \overline{L}_2$$

DE MORGAN FORMULAS

$$L_1 + L_2 = \overline{\overline{L}_1 \cdot \overline{L}_2}$$

$$L_1 \cdot L_2 = \overline{\overline{L}_1 + \overline{L}_2}$$

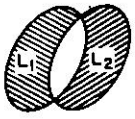
These can be obtained by complementing the complemented sum and product formulas.

EXCLUSIVE SUM

The exclusive sum, $\oplus$, of logical variables is defined by

$$L_1 \oplus L_2 = (L_1 + L_2) \cdot \overline{(L_1 \cdot L_2)}.$$

This is also called the exclusive OR. $L_1 \oplus L_2$ is the shaded area of the "set" diagram below.



In other words, the exclusive sum is the sum $L_1 + L_2$ minus the product $L_1 \cdot L_2$. A more convenient expression for $\oplus$ can be derived.

$$\begin{aligned} L_1 \oplus L_2 &= (L_1+L_2) \cdot \overline{(L_1 \cdot L_2)} \\ &= (L_1+L_2) \cdot (\overline{L}_1+\overline{L}_2) \\ &= L_1 \cdot \overline{L}_1 + L_1 \cdot \overline{L}_2 + L_2 \cdot \overline{L}_1 \\ &\quad + L_2 \cdot \overline{L}_2 \\ &= L_1 \cdot \overline{L}_2 + L_2 \cdot \overline{L}_1. \end{aligned}$$

Fundamentals of Vector Analysis

The development of vector operators given below is within the framework of Euclidean (x, y, or x, y, z) space. Due to the invariance property of vectors and vector operators under transformation to other coordinate systems of engineering interest, it is reasonable to proceed in this manner. Sometimes we will show the representation of the vector operator under discussion in other coordinate systems for the purpose of illustration. Indeed, the main motivation for using vector notation is its non-dependence on a particular coordinate system.

DEFINITIONS

$(A \cdot B)$ is the scalar (dot) product of two vectors.

$$A \cdot B = |A| \cdot |B| \text{Cos } (A, B)$$

$(A \times B)$ is the vector (cross) product of two vectors.

If

$$C = A \times B$$

then

$$|C| = |A| \cdot |B| \text{ Sin } (A, B)$$

Note that

$$(C \times (A \times B)) = 0$$

∇ is called the vector operator del,

$$\nabla \triangleq \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}$$

(Here ordered n-tuples are used instead of the customary i j k unit vector notation, i.e. $\frac{\partial}{\partial x} \cdot \frac{\partial}{\partial y} \triangleq \frac{\partial}{\partial x} i + \frac{\partial}{\partial y} j$).

If $\phi = \phi(x, y, z)$ is a scalar-valued function, then

$$\nabla \phi = \frac{\partial \phi}{\partial x}, \frac{\partial \phi}{\partial y}, \frac{\partial \phi}{\partial z}$$

is a vector-valued function also known as grad ϕ.

∇ has different forms in other coordinate systems.

Example: In cylindrical coordinates

$$\nabla = \frac{\partial}{\partial r}, \frac{1}{r}\frac{\partial}{\partial \theta}, \frac{\partial}{\partial z}$$

For a vector $V = Vx, Vy, Vz$:

$$\nabla \times V \triangleq \frac{\partial V_z}{\partial y} - \frac{\partial V_y}{\partial z}, \frac{\partial V_x}{\partial z} - \frac{\partial V_z}{\partial x}, \frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y}$$

is a vector-valued function known as curl V.

$\nabla \cdot \nabla = \nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ is known as the Laplacian.

SUMMARY OF OPERATOR ALGEBRA (greek letters are scalar-valued functions, capital letters are vector-valued functions)

$$\nabla \cdot (\alpha V) = \alpha(\nabla \cdot V) + V \cdot (\nabla \alpha)$$

$$\nabla \times (\alpha V) = \alpha(\nabla \times V) + (\nabla \alpha) \times V$$

$$\nabla \cdot (V \times U) = U \cdot (\nabla \times V) - V \cdot (\nabla \times U)$$

$$\nabla(V \cdot U) = V \times (\nabla \times U) + (V \cdot \nabla) U + U \times (\nabla \times V) + (U \cdot \nabla) V$$

$$\nabla \times (V \times U) = (U \cdot \nabla) V - (V \cdot \nabla) U - U(\nabla \cdot V) + V(\nabla \cdot U)$$

$$\nabla \times (\nabla \alpha) = 0$$

$$\nabla \cdot (\nabla \times V) = 0$$

$\nabla \times (\nabla \times A) = \nabla(\nabla \cdot A) - \nabla^2 A$ (this defines ∇^2 which is not a true vector operation).

$$A \times B = - B \times A$$

$A \cdot (B \times C) = (A \times B) \cdot C$ (triple scalar product)

DIFFERENTIAL OPERATIONS

The remainder of what follows will be derived for two dimensions but may be readily extended to three.

Divergence:

If $f(x, y)$ is a scalar-valued function then the family $f = c$ of curves in the plane are level lines for f. If

f is thought of as a potential then these curves are equipotential lines.

$$df = \frac{\partial f}{\partial x}\,dx + \frac{\partial f}{\partial y}\,dy = 0$$

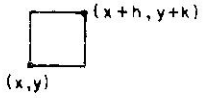
$$\nabla f \cdot (dx,\ dy) = 0$$

where (dx, dy) is a vector element of arc along the curve f = c. (This is so because we constrain the values of x, y so that f = c). Thus we see that

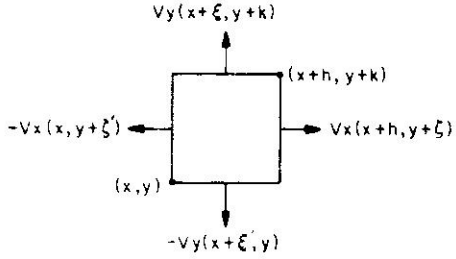
$$\nabla f \perp (dx,\ dy),$$

and the family of curves obtained from the differential tangent field, ∇f, are orthogonal to the family of level lines and represent a flux (or flow). $\nabla f \cdot N \triangleq \frac{df}{dN}$ is called the directional derivative of f in the N direction (N is a unit vector) at the point (x, y). The meaning is obvious. $\nabla \cdot V = \frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y}$ is a scalar-valued function known as the divergence of the vector-valued function, V. It is commonly written as div V.

Consider a small rectangle in the x, y-plane



We think of V as a flux, and determine the net emergence of flux from the rectangle.



We have

$$\text{Outflow} \quad \left[V_x(x+h,\ y-\xi) - V_x(x,\ y+\xi')\right] k + \left[V_y(x+\xi,\ y+k) - V_y(x+\xi',\ y)\right] h$$

$$\frac{\text{Outflux}}{\text{unit area}} = \frac{V_x(x+h,\ y+\xi) - V_x(x,\ y+\xi')}{h} + \frac{V_y(x+\xi,\ y+k) - V_y(x+\xi',\ y)}{k}$$

In the limit as h, $k \longrightarrow 0$ we have

$$\frac{\text{Outflux}}{\text{unit area}} = \frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} = \nabla \cdot V = \text{div } V$$

Thus if ϕ is a conservative potential field

$$\nabla \cdot \nabla \phi = 0 \text{ or } \nabla^2 \phi = 0$$

At a point x, y; $\nabla^2 \phi \neq 0$ implies a local $\frac{\text{source}}{\text{sink}}$ in the case of incompressible flow. Note that with compressible steady flow $\nabla^2 \phi \neq 0$, in general, without the presence of sources or sinks. In transient physical processes $\nabla^2 \phi$ is a measure of the change of energy from one form to another. For example, in heat transfer processes heat is stored locally by the distributed heat capacity of the medium in which the process occurs. Thus, if T is the temperature at (x, y), the local conductive heat transfer is $k \nabla T$ where k is the thermal conductivity, and the local heat stored by the heat capacity of the medium is $c\Delta T$ where c is distributed heat capacity. The loss of thermal flux (heat flow) from the conductive process equals the heat flux required for heat storage and this time-varying relationship is given by

$$\nabla \cdot k \nabla T = c\,\frac{\partial T}{\partial t}$$

or

$$\nabla^2 T = \frac{c}{k}\,\frac{\partial T}{\partial t} = \frac{1}{K}\,\frac{\partial T}{\partial t} \quad \text{(Diffusion equation).}$$

where K is the thermal diffusivity constant.

In the case of the small oscillations of a uniform membrane, if w(x, y) is defined to be deflection, then the potential energy stored by deformation of the membrane is a function of ∇w while the local kinetic energy of motion due to the mass of the membrane is a function of $\frac{\partial w}{\partial t}$. Thus the time-varying transfer of energy from one state to the other is described by

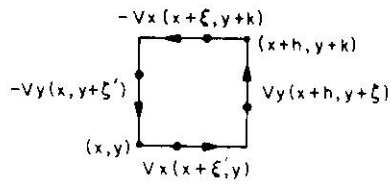
$$\nabla^2 w = \frac{1}{c^2}\,\frac{\partial^2 w}{\partial t^2} \quad \text{(wave equation)}$$

where c is the wave propagation velocity.

Curl:

If we think of the vector-valued function, V, as a velocity field, we can interpret curl V in a convenient

way. Consider the tangential velocity around the sides of a small rectangle.



The $\frac{\text{circulation}}{\text{unit area}}$ (spin) around the boundary is given by

$$\frac{V_y(x+h,\ y+\xi) - V_y(x,\ y+\xi')}{h} + \frac{V_x(x+\xi',\ y) - V_x(x+\xi,\ y-k)}{k}$$

In the limit as h, k $\longrightarrow$ 0 we have

$$\frac{\text{circulation}}{\text{unit area}}(\text{spin}) = \frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y} = \nabla x\, V = \text{curl } V.$$

To visualize the result in three-dimensions, we think of an infinitesimal paddle wheel located at the point (x, y, z). This paddle wheel is angularly oriented so that its shaft has the greatest rate of spin. Using the righthand rule, the shaft then points in the direction of ∇xV and its angular velocity is proportional to the magnitude of ∇xV.

If $\nabla xV = 0$, V is said to be an irrotational field.
If $V = \nabla xA$, V is said to be a solenoidal field.
If $V = \nabla\cdot\phi$ then V is irrotational. ($\nabla x \nabla\cdot\phi = 0$).
If $V = \nabla xA$ then V has zero divergence ($\nabla\cdot\nabla xA = 0$).

VECTOR TRANSFORMATION THEOREMS

Theor 1: (Divergence or Gauss theorem)

Let R be a region over which a vector valued function v is defined, then (differentiability assumed)

$$\int_R \nabla\cdot V = \int_{\partial R} V\cdot N$$

where n is a unit exterior normal to ∂R (boundary of R).

Theor 2: (Stokes' theorem)

Let R be a 3-dimensional region over which a vector valued function V is defined, and let σ be a 2-dimensional subregion of R. then (differentiability assumed)

$$\int_\sigma N\cdot(\nabla xV) = \int_{\partial\sigma} V\cdot ds$$

where N is a unit positive (sense to be determined by $\partial\sigma$) normal to σ and ds is a direction vector which lies in $\partial\sigma$.

Partial Differential Equations

This section treats the class of partial differential equations which can be represented

$$\nabla \cdot K \nabla \phi = \Xi\phi, \quad \phi = \phi(x_1, \cdots, x_n, t)$$

where the operation, Ξ, is defined by one of

$\Xi\phi = 0$ (Laplace equation)

$\Xi\phi = k$ (Poisson equation)

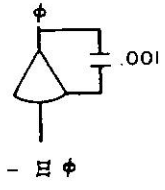
$\Xi\phi = k\phi$ (Helmholtz equation)

$\Xi\phi = C(X)\frac{\partial \phi}{\partial t}$ (Diffusion equation)

$\Xi\phi = M(X)\frac{\partial^2 \phi}{\partial t^2}$ (Wave equation)

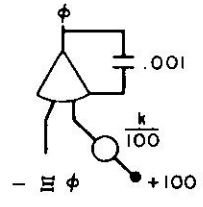
The analog computer is used to integrate $\Xi\phi$, in other words to generate Ξ^{-1}. This will be discussed before considering the generation of $\nabla \cdot K \nabla\phi$. The block programs for these cases are

Laplace:



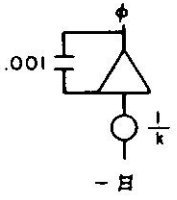
The high-gain amplifier forces $\Xi\phi = 0$ when connected to the remainder of the program. The capacitor is used to reduce high-frequency gain which may result in instability.

Poisson:



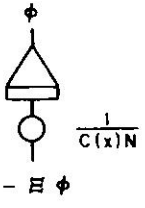
The high-gain amplifier ensures $\Xi\phi - k = 0$.

Helmholtz:

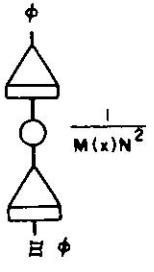


The capacitor is added to prevent algebraic loop instability.

Diffusion: (N is the time scale factor)



Wave: (N is the time scale factor)



With the blocks for $\Xi\phi$ available, all that remains is to find how to represent $\nabla \cdot K\nabla\phi$; the Laplacian of ϕ. The form of ∇ will depend on the coordinate system (see Chapter 13). To illustrate the concept we will derive the Laplacian for one dimension first and then develop it for both two-dimensional Euclidean and Reimannian manifolds. The extension to three dimensions will be obvious. For simplicity it will be assumed that K is not a function of time. For the case where K is a function of time, the pot set to K is replaced by a multiplier.

ONE DIMENSION

$$\nabla \cdot K\nabla\phi = \frac{\partial}{\partial x}\left[K(x)\ \frac{\partial}{\partial x}\phi(x,t)\right].$$

The derivatives will be replaced by finite differences:

Since

$$\frac{\partial}{\partial x} f(x,t) = \lim_{\Delta x \to 0} \frac{f(x+\Delta x, t) - f(x,t)}{\Delta x}$$

then, for small Δx

$$\frac{\partial}{\partial x} f(x+\frac{\Delta x}{2},\ t) = \frac{f(x+\Delta x,\ t) - f(x,\ t)}{\Delta x}$$

Adopting the notations

$$x_{n+\frac{1}{2}} = \frac{x_{n+1} + x_n}{2}$$

and

$$f(x_n,\ t) = f_n \text{ for any } n$$

we have, for finite differences

$$\frac{\Delta f\left(\frac{x_2 + x_1,\ t}{2}\right)}{\Delta x} = \frac{f(x_2,\ t) - f(x_1,\ t)}{x_2 - x_1}$$

For any n

$$\Delta f\ \frac{\left(\frac{x_{n+1} + x_n,\ t}{2}\right)}{\Delta x} = \frac{\Delta f\left(x_{n+\frac{1}{2}},\ t\right)}{\Delta n} =$$

$$= \frac{\Delta f_{n+\frac{1}{2}}}{\Delta x} = \frac{f(x_{n+1},\ t) - f(x_n,\ t)}{x_{n+1} - x_n} =$$

$$= \frac{f_{n+1} - f_n}{x_{n+1} - x_n}$$

Thus

$$\left[K\nabla\phi\right]_{x_{n+\frac{1}{2}}} = K(x_{n+\frac{1}{2}}) \cdot \frac{\phi(x_{n+1},\ t) - \phi(x_n,\ t)}{x_{n+1} - x_n}$$

$$= K_{n+\frac{1}{2}} \cdot \frac{\phi_{n+1} - \phi_n}{x_{n+1} - x_n}$$

Similarly

$$\left[K\nabla\phi\right]_{x_{n-\frac{1}{2}}} = K_{n-\frac{1}{2}} \cdot \frac{\phi_n - \phi_{n-1}}{x_n - x_{n-1}}$$

Using the same approximation

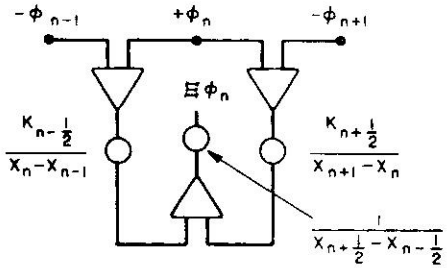
$$\left[\nabla \cdot K\nabla\phi\right]_{x_n} = \frac{\left[K\nabla\phi\right]_{x_{n+\frac{1}{2}}} - \left[K\nabla\phi\right]_{x_{n-\frac{1}{2}}}}{x_{n+\frac{1}{2}} - x_{n-\frac{1}{2}}} = \Xi\phi_n$$

Therefore, by substituting the different equations previously obtained, we have

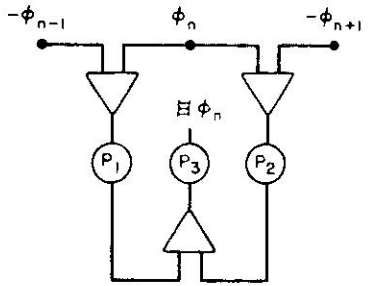
$$\frac{K_{n+\frac{1}{2}}}{X_{n+1} - X_n}\left[\phi_{n+1} - \phi_n\right] - \frac{K_{n-\frac{1}{2}}}{X_n - X_{n-1}}\left[\phi_n - \phi_{n-1}\right] =$$

$$= \left(X_{n+\frac{1}{2}} - X_{n-\frac{1}{2}}\right) \Xi\phi_n$$

The program which generates $\Xi\phi_n$ is



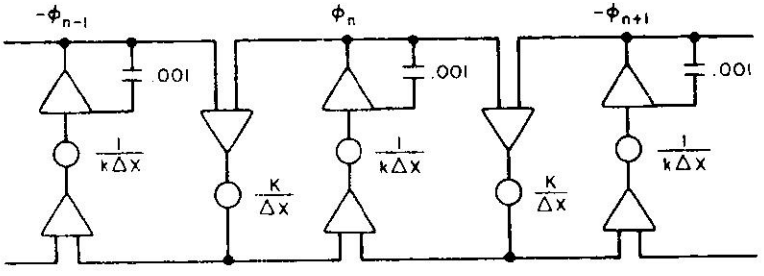
If $x_{n+1} - x_n = \Delta x$, for all n, then the program reduces to



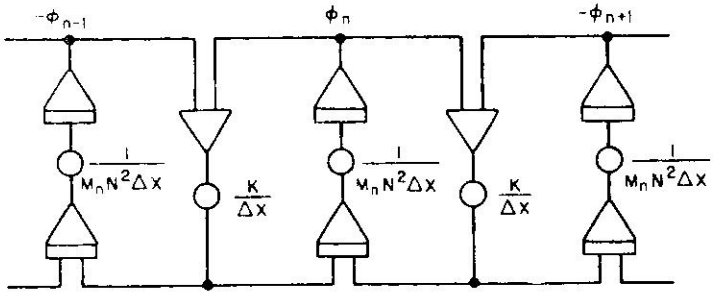
$$P_1 = \frac{K_{n-\frac{1}{2}}}{\Delta x},\ P_2 = \frac{K_{n+\frac{1}{2}}}{\Delta x},\ P_3 = \frac{1}{\Delta x}.$$

Finally, we have the program for all five types of equations above. Two are given below as examples.

Helmholtz:



Wave:



ONE-DIMENSIONAL BOUNDARY CONDITIONS

Boundary conditions of two types are commonly encountered:

$\phi(x,t)$ f(t) [Type 1]

$K(x)\nabla\phi(x,t)$ f(t) [Type 2]

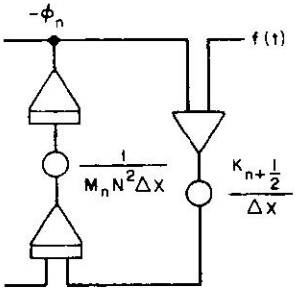
Sometimes both types are specified simultaneously as a mixed boundary condition. These are approximated by

$$\phi_n = f(t),\ x_n = \alpha$$

$$K_{n-\frac{1}{2}}\nabla\phi_{n+\frac{1}{2}} = f(t),\ x_{n+\frac{1}{2}} = \alpha$$

The programs are shown below for the Wave equation, but are typical for all $\Xi\phi$.

Type 1:



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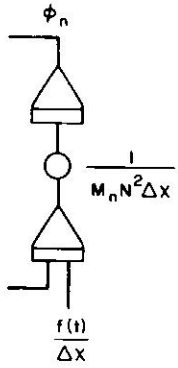
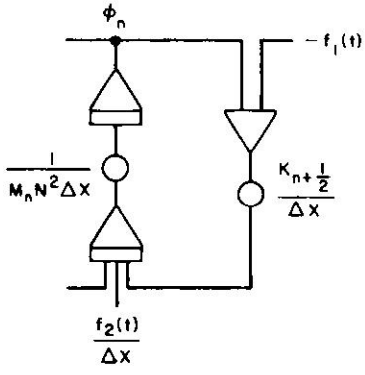


Mixed boundary conditions are represented by



This discussion can be extended to higher-dimension cases by treating each of the boundary points in the same fashion.

TWO-DIMENSIONAL EUCLIDEAN MANIFOLD

A two-dimensional Euclidean manifold is commonly called an x, y-coordinate system. Here

$$\nabla \cdot K\nabla\phi = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right) \cdot \left(K(x, y)\frac{\partial\phi}{\partial x}, K(x, y)\frac{\partial\phi}{\partial y}\right)$$

and

$$\nabla \cdot K\nabla\phi = \frac{\partial}{\partial x} K \frac{\partial\phi}{\partial x} + \frac{\partial}{\partial y} K \frac{\partial\phi}{\partial y} \equiv \Xi\phi$$

As for the one-dimensional case, finite difference approximations are made for the derivatives: we will adopt the notation

$$\phi_{n, m} \triangleq \phi(x_n, y_m)$$

$$\frac{K_{n+\frac{1}{2}, m}}{x_{n+\frac{1}{2}} - x_{n-\frac{1}{2}}}\left(\frac{\phi_{n-1, m} - \phi_{n, m}}{x_{n-1} - x_n}\right) - \frac{K_{n-\frac{1}{2}, m}}{x_{n+\frac{1}{2}} - x_{n-\frac{1}{2}}}\left(\frac{\phi_{n, m} - \phi_{n-1, m}}{x_n - x_{n-1}}\right)$$

$$+ \frac{K_{n, m+\frac{1}{2}}}{y_{m+\frac{1}{2}} - y_{m-\frac{1}{2}}}\left(\frac{\phi_{n, m+1} - \phi_{n, m}}{y_{m+1} - y_m}\right)$$

$$- \frac{K_{n, m-\frac{1}{2}}}{y_{m+\frac{1}{2}} - y_{m-\frac{1}{2}}}\left(\frac{\phi_{n, m} - \phi_{n, m-1}}{y_m - y_{m-1}}\right) \equiv \Xi\phi_{n, m}$$

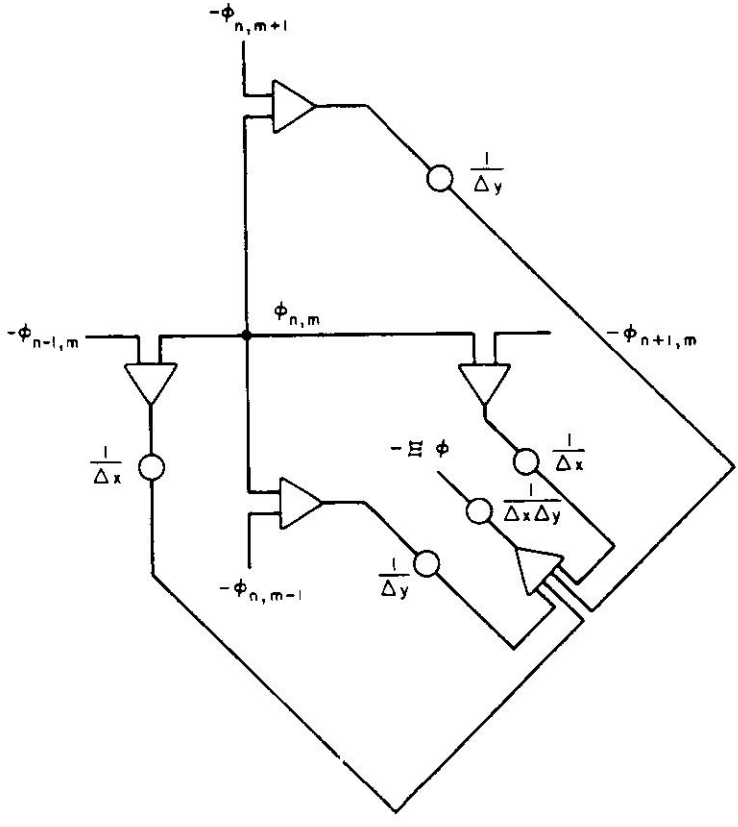
If $x_{n+1} - x_n = \Delta x$, $y_{m+1} - y_m = \Delta y$, for all n, m, then the equation reduces to

$$\frac{K_{n+\frac{1}{2}, m}}{\Delta x}\left(\phi_{n+1, m} - \phi_{n, m}\right) + \frac{K_{n-\frac{1}{2}, m}}{\Delta x}\left(\phi_{n-1, m} - \phi_{n, m}\right)$$

$$+ \frac{K_{n, m+\frac{1}{2}}}{\Delta y}\left(\phi_{n, m+1} - \phi_{n, m}\right) + \frac{K_{n, m-\frac{1}{2}}}{\Delta y}\left(\phi_{n, m-1} - \phi_{n, m}\right)$$

$$= \Delta x \Delta y \Xi\phi_{n, m}.$$

The program is



TWO-DIMENSIONAL RIEMANN MANIFOLD

Let the metric for the manifold be given by (ds = arc length)

$$ds^2 = g_{ij}\, dx^i dx^j .$$

In what follows we will use summation notation (i.e., we sum on repeated indices).

$$g = |g_{ij}| = g_{ik} G^{ik} \text{ (no sum on i)}$$

so that G^{ij} is the cofactor of g_{ij} in the determinant $|g_{ij}|$.

We define

$$g^{ij} = \frac{G^{ij}}{g} .$$

Note that

$$g^{ij}\, g_{ik} = \delta^{\,j}_{k} .$$

It can be shown, that if ϕ is a scalar function,

$$\nabla^2 \phi = \frac{1}{\sqrt{g}} \left(\frac{\partial}{\partial x^i}\right) \left(\sqrt{g}\; g^{ij}\; \frac{\partial \phi}{\partial x^j}\right)$$

Thus, we have a general expression for $\nabla^2 \phi$ in non-orthogonal curvilinear coordinates. We could treat the non-orthogonal case. However, that treatment is much more complicated than for the orthogonal coordinates. Since the latter is of greater practical interest, we will restrict our attention to

$$g_{ij} = 0, \quad i \neq j,$$

$$g^{ij} = 0, \quad i \neq j$$

Thus, in three dimensions,

$$ds^2 = g_{11}(dx^1)^2 + g_{22}(dx^2)^2 + g_{33}(dx^3)^2$$

$$g = g_{11}\, g_{22}\, g_{33}$$

$$g^{ii} = \frac{1}{g_{ii}} \text{ (no sum on i)}$$

We denote

$$\phi(x^i, x^j, x^k);\ x^\alpha = A_\alpha, \alpha = i, j, k,\ A_\alpha \text{ are constant}$$

by $\phi_{i,j,k}$.

Consider the diffusion equation

$$\nabla \cdot K \nabla \phi = \Xi\phi$$

We will need to replace the space derivatives with finite differences.

$$\nabla \cdot K \nabla\phi = \frac{1}{\sqrt{g}} \frac{\partial}{\partial x^i} \left(K \sqrt{g}\, g^{ij} \frac{\partial \varphi}{\partial x^j}\right)$$

$$\Xi\phi,\ K = K(x^1, x^2, x^3)$$

$$\frac{\partial}{\partial x^i} \left(K \sqrt{g}\, g^{ij} \frac{\partial \varphi}{\partial x^j}\right) = \sqrt{g}\ \Xi\phi$$

Now

$$g^{ij} = 0,\ i \neq j$$

$$\sqrt{g}\, g^{11} = \frac{\sqrt{g}}{g_{11}} = \frac{\sqrt{g_{22} g_{33}}}{\sqrt{g_{11}}}$$

$$\sqrt{g}\, g^{22} = \frac{\sqrt{g_{11} g_{33}}}{\sqrt{g_{22}}}$$

$$\sqrt{g}\, g^{33} = \frac{\sqrt{g_{11} g_{22}}}{\sqrt{g_{33}}}$$

and

$$\frac{\partial}{\partial x^1} \left(\frac{K\sqrt{g_{22}}\sqrt{g_{33}}}{\sqrt{g_{11}}} \frac{\partial \phi}{\partial x^1}\right) + \frac{\partial}{\partial x^2} \left(\frac{K\sqrt{g_{11}}\sqrt{g_{33}}}{\sqrt{g_{22}}} \frac{\partial \phi}{\partial x^2}\right) + \frac{\partial}{\partial x^3} \left(\frac{K\sqrt{g_{11}}\sqrt{g_{22}}}{\sqrt{g_{33}}} \frac{\partial \phi}{\partial x^3}\right) = \sqrt{g}\ \Xi\ \phi$$

When approximated with finite differences

$$\frac{\partial}{\partial x^1} \left(\frac{K\sqrt{g_{22}}\sqrt{g_{33}}}{\sqrt{g_{11}}} \frac{\partial \phi}{\partial x^1}\right) \rightarrow \frac{1}{\Delta x^1 \Delta x^2 \Delta x^3} \cdot \left\{ \left[\frac{\Delta x^2 \Delta x^3}{\Delta x^1} \left(\frac{K\sqrt{g_{22}}\sqrt{g_{33}}}{\sqrt{g_{11}}}\right)_{i+1/2,k,j}\right] \cdot \left[\phi_{i+1,j,k} - \phi_{i,j,k}\right] + \left[\frac{\Delta x^2 \Delta x^3}{\Delta x^1} \left(\frac{K\sqrt{g_{22}}\sqrt{g_{33}}}{\sqrt{g_{11}}}\right)_{i-\frac{1}{2},j,k}\right] \cdot \left[\phi_{i-1,j,k} - \phi_{i,j,k}\right] \right\}$$

and similarly for the other terms. Let us consider the one-dimensional projection to determine the significance of these terms. From the definition of the metric, clearly

$$\Delta x^1 \sqrt{g_{11}}$$

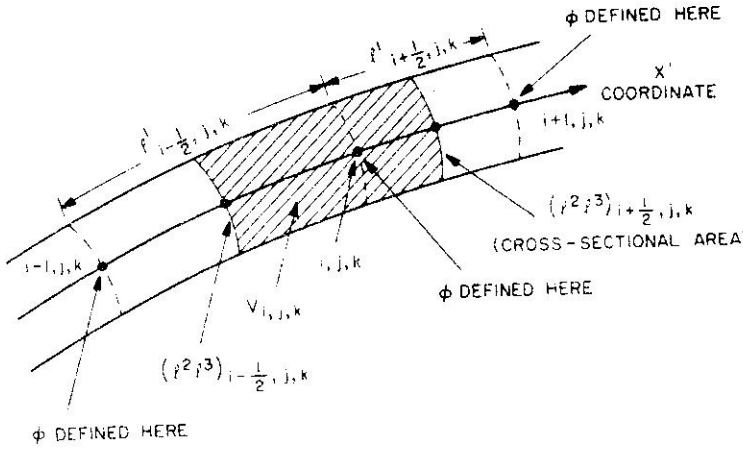
$$\Delta x^2 \sqrt{g_{22}}$$

$$\Delta x^3 \sqrt{g_{33}}$$

are lengths in the x^1, x^2, x^3 directions respectively. We denote these by l^1, l^2, l^3 respectively. $\Delta x^1 \Delta x^2 \Delta x^3 \sqrt{g}$ is the volume $V = l^1 l^2 l^3$.

In general, the value of the lengths and the volume for increments in x^1, x^2, x^3 depends on location. The one-dimensional projection of the problem is

$$\left[\left(\frac{l^2 l^3 K}{l^1}\right)_{i-\frac{1}{2},j,k} \left(\phi_{i-1,j,k} - \phi_{i,j,k}\right)\right] + \left[\left(\frac{l^2 l^3 K}{l^1}\right)_{i-\frac{1}{2},j,k} \left(\phi_{i-1,j,k} - \phi_{i,j,k}\right)\right] = V_{i,j,k}\ \Xi\ \phi_{i,j,k}$$



Thus, for example, we see that, in the Diffusion equation

$$\left(\frac{l^2 l^3 K}{l^1}\right)_{i-\frac{1}{2},j,k} \quad \text{and} \quad \left(\frac{l^2 l^3 K}{l^1}\right)_{i+1/2,j,k}$$

are lumped conductivities defined at appropriate locations and $V_{i,j,k}$ is a lumped capacity, also defined at an appropriate location. The extension to the non-projected problem in three-dimensions is obvious. It is interesting to note that the theoretical result agrees with our intuition.

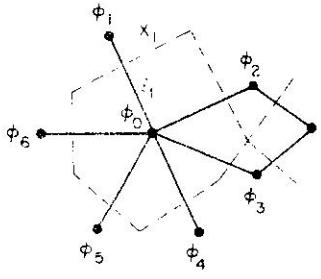
ASYMMETRIC LATTICE

The set of space points over which the operator

$$\nabla \cdot K \nabla \phi$$

is defined is called a lattice. In arbitrary regions one cannot find a metric in any simple way. Thus, the approach developed for the Riemann manifold is not applicable. If a Euclidean system is used, then the boundary must be composed of a collection of orthogonal line segments. This has two disadvantages: the lattice density must be high on the boundary in order to represent the boundary. The lattice density on the boundary determines the lattice density in the interior of the region, leading to an exorbitant equipment requirement for the program. The asymmetric lattice representation of $\nabla \cdot K\nabla\phi$ will allow one to avoid both of these difficulties.

Consider a lattice whose only restriction is that a set of perpendiculars to the branches (one for each) can be found such that the perpendiculars in each polygon enclosed by a branch loop intersect at only one point.



Referring to the figure above,

1. Let a point function ϕ_α be defined over the lattice
2. Consider one point of the lattice where we arbitrarily choose ϕ_0 and denote by ϕ_i the ϕ's at branch connected neighbors
3. Define ℓ_i to be the length of the branch between lattice points associated with ϕ_0, ϕ_i.
4. Define r_i to be the length of the $\perp$ to ℓ_i
5. Define the symmetry ratio $Y_i = \frac{r_i}{\ell_i}$

Now consider the representation of $\nabla^2\phi$ at the lattice point 0 given by

$$0(\phi_o) \triangleq \sum_\alpha \frac{Y_i}{A_0} (\phi_i - \phi_0)$$

Where α is the index set of the neighbors. We will choose the Y_i and A_0 such as to minimize error. Now for the continuous medium (where we denote the location of lattice point i by S_i) each $\phi(S_i)$ is given in terms of $\phi(S_o)$ and the derivatives of ϕ at S_o by

$$\phi(S_i) = \phi(S_o) + \sum_{n=1}^{\infty} \frac{1}{n!} \left(x_i \frac{\partial}{\partial x} + y_i \frac{\partial}{\partial y}\right)^n \phi(S_o)$$

We have assigned a Cartesian metric to the domain so that ℓ_i is the pair (x_i, y_i). Thus the representation $0(\phi_o)$ is given by

$$\sum_\alpha Y_i \sum_{n=1}^{\infty} \frac{1}{n!} \left(x_i \frac{\partial}{\partial x} + y_i \frac{\partial}{\partial y}\right)^n$$

or

$$\sum_{n=1}^{\infty} \frac{1}{n!} \sum_\alpha Y_i \left(x_i \frac{\partial}{\partial x} + y_i \frac{\partial}{\partial y}\right).$$

Thus

$$0(\phi_o) = \sum_\alpha Y_i x_i \phi_{xo} + \sum_\alpha Y_i y_i \phi_{yo} + \frac{1}{2} \sum_\alpha Y_i x_i^2 \phi_{xxo} + \frac{1}{2} \sum_\alpha Y_i y_i^2 \phi_{yyo} + \sum_\alpha Y_i x_i y_i \phi_{xyo} + \text{higher order terms}$$

Now we require

$$\sum_\alpha Y_i x_i = 0, \quad \sum_\alpha Y_i y_i = 0 \qquad (1)$$

(1), above, is the x and y projection of $\sum_\alpha Y_i \ell_i$.

$$\sum_\alpha Y_i \ell_i = \sum_\alpha r_i$$

$\sum_\alpha r_i$ projected on x, y is zero since the polygon formed by the r_α is closed. Thus, (1) is automatically satisfied. Evidently our choice of Y_i was suitable.

Define

$$e_x = \frac{1}{2} \sum_\alpha Y_i x_i^2, \quad e_y = \frac{1}{2} \sum_\alpha Y_i y_i^2, \quad e_{xy} = \sum_\alpha Y_i x_i y_i$$

Then 0 can be expressed

$$0(\phi_o) = e_x \phi_{xxo} + e_y \phi_{yyo} + e_{xy} \phi_{xyo} + \text{higher order terms.}$$

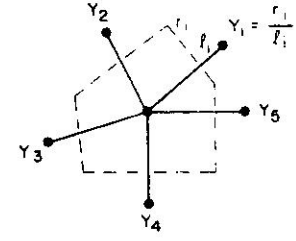
We want to reduce this to canonical form. The result above is independent of an orthogonal transformation on (x, y). Note that there exists an orthogonal transformation such that $e_{xy} = 0$. Henceforth, without loss of generality, we will assume $e_{xy} = 0$.

Thus,

$$0(\phi_o) = e_x \phi_{xxo} + e_y \phi_{yyo} + \text{higher order terms.}$$

$$0(\phi_o) = \left(\frac{e_x + e_y}{2}\right)(\phi_{xxo} + \phi_{yyo}) + \left(\frac{e_x + e_y}{2}\right)(\phi_{xxo} - \phi_{yyo}) + \text{higher order terms.}$$

We see that if e_x is significantly different in magnitude from e_y, then 0 is a poor approximation of ∇^2. Thus we require the polygon formed by the perpendiculars to have relatively good symmetry properties. The higher order terms can be reduced by increasing the lattice density. One can get an intuitive feeling for the symmetry properties of the polygon by observing that the system has a physical interpretation in terms of moments of inertia as shown below.



Y_i = Mass at ℓ_i

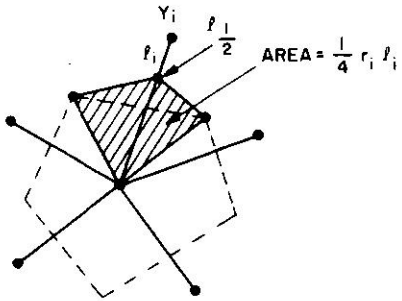
All that remains is to find the normalizing constant A_o. We choose

$$A_o = \frac{\beta_x + \beta_y}{2}$$

$$A_o = \frac{1}{4}\sum_{\alpha} Y_i(x_i^2 + y_i^2) = \frac{1}{2}\sum_{\alpha} Y_i \ell_i^2$$

$$A_o = \frac{1}{4}\sum_{\alpha} r_i \ell_i .$$

Geometrically,



Interpretation:

If ℓ_{ij} is a branch from ϕ_i to ϕ_j, then the lumped flux from polygon i to polygon j corresponding to $\nabla\phi$ is $\frac{r_{ij}}{\ell_{ij}}\left[\phi_i - \phi_j\right]$ so that $Y_{ij} = \frac{r_{ij}}{\ell_{ij}}$ is a lumped admittance. A_j is the area associated with lattice point j.

MacNeal, R.H., "An Asymmetrical Finite Difference Network", Quarterly Appl Math, October 1953)

Correlation Analysis

PROBABILITY THEORY

Sample space:

A sample space, S, is the collection of all outcomes of an experiment.

Probability:

P(S) is a function defined over S. P maps S into the interval $0 \leq P(S) \leq 1$. P is not necessarily univalent. The integral (or sum) over the range of P is unity. In case S is finite, P is said to assign a probability to each point of S. In case S is infinite, P is said to define a probability density over S. Suppose S_α is a nested collection of subsets of S such that $S_i \subset S_{i+1}$ for all i. The extremum of $S_\alpha = S$ and the infemum of S_α is empty. The measure of the range of P for the monotone sequence S_α is the probability distribution for S with respect to the collection S_α.

EXPECTATION AND VARIANCE

The expectation of S, E(S), is the measure of SP(S). The variance, V(S); is the measure of

$$S^2P(S) - E^2(S) \quad .$$

Example:

Suppose S is given by $-\infty < x < \infty$ and

$$P(x) = (2\pi)^{-\frac{1}{2}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right] \quad .$$

Then

$$E(x) = \int_{-\infty}^{\infty} x\,P(x)\,dx = \mu$$

$$V(x) = \int_{-\infty}^{\infty} x^2 P(x)dx - \mu^2 = \sigma^2$$

Let the S_α be defined by $-\infty < x < x_\alpha$, then

$$\phi(x_\alpha) = \int_{-\infty}^{x_\alpha} P(x)dx$$

is the distribution function.

STATIONARY RANDOM PROCESSES

If the statistics of a process are time-independent, the process is said to be stationary.

Suppose f(t) is a random function defined for $-\infty < t < \infty$.

Let the domain of f be denoted by D. We define an ordered countable set $\{D_\alpha\}$ so that

$$D_i : x_i \leq t < x_{i+1} \cdot x_{i+1} - x_i > \lambda \ .$$

$$\cup D_i = D$$

If $f_i = f(D_i)$, then the collection f_α is an ensemble. If f is stationary and λ is sufficiently large, the ensemble will be ergodic. (That is, the statistical properties of the members of the ensemble are identical.) Henceforth, all ensembles considered will be assumed ergodic.

FIRST AND SECOND PROBABILITY DENSITIES

Let S be the sample space consisting of all possible values for the ensemble $\{f_i(t_i + \Delta)\}$ where $\Delta < \lambda$. P(S) is said to be the first probability density. P(S) is independent of Δ, since f is stationary. The ensemble is ergodic so that

$$E(S) = \lim_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f(t)dt$$

$$V(S) = \lim_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f^2(t)dt - E^2(S)$$

Let S_T be the sample space consisting of all possible pairs of values $(f_i(t_i + \Delta), f_i(t_i + \Delta + T))$ for the ensemble where $\Delta + T < \lambda$. $P_T(S_T)$ is said to be the second probability density. $P_T(S_T)$ depends only on T, not on Δ. The ensemble is ergodic so that

$$E_T(S_T) = \lim_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f(t)f(t+T)dt \ .$$

(It can be shown that this equation is valid for $T > \lambda$.)

AUTOCORRELATION FUNCTION

$E_T(S_T)$, above, is the autocorrelation function for f and is denoted by $\phi_{ff}(T)$. That is,

$$\phi_{ff}(T) = \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f(t)f(t+T)dt$$

The autocorrelation function has the properties:

1) $\phi_{ff}(T) = \phi_{ff}(-T)$

2) $\phi_{ff}(o)$ is the average power of f.

3) $\left|\phi_{ff}(T)\right| \leq \phi_{ff}(o)$

Proof:

$$\left|\phi_{ff}(T)\right| \leq \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} \left|f(t)\right| \cdot \left|f(t+T)\right| dt$$

$$\leq \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} \frac{1}{2} \left\{ \left|f(t)\right|^2 + \left|f(t+T)\right|^2 - \left[\left|f(t)\right| - \left|f(t+T)\right|\right]^2 \right\} dt$$

$$\leq \phi_{ff}(o) - \operatorname*{Lim}_{\delta \to \infty} \frac{1}{4\delta} \int_{-\delta}^{\delta} \left[\left|f(t)\right| - \left|f(t+T)\right|\right]^2 dt$$

4) $f \in P_\nu \longrightarrow \phi_{ff} \in P_\nu$ (is periodic with period ν)

Proof: $f(t+T) = f(t+T+\nu)$

5) ϕ_{ff} contains no phase information about f.

6) For every f there exists a unique ϕ_{ff}; the converse is not true.

7) If $f \notin P_\nu$ for any ν, then $\operatorname*{Lim}_{T \to \infty} \phi_{ff}(T) = 0$

8) If f can be represented by

$$f = \sum_{n=-\infty}^{\infty} A_n \operatorname{Sin}(\omega_n t + \phi_n),$$

then

$$\phi_{ff}(T) = \sum_{n=-\infty}^{\infty} \phi_{nn}$$

where $\phi_{nn} = \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} A_n^2 \operatorname{Sin}(\omega_n t + \phi_n) \cdot \left(\operatorname{Sin}(\omega_n t + T + \phi_n)\, dt\right)$

Proof:

$$\operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \left(\int_{-\delta}^{\delta} A_n \operatorname{Sin}(\omega_n t + \phi_n) \right) \cdot A_m \operatorname{Sin}(\omega_m t + T + \phi_m) dt = 0, \quad m \neq n .$$

9) If f, $f' \in$ bd, then $\phi_{f'f'}(T) = -\phi''_{ff}(T)$.

Proof:

$$\phi_{f'f'}(T) = \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f'(t)f'(t+T)dt$$

$$= \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \left\{ \left[f(t)f'(t+T)\right]_{-\delta}^{\delta} - \int_{-\delta}^{\delta} f_1(t)f''(t+T)dt \right\}$$

$$= -\frac{d^2}{dT^2} \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f_1(t)f_2(t+T)dt$$

CROSS-CORRELATION FUNCTION

Suppose f, g are two stationary random functions. f, g can be decomposed (as above) into two ergodic ensembles f_α, g_α. The union of these ensembles is a composite ensemble of pairs $(f, g)_\alpha$. Let S_T be the sample space consisting of all possible pairs of values $(f_i(t_i + \Delta), g_i(t_i + \Delta + T))$ for the composite ensemble, where $\Delta + T < \lambda$ (λ is the ensemble duration). Since the ensemble is ergodic

$$E_T(S_T) = \operatorname*{Lim}_{\delta \to \infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f(t)g(t+T)dt$$

E_T is the cross-correlation function for the pair (f, g) and is denoted by $\phi_{fg}(T)$.

It can be shown that $\phi_{fg}(T)$ is valid for $T > \lambda$. The cross-correlation function has the properties:

1) Generally $\phi_{fg}(T) \neq \phi_{fg}(-T)$.

Consider $g(t) = \frac{1}{\epsilon}$, $-\epsilon \leq t \leq \epsilon$

$= 0, \quad |t| > \epsilon$

2) $\phi_{fg}(T) = \phi_{gf}(-T)$

3) Max $\phi_{fg}(T)$ does not necessarily occur for T=0.

4) $\left|\phi_{fg}(T)\right| \leq \sqrt{\phi_{ff}(o)\,\phi_{gg}(o)}$

Proof:

$$\phi_{fg}^2(T) \leq \operatorname*{Lim}_{\delta\to\infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f^2(t) g^2(t+T)dt \leq$$

$$\left[\operatorname*{Lim}_{\delta\to\infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f^2(t)dt\right] \cdot$$

$$\left[\operatorname*{Lim}_{\delta\to\infty} \frac{1}{2\delta} \int_{-\infty}^{\infty} g^2(t+T)\,dt\right]$$

AUTOCORRELATION FOR A SUM OF FUNCTIONS

Henceforth we will denote

$$\operatorname*{Lim}_{\delta\to\infty} \frac{1}{2\delta} \int_{-\delta}^{\delta} f(t)dt$$

by Mean $\{f(t)\}$, or just $M\{f\}$ wherever convenient. Let $f(t) = f_1(t) + f_2(t)$.

$$\phi_{ff}(T) = \text{Mean}\left\{\left[f_1(t)+f_2(t)\right]\left[f_1(t+T)+f_2(t+T)\right]\right\}$$

$$= M\left\{f_1(t)f_1(t+T)\right\} + M\left\{f_1(t)f_2(t+T)\right\}$$

$$+ M\left\{f_2(t)f_1(t+T)\right\} + M\left\{f_2(t)f_2(t+T)\right\}$$

Thus,

$$\phi_{ff} = \phi_{f_1f_1} + \phi_{f_1f_2} + \phi_{f_2f_1} + \phi_{f_2f_2}.$$

The general rule for a linear combination can be deduced easily.

EXAMPLES OF AUTOCORRELATION FUNCTIONS

Example 1 (sinewave):

Let $f = A\sin(\omega t + \psi)$, then

$$\phi_{ff} = \text{Mean}\left\{A^2 \sin(\omega t + \psi)\sin(\omega t + \omega T + \psi)\right\}$$

Since $f \in P_\omega$,

$$\phi_{ff} = \frac{\omega A^2}{2\pi} \int_{\alpha}^{\alpha + \frac{2\pi}{\omega}} \sin(\omega t + \psi)\sin(\omega t + \omega T + \psi)\,dt$$

$$\phi_{ff} = \frac{A^2}{2\pi} \int_{\alpha\omega + \psi}^{\alpha\omega + \psi + 2\pi} \sin(\zeta)\sin(\zeta + \omega T)\,d\zeta$$

$$\phi_{ff} = \frac{A^2}{4\pi} \int_{0}^{2\pi} \cos\omega T\,dt = \frac{A^2}{2}\cos\omega T$$

Example 2 (general random function):

Suppose f is defined by

a) $f(n\delta + t) = f(n\delta)$, $o \leq t < \delta$

b) $P\left[f(n\delta) = x\right] = P(x)$

c) $E\left[f(n\delta)\right] = o$

then

$$E\left[f(\zeta)f(\zeta + T)\right] = \int_{-\infty}^{\infty} \left[xP(x)\right]\left[x\left(1 - \left|\frac{T}{\delta}\right|\right)\right]dx +$$

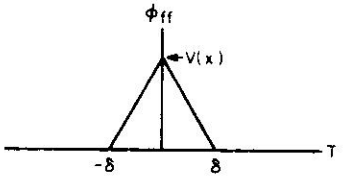
$$\iint_{-\infty}^{\infty} \left[xP(x)\right]\left[yP(y)\right]\left|\frac{T}{\delta}\right| dxdy, \quad |T| < \delta$$

$$= \iint_{-\infty}^{\infty} \left[xP(x)\right]\left[yP(y)\right] dxdy, \quad |T| > \delta.$$

But $\iint_{-\infty}^{\infty} xyP(x)P(y) = o$, so that

$$\phi_{ff} = \left(1-\left|\frac{T}{\delta}\right|\right) \int_{-\infty}^{\infty} x^2 P(x)dx = V(x)\left(1-\left|\frac{T}{\delta}\right|\right),\ T \le \delta$$

$$= 0,\ T > \delta$$



Example 3 (binary noise):

Binary noise is a special case of (2), above, where

$$P(x) = \frac{1}{2}\, u_1 (x - x_0) + \frac{1}{2}\, u_1 (x - x_0)$$

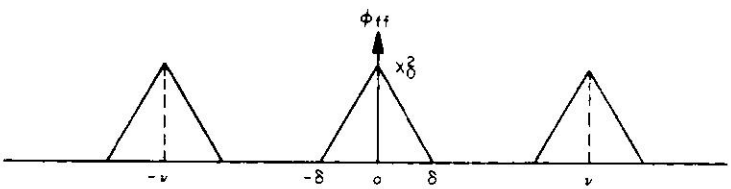
That is f takes on values of x_0, $-x_0$, with probabilities of $\frac{1}{2}$.

Then $V(x) \quad x_0^2$ and

$$\phi_{ff} \quad x_0^2 \left(1-\left|\frac{T}{\delta}\right|\right)$$

Example 4 (periodic binary noise):

Suppose f is defined as in (3), above, except that $f(\zeta) = f(\zeta + \nu)$ for large ν. Then ϕ_{ff} is periodic.



POWER SPECTRAL DENSITY

The operator F denotes the Fourier transform, so that $Fg = G(\omega)$.

$$\Phi_{gg}(\omega) = F\phi_{gg} = \operatorname{Lim}_{\delta\to\infty} \int_{-\delta}^{\delta} e^{-j\omega T} dT$$

$$\cdot \left[\operatorname{Lim}_{\delta\to\infty} \frac{1}{2\lambda} \int_{-\lambda}^{\lambda} g(t)g(t-T)\,dt\right]$$

$$\Phi_{gg}(\omega) = \operatorname{Lim}_{\delta\to\infty} \frac{1}{2\lambda} \left\{\int_{-\lambda}^{\lambda} g(t)dt \right.$$

$$\left. \cdot \left[\operatorname{Lim}_{\delta\to\infty} \int_{-\delta}^{\delta} g(t+T)e^{j\omega T} dT\right]\right\}$$

$$\Phi_{gg}(\omega) = \operatorname{Lim}_{\delta\to\infty} \frac{1}{2\lambda} \left\{\int_{-\lambda}^{\lambda} g(t)\, e^{j\omega t} dt \right.$$

$$\left. \cdot \left[\operatorname{Lim}_{\delta\to\infty} \int_{-\delta}^{\delta} g(\zeta)e^{-j\omega\zeta} d\zeta\right]\right\}$$

$$\Phi_{gg}(\omega) = \operatorname{Lim}_{\delta\to\infty} \frac{1}{2\lambda} \left[\int_{-\lambda}^{\lambda} g(\zeta)e^{-j\omega\zeta} d\zeta\right]^2$$

$\Phi_{gg}(\omega)$ is said to be the power spectral density. We have

$$\phi_{gg}(T) = \int_{-\infty}^{\infty} \Phi_{gg}(\omega)e^{j\omega T} dT .$$

WHITE NOISE

White noise has constant power spectral density of arbitrary magnitude (say A). Thus, the autocorrelation function for white noise is

$$\phi_{gg} = Au_1(T),$$

where u_1 is the unit impulse.

PERIODIC WHITE NOISE

If f satisfies the requirements for white noise for some interval δ, where δ is large, and if $f(t+\delta) = f(t)$, then

$$\phi_{ff}(T) = A \sum_{n=-\infty}^{\infty} u_1 (T - n\delta).$$

FINITE CORRELATION FUNCTION

If f, g are defined only for $0 \leq t < \infty$, then

$$\phi_{fg} \quad \lim_{\delta \to \infty} \frac{1}{\delta} \int_0^{\delta} f(t)\, g(t+T)\, dt.$$

ϕ_{fg} can be approximated by a sum:

$$\phi_{fg} \approx \text{Mean} \sum_{m=1}^{N} f(m\Delta t)\, g(m\Delta t + T) \qquad (1)$$

In this case Δt must be small enough that the high frequency components of f, g are adequately represented (see Chapter 16). N must be large enough that the mean of the sum is a good approximation to ϕ_{fg}.

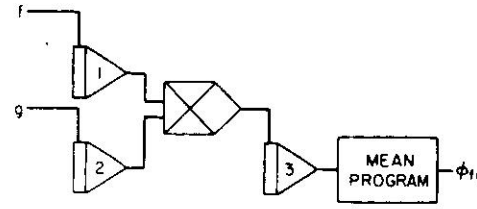
CORRELATION PROGRAMS

Simple computer programs for (1) require that

$$\Delta t \geq T. \qquad (2)$$

To obtain the best approximation $\Delta t = T = \tau$, where τ is the minimum time required for sampling in the computer program. (2) imposes a limitation on the magnitude of T. That is if T is large, then so is Δt. Thus, for large T, relatively few samples are made of f, g. This restriction is not unduly severe, because ϕ_{fg} cannot be determined accurately for large T together with finite histories for f, g.

If (1) is to be implemented directly, the program is



Integrator 1 samples f and then after an interval, T, integrator 2 samples g. Integrator 3 is in hold until both samples are made and then it samples the product $f(t_i)\, g(t_i + T)$. The output of integrator 3 is averaged by a Mean Program (Chapter 3) which in turn generates ϕ_{fg}. If T is to be specified accurately, the integrator capacitors must be as small as possible to minimize the effect of the IC time constant.

The total sampling time can be reduced by replacing integrator 1 with a quantizer whose input is ftogether with dither (see reference). f will be represented by a two-bit word (output of the quantizer).

The table below defines the quantizing function

OUTPUT	BINARY OUTPUT	DECIMAL OUTPUT
$-2 \leq x < -1$	00	-2
$-1 \leq x < 0$	01	-1
$0 \leq x < 1$	10	+1
$1 \leq x < 2$	11	+2

System Optimization

System optimization is a procedure for generating a response, y_s, of a known experimental system so that it matches, as closely as possible, some desired response y_d. y_d may come from tape or may be the response of a known but more complex system. In what follows we will assume that either an external device generates y_d or else we know the computer program for it. A measure of the accuracy of fit of y_s needs to be established. This is called the Criterion Function (CF). The CF has different forms depending on whether dynamic or static optimization is required. The exact form of the CF in either case is a matter of technical judgment and will depend on the particular situation. The CF for the dynamic problem will need to take account of the transient behavior of both y_s and y_d over some interval of time. Typical choices for the CF are

STATIC

$$F = \frac{1}{2}(y_s - y_d)^2$$

DYNAMIC

$$f = \int_0^T \left[y_s(t) - y_d(t)\right]^2 dt.$$

(Note that the CF is defined so that it is non-negative)

The optimization problem amounts to finding maxima or minima of the CF. Since y_s is a function of its parameters, say $C_1, \ldots, C_n$, so is the CF. Thus the CF can be viewed as a surface over the parameter plane. In general the CF will have several maxima and minima. We will restrict our attention to finding the nearest minimum from some initial point in the parameter plane. Once techniques are developed for the minimum problem, they can be applied with modifications, which will be obvious, to the maximum problem.

We will develop two methods for finding a minimum: steepest descent and relaxation. The static and dynamic optimization problems will be treated separately.

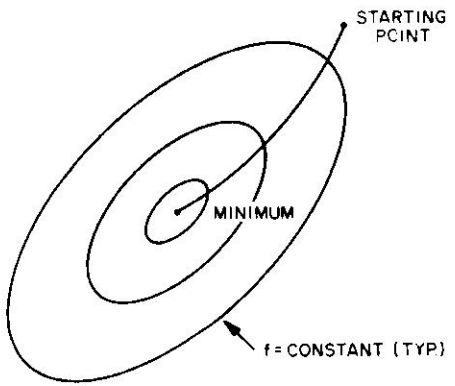
STATIC PROBLEM

The family of curves f = constant on the surface for f, the CF, are constant elevation contour lines. Differentiating

$$df = \sum_{j=1}^{n} \frac{\partial f}{\partial C_j} dC_j = \nabla f \cdot d\bar{C} = 0$$

where $\bar{C}$ is the parameter vector -- i.e., $\bar{C} = [C_1, C_2, \ldots, C_n]$ (Remember that the CF is a function of the parameters of y_s.)

We see that ∇f is perpendicular to $d\bar{C}$ and $d\bar{C}$ is a differential vector which is tangential to the space curve f = constant. The projection of the curve on the parameter plane is identical geometrically to the space curve because it is at constant elevation over the plane. The projection of ∇f on the parameter plane is perpendicular to the curve. It is evident that ∇f corresponds to the slope of the surface f and $\nabla f = 0$ at the minimum. To get to the minimum from some point on the surface, then, all we need to do is follow $-\nabla f$. (If we wanted to find the maximum we would follow $+\nabla f$.) The projection of the path on the parameter plane is



If the system is static (algebraic) we can change the parameters of y_s while following $-\nabla f$ without introducing transients in the system. Now if

$$f = \frac{1}{2}(y_s - y_d)^2$$

then

$$\nabla f = (y_s - y_d)\nabla y_s.$$

If we let $e = y_s - y_d$, then $\bar{C}$ can be determined by (since we follow $-\nabla f$)

$$\bar{C} = -e \int \nabla y_s dt.$$

or in scalar form

$$C_1 = -e \int \frac{\partial y_s}{\partial C_1} dt.$$

$$\vdots$$

$$C_n = -e \int \frac{\partial y_s}{\partial C_n} dt.$$

In practice, it is usually advisable to use gain factors, K_k, so that

$$C_1 = -K_1 e \int \frac{\partial y_s}{\partial C_1} dt$$

$$\vdots$$

$$C_n = -K_n e \int \frac{\partial y_s}{\partial C_n} dt .$$

K is chosen so that the procedure converges but at the same time is stable. When $\nabla f = 0$, the integrals will be stationary and $\bar{C}$ will be the parameter vector (point on the parameter plane) corresponding to the minimum of f. ∇y_s is generated by differentiating the generating equation for y_s with respect to the parameters C_i.

DYNAMIC PROBLEM

Except under special circumstances, ∇f cannot be generated on an instantaneous basis. Even if it could, the parameters could not be changed during the determination of f. Since the calculation of f is carried out over a finite time interval, varying the parameters would lead to a result which is not the CF.

Some definitions for f will permit ∇f to be computed as often as is f. For example, if

$$f = \frac{1}{2} \int_0^T (y_s - y_d)^2 dt$$

then

$$\nabla f = \int_0^T (y_s - y_d) \nabla y_s dt.$$

As soon as we know the components of y_s, we can use a steepest-descent method. After each solution a new position in the parameter plane is chosen by taking a finite step along $-\nabla f$. Now ∇y_s can be generated by the parameter-influence equation method. The differential equation for each component of ∇y_s is obtained by differentiation of the generating equation for y_s. For example, if

$$C_1 \ddot{y}_s + C_2 y_s = 0, \quad \dot{y}_s(o) = 0, \quad y_s(o) = A,$$

the equations for $\frac{\partial y_s}{\partial C_1}$, $\frac{\partial y_s}{\partial C_2}$ can be obtained by differentiating first with respect to C_1 and then C_2.

$$\frac{\partial}{\partial C_1} : C_1 \frac{d^2}{dt^2} \left(\frac{\partial y_s}{\partial C_1}\right) + C_2 \frac{\partial y_s}{\partial C_1} = -\ddot{y}_s,$$

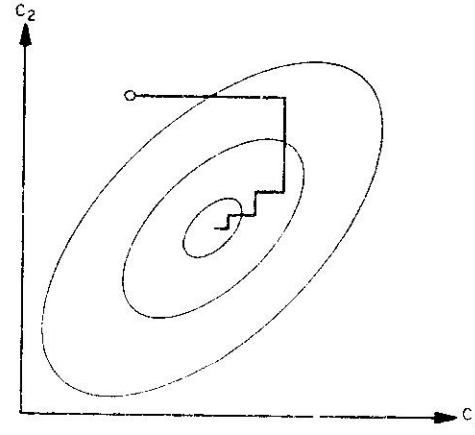
$$\frac{d}{dt} \left(\frac{\partial y_s(o)}{\partial C_1}\right) = 0, \quad \frac{\partial y_s(i)}{\partial C_1} = 0$$

$$\frac{\partial}{\partial C_2} : C_1 \frac{d^2}{dt^2} \left(\frac{\partial y_s}{\partial C_2}\right) + C_2 \frac{\partial y_s}{\partial C_2} = -y_s,$$

$$\frac{d}{dt} \left(\frac{\partial y_s(o)}{\partial C_2}\right) = 0, \quad \frac{\partial y_s(o)}{\partial C_2} = 0.$$

These parameter-influence equations can be solved with an analog program. Their non-homogeneous terms are obtained from outputs of the generating program for y_s. It will be noticed that they have identical form except for the non-homogeneous terms. Due to equipment limitations, it is usually necessary to solve them one at a time, switching in the correct non-homogeneous inputs from the y_s program in a suitable way. This leads to the use of the relaxation method.

With the relaxation method we change only one parameter, C_i, until the component, $(\nabla f)_i$, corresponding to the parameter is zero or nearly so. The procedure is applied to all the parameters on a cyclic basis. An example of the resulting path in a two dimensional parameter plane is



This method obviously is ideal for use with the parameter-influence equations. Nothing needs to be changed in the influence equation program except the non-homogeneous term.

In the event it is not convenient to use the parameter-influence method, successive values of f can be calculated for a sequence of values of C_i. This is continued until two values of f bracket $(\nabla f)_i = 0$. Then the procedure is applied varying C_{i+1} and so on. This will also lead to the minimum for f. In either case the subscript indexing and switching of non-homogeneous terms is done with a digital logic program. In the latter case, successive values of f are retained by a two or three word memory chain and comparisons made by comparators.

With either method the step size must be determined by a gain factor which ensures proper convergence.

Medical Applications

Originally published by: Beckman Instruments, Inc.
Author: Hiroshi Hara

ANALOG SIMULATION OF VENTRICULAR PUMP ACTION

Due to the complexity and non-linearity involved, the building of an analog model of blood circulation is one of the challenging problems in biomedical science. This example is by no means intended to cover the subject, but illustrates how iterative programming is conveniently used in simulating ventricular pump action.

The ventricle has an inlet valve (tricuspid valve) and an outlet valve (pulmonary valve). A cardiac cycle consists of two periods called the diastole and the systole, as shown in Figure 1. During the diastole, the heart muscle relaxes and blood flows into the ventricle as the inlet valve opens. At the completion of the diastole, the systole begins. During this period the heart muscle contracts and as the ventricular pressure exceeds the arterial pressure, the outlet valve opens, expelling blood from the ventricle. An electric analog of the ventricle is shown in Figure 2. The analogous quantities are indicated below.

Blood Pressure	~	Voltage
Blood Flow	~	Current
Blood Volume	~	Charge

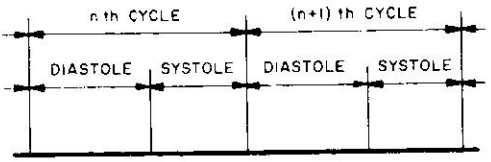


FIGURE 1

The contraction and relaxation of the muscular wall of the ventricle is simulated by decrease and increase, respectively, of capacitance c_1 in some prescribed manner. If we let $E = \frac{1}{c_1}$ = elastance of the ventricle, the pump action is assumed to be described by the following equations:

$$\left[E_d\right]_n = A - (A - E^s_{n-1})\, e^{-\frac{t}{\tau}} + B\left[q_d\right]_n \qquad (1)$$

$$\left[E_s\right]_n = E^d_n + \Psi_n t, \qquad \Psi_n = f(q^d_n) \qquad (2)$$

where

$\left[E_d\right]_n$ = Elastance during n th diastole

$\left[E_s\right]_n$ = Elastance during n th systole

E^d_n = Elastance at the end of n th diastole

E^s_{n-1} = Elastance at the end of (n-1) th systole

$\left[q_d\right]_n$ = Blood volume during n th diastole

Ψ_n = Slope of $\left[E_s\right]_n$ to be determined as a function of q^d_n, the blood volume at the end of n th diastole.

A, B, and τ are positive constants.

Since the static work done by the heart at a particular value of q^d_n is known experimentally (Starling's Curve), Ψ_n must be found as a function of q^d_n such that experimental results are duplicated. The work done during the systole is

$$W_s = k \int_0^{T\text{systole}} v_2 i_{12}\, dt,$$

where v_2 = arterial pressure

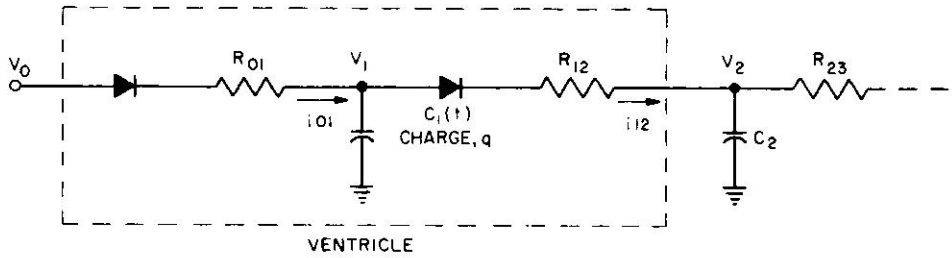
i_{12} = blood flow out of ventricle

k = constant

and consequently for a certain q^d_n, Ψ_n must be such that $\left[W_s\right]_n = \left[W_s\right]$ Starling. In other words, iteration with respect to Ψ_n is required.

The passive circuit shown in Figure 2, equations (1) and (2), and an iteration circuit are implemented as shown in Figure 3. Note that two iterative cycles are required to simulate one cardiac cycle. The distinction between the diastole and systole is made by a function relay (Relay K0) which in turn is controlled by one of the memory integrators in a chain of four. The action of this circuitry is shown by the timing diagram in Figure 4. Since the compute intervals for the diastole and systole differ, the comparator which controls the compute interval of the iterative control program must, necessarily, require two different reference voltages which are switched alternately by relay K0. The function of the M2 - M1 memory chain is to make

ELECTRIC ANALOG OF A VENTRICLE



V_0 : VENOUS PRESSURE
V_1 : VENTRICULAR PRESSURE
V_2 : ARTERIAL PRESSURE
R_{01} : INLET VALVE RESISTANCE
R_{12} : OUTLET VALVE RESISTANCE
C_1 : VENTRICLE CAPACITANCE = $\frac{1}{E}$, WHERE E = ELASTANCE
q : BLOOD VOLUME
W_s : WORK DONE BY THE VENTRICLE DURING SYSTOLE = $k\int v_2\, i_{12}\, dt$, WHERE k = CONSTANT

FIGURE 2

the final value of q (blood volume) at the end of the nth diastole available throughout the nth systole. ($\overline{M}$ denotes complementary memory.) Note that relay KO prevents this memory chain from learning the end systolic blood volume.

In order to determine the required functional relationships between q_n^d and Ψ_n, a simple iteration circuit is provided. With some Ψ_n at the output of M3, systolic work is computed, and this is compared to the output of FG 2 which follows Starling's curve. The error is repeatedly used to up-date Ψ_n until the desired Ψ_n is obtained. The above procedure is repeated for various values of v_0 until enough information is obtained to set up FG 1. With FG 1 in the circuit, a ventricular model is ready to be used as a part of a circulation model which will not be discussed here.

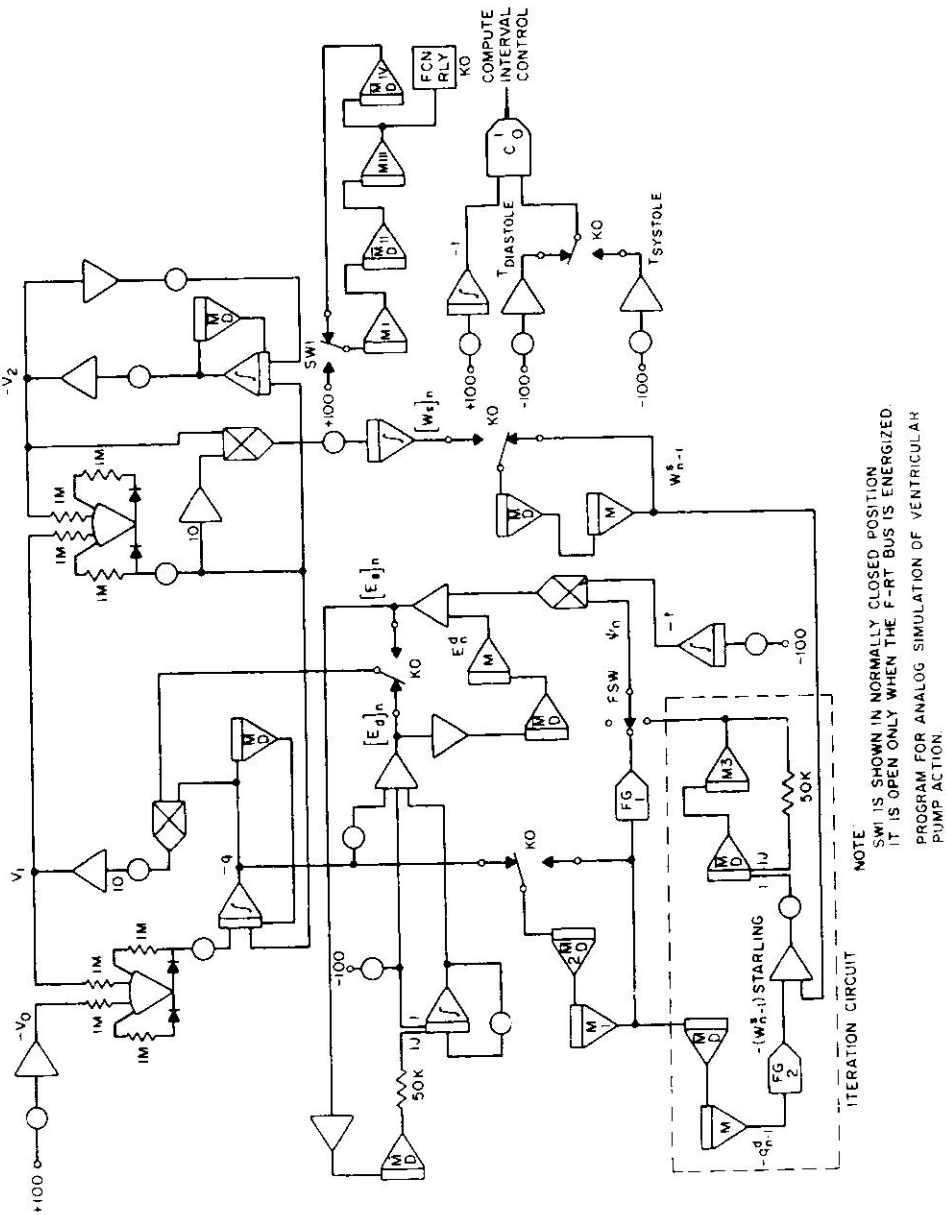
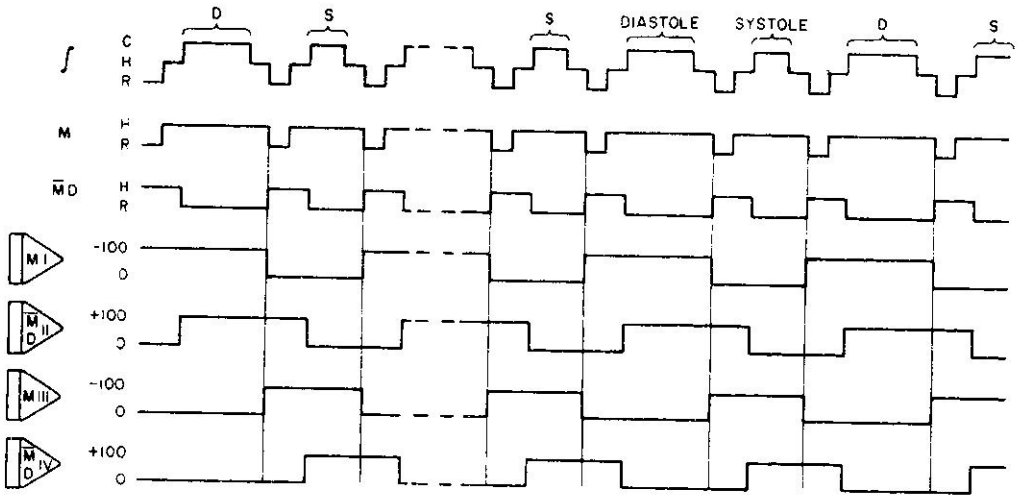

COMPUTE INTERVAL CONTROL
FCN RLY
KO
SW1
$T_{DIASTOLE}$
$T_{SYSTOLE}$
$-V_2$
V_1
$-V_0$
$[W_s]_n$
W^s_{n-1}
$[E_e]_n$
$[E_d]_n$
E^d_n
ψ_n
FSW
$-(W^s_{n-1})$ STARLING
$-q^d_{n-1}$
ITERATION CIRCUIT
NOTE
SW1 IS SHOWN IN NORMALLY CLOSED POSITION
IT IS OPEN ONLY WHEN THE F-RT BUS IS ENERGIZED.
PROGRAM FOR ANALOG SIMULATION OF VENTRICULAR PUMP ACTION.

FIGURE 3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R
M I
-100
0
M̄ D II
+100
0
M III
-100
0
M̄ D IV
+100
0

FIGURE 4

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I, DH Butani, hereby declare that the particulars given above are true to the best of my knowledge and belief.



Dated 31 March, 1969 Signature of Publisher

Labour's Viewpoint in Applications of Computers

Ted F Silvey*

American trade union people, to the extent of their information, have a positive feeling about the development and use of electronic computers in today's society. I say "to the extent of their information", because everybody has the same need; the need to know. People oppose what they fear and they fear what they don't understand.

Automation is a strong impact on our economy and work force. Labour union officers and informed members have studied the question and see the possibilities that automation promises for the future, but at the same time we see the troubles through which we must pass to get to those possibilities. The trade union person sees in automation that we can eliminate both drudgery and poverty in our country and this is an achievement we earnestly seek. To do this would be to fulfil the ancient prophecies and the writings of philosophers through many centuries.

LET ME SAY WHAT WE BELIEVE AUTOMATION to be. Computers are only one part of this technology. When a human being works or engages in any of the activities of living he uses this marvellous mechanism which is his body and brain in three distinct ways, properly coordinated:

i. Muscular strength and manual dexterity, called skill. Here we use our muscles and our fingers in a multitude of trained movements to accomplish work.

ii. The physical senses and personal control exercised therefrom. This is human perception and our response, to control and manage what we perceive in our environment.

iii. Two (of many) functions of the brain: memory and decision-making. Memory is the "newsreel of life", the stored up accumulation of all the bits of data we have received through our perceptive senses. Decision-making is a process of saying Yes! or No!, either automatically through the autonomic nervous system or deliberately, by taking thought and making judgments.

Another One, Two, Three

The important thing now to note is that in the last decade and a half we have, for the first time in human history, replaced and extended these three human functions with inanimate apparatus which is able to do these things better, faster, cheaper than people can do them.

*AFL-CIO Speaker's Bureau, Washington

So then here is the complete picture of automation :

i. Highly engineered mechanisation, which extends and replaces man's muscular strength and manual skills. Mechanisation means parts moving in relation to each other. Tools and machinery have evolved over several centuries into the present-day monstrous, complex, intricate, almost miraculous automatic machinery. Many of us have lived through a period embracing the simple mechanical farm butter-churn to the present enormous transfer machines, numerically controlled machine tools, and 50,000-ton-per square-inch forging presses.

ii. Instrumentation and automatic control extend and replace man's perceptive senses and personal control. I understand that today there can be up to 2,000 instrument installations in as many places in a single refinery, each to perceive what is happening at each specific place in the complex operation. Messages are sent from each point to a control center for the maintenance of "on-flow" and quality control, as in the "Advanced Control System for New British Petroleum Refinery" at Belfast in Ireland, tied, of course, to :

iii. The electronic computer, which is the central organ to receive data and process it, then send out instructions to maintain the control, operating through memory and decision-making.

Without Motivation

All this apparatus is quite wonderful, some of it appears even to be miraculous. When people are first told about automation and computers, they invariably raise the question: Is it good or bad? Actually the apparatus is neither moral nor immoral. It is—as a psychologist would say—"without motivation".

Moral means that relationship between people, the consequences of which are good. Immoral means that relationship between people, the consequences of which are bad. People, not the apparatus, must make the decisions about the use of this wondrous new technology. The apparatus is neutral. People are good or bad in the decisions they make and the policies they develop.

Nuclear energy unquestionably is the most tremendous breakthrough of scientific knowledge in the entire history of mankind. Nuclear energy is neither good nor bad. Nuclear energy, with this technology used for good,can eliminate the twin ancient enemies of mankind: drudgery and poverty, and this could be done in our lifetime—even in two decades—if we are willing. On the other hand, nuclear energy with this technology used in atom and hydrogen bombs could destroy most of the life on earth and eliminate civilization. The decision is not to be made by the apparatus which is inanimate, but by living people concerned with matters of morality and human behaviour.

Technical people who have grown up in education and work practices accept this revolution in high-speed, continuous-process industries. But remember that many of these concepts are highly esoteric and are not known to a great mass of the population who have not been forced into examination of this technology. So let me pick up again the statement I made at the beginning : "People oppose what they fear and they fear what they don't understand."

Can Now Know Why ?

The anthropologist is one of a profession which studies people's fears, among other things, and the superstition and mythology arising out of ignorance and fear. Dr. Saul Padover has said in connection with the current great revolution of science and technology :

> "This is the answer to age-old drudgery, poverty, misery, disease and pain. The long period of domination of mysticism is ending. People now can know WHY many things are as they are, instead of depending on myths and superstitions."

Here then is emphasised the need for information, education, knowledge. We have deliberately got to develop a more educated citizenry, to work diligently and vigorously

toward greater education, not only to know how to operate the technology but to know better also the humanities that will enable us to make science and technology the servant of man, instead of it being our master.

The AFL-CIO has, as one of its important legislative objectives, a programme of federal aid to education. This objective is based on the premise that the resources of the whole nation must be applied to the educating of each citizen to the maximum of his capacity to learn and benefit, to benefit both himself and the society which makes education possible. Our idea is not to use our resources for more education merely because the Russians will out-distance us if we don't, but because we must have education and knowledge for our purposes and out of our own traditions.

"... Working With Knowledge"

Having information, education, knowledge is peculiarly related to the existence and operation of computers which handle only one product : INFORMATION. The bits of data that are put into the computer's memory and the programmes we write to tell it what to do with that information constitute a new kind of work. **This change from our traditional working with material to this new working with knowledge is one of the most significant things happening in our society.**

I pick up a penetrating article on this very point by Dr. Peter Drucker :

> "A society in which automation has become a governing concept of production and distribution is, of necessity, an 'educated society.' It is a society in which **knowledge rather than man's animal energy is the central resource.** It is a society which puts to work the one specific quality in which the human being excels—for man is neither a particularly strong animal nor endowed with outstanding manual dexterity. In the highly advanced industrial countries, the largest employee group is already the people who are supposed to work with knowledge rather than with their hands."
>
> "... If freedom is defined as 'ability to choose', then the advent of the educated society, based on the ideas that underlie automation, is one of the biggest steps towards freedom in the history of the race....
>
> "We may need a change in the very idea of 'skill. Instead of being what one has learned, **skill will have to become the capacity to learn,** that is, to apply ideas regarding work to new tasks. We speak today of an I.Q., an Intelligence Quotient, and mean thereby the ability of a man to apply knowledge to new situations. **We may have to develop something like a S. Q., a Skill Quotient,** that measures the ability of a man to transfer experience from one kind of material and one set of tools to new materials and new tools...
>
> "The fundamental insights that underlie automation are insights of great power, of great beauty of structure, rhythm and architecture. They enable us to do great new things socially and culturally as well as technically and economically."

Men's Hands and Tools

Most trade union people still have in their thoughts the ideas of work with materials, because that is what working people have done for so many centuries. Their hands and tools have been in the earth and on the multitude of materials that come out of the earth: clay, glass, leather, metal, wood, rubber, fabric, plastics, and so forth. Work has meant the application of human effort and intelligence to the fabricating of these resources of the earth into useable products. **Now we are living through a transition period in which already most people are handling information,** working with knowledge instead of working with material. This is true because of this great technology; the inanimate apparatus does so much of the work that human muscles and manual manipulation have accomplished in past centuries.

We look back on the ancient and great civilization of the City-States of Greece, and remember the great culture and knowledge of this past "Golden Age". Yet there were only a couple of thousand people at the most who fulfilled a life of philosophy, drama and literature, art and sculpture, government and science. We forget that these few people of mental achievement existed because of a huge

mass of human slaves beneath them. Somebody had to grow and prepare the food, do the housekeeping and carry the slops.

In today's society we have a present and potential understanding of science and a development of technology so great that all our people can be secure and be able to enlarge their intellects. Now we have beneath our society not a mass of human slaves but a mass of inanimate apparatus able to fulfil all human needs if we will but use it for that end.

Our trouble is that a conflict exists in our society—a conflict between old and out-dated ideas about money and economics and the new and modern ideas of science and technology. May I just forthrightly assert that our current dominating concept of private profit being the only important thing must give way to a new concept that social profit must come first. **Technology is forcing society to function primarily for the benefit of all people in it,** with private profit necessary but secondary. Private profit must be found by individuals as a result of having first provided for the welfare and security of all. If you are mentally equating my remark with "Welfare State", by all means do so. I make no apologies for the use of this good phrase which is one of the objectives of the United States Constitution : "...to promote the general welfare".

Old Economic Ideas

The question here is whether the well-being and security of all our people, through the full use of our new technology, will come by a revised application of our entrepreneurial resources (our great reservoir of management ability), or by government programmes, or by a combination of both.

The Capitalist concept was a simple one in a society where only human labour and primitive tools applied to materials. There was a shortage of everything that people needed for sustaining and enjoying life. The idea was that an entrepreneur would place his own savings and the savings of others as an investment in an enterprise, the sole purpose of which was the securing of as much private profit as could be obtained.

Capitalism brought the first industrial revolution. Great new wealth was created but great human misery was the accompaniment, because the wealth was held by a few instead of being widely distributed. Yet for a century and a half the idea was almost universally held that the entrepreneur, no matter how selfish and greedy, was benefiting society.

The argument was that if a coal operator would open a mine, the coal that was useless in the earth became useful to people for fuel and transportation and thus the mine operator benefited people by providing the coal.

A textile manufacturer who opened a mill was providing a market for wool and cotton, was hiring labour supplemented by water power and simple machinery, to turn out fabric that people would not otherwise have if they depended entirely on the farm woman's homespun. The fact that children had their lives stunted, that men and women were overworked, underpaid, had their health ruined and their lives frustrated was accepted as a necessary concomitant of the Capitalist system.

The brutal lines of Markham's **Man With a Hoe** gave literary expression of this long terror :

> "Bowed by the weight of centuries . . . the emptiness of ages on his face . . . solid and stunned, a brother to the ox . . . slave of the wheel of labour."

Social Protest by Unions

The labour movement came into existence as an instrument of social protest against this excess of human exploitation that provided the excess of private profit . . . . This first industrial revolution extended even down to World War I. My own father was killed in 1910 in a pipe mill accident. The accident happened late on a Saturday morning; he was working 66 hours a week for 10 cents an hour. There was no Workmen's Compansation and my mother had to sign a quit claim to get $ 500 for his corpse!

The Adam Smith notion that private profit is the only important thing continued into my

later life. I have even heard the idea at a Computer Conference, that the whole end and objective of computer technology in industry is to increase profit.

I raise the question : Does the private enterprise system exist primarily to make a profit for the owners, with the secondary or by-product result the providing of goods and services for people...or does the private enterprise system exist primarily to provide goods and services for people with the secondary or by-product result of making a private profit for owners and managers?

There is a mental disease people suffer, which is called "cultural lag". This phrase is from a text book of Chicago University Sociologist William Fielding Ogburn. Cultural lag is the inability, the unwillingness, or the outright refusal of man to adapt his social institutions to evolving technology. It is the refusal of people to change inter-organizational and inter-institutional relationships, preferring to keep the concepts and practices of an earlier rural society at the same time we have the tremendous technology of our highly interrelated and interdependent society of today.

Mooers' Law

A closer-up application of cultural lag comes even with respect to the information that management gets from the utilization of computers. Mr. Calvin N Mooers, proprietor of the Zator Company of Cambridge, Massachusetts, has modestly given his name to a "Mooers' Law." He writes :

> "It is my considered opinion, from long experience, that our customers will continue to be reluctant to use information systems—however well devised—so long as one feature of our present intellectual and engineering climate prevails. This feature—and its prevalence is all too commonplace in many companies, laboratories and agencies—is that for many people it is more painful and troublesome to have information than for them not to have it. For people in such a situation, we can expect they will tend to avoid using a retrieval system which is efficient at putting information into their hands. This contradictory principle can be stated:
>
> **"MOOERS' LAW :** An information retrieval system will tend NOT to be used whenever it is more painful and troublesome for a customer to have information than for him not to have it.
>
> "If this law is true—and I believe it is—this is indeed a pessimistic and even a cynical conclusion. In the building and planning of our information handling and retrieving systems, we have tended to believe implicitly, and to assume throughout, that having information easily available was always a good thing, and that all people who had access to an information system would want to use the system to get the information. It is now my suggestion that many people may not want information, and that they will avoid using a system precisely BECAUSE it gives them information."

Society's Use of Initiative

In the technological and sociological interdependence of today's society, the point is not how self-reliant one is, or how much individual initiative one has, but rather how society responds in the use of these qualities. Let me give two examples :

i. An engineer friend of mine in Pittsburgh tells me of his neighbour in the upper middle income bracket, now unemployed, who for many years had been with a small pharmaceutical firm. Technically qualified, hard working, and a good salesman, he was, after a quarter century with the firm, a "success". Unknown to him a merger took place. Suddenly he discovered that the company with which he had such long and mutually successful employment no longer existed, being gobbled up by a huge chemical corporation. He and several score of his fellows were done — definitely dumped, discharged, fired, sacked!

There was no recourse and he had to enter the labour market in upper middle age

facing **the almost universal corporation rule that a person past 50 years of age will not be hired.** This man has skill, ability, self-reliance, initiative—all the good qualities—but society refuses to utilize them at the level of his worth. His self-reliance and individual initiative come up against an immoveable wall of corporation manipulations and a unilaterally enforced rule about age.

ii. Some years ago in the city of Washington there was a publicly prominent person known as "Catfish Turner". This man had self-reliance and initiative, plus management skills of such high competence that it was pretty close to genius. His career was in the illegal distribution and sale of narcotic drugs. The police had much trouble to catch up with him, so skilful he was.

The problem in his life was that he was born a Negro and he suffered discrimination on that account. If he had not been discriminated against as a coloured man, he could have used his abilities and initiative to go on to great achievement in useful operations. But all his individual initiative was worth nothing in a society which said it could not employ him because of the prejudicial attitude of people about the colour of his skin.

In these two instances, self-reliance and individual initiative were thwarted—in the latter case, even turned to anti-social ends. The virtues that were considered noble in an earlier rural society when exemplified by an individual are now useless, no matter how diligently they are exercised, unless society will allow them to be put to use.

Continued Unemployment

We of the trade unions are tremendously concerned about the continuing serious unemployment in our society. We also have a deep concern about the general indifference and what seems to be a lack of public interest in this matter. But there is a new thing in the country's manpower statistics. Traditionally when employment went up, unemployment went down; as unemployment went up, the number of jobs went down. This no longer is true. **For several years now employment has gone up and unemployment has gone up with it.**

This statistical paradox is true in other areas as well. I already have mentioned the great need for more education; when we look around we realise that throughout the country education is going up, but ignorance is also going up ! This point, too, is a by-product of technology. The more we learn about man in his natural environment the more we know we need to know. The more factors of information we put into the interdependent complex that is the Ameri an society, the more complicated are the inter-relationships and the more wisdom we need to apply to deal with them.

The real cause of unemployment in our country is the slow rate of economic growth; this is a point both the trade union movement and the Kennedy Administration had been hammering on for a couple of years. **Of all the world's industrialised countries, the United States has the slowest annual rate of growth.**

The question may be raised: **"Does automation cause unemployment?" The answer is Yes ! The question also can be asked: "Does automation create new job opportunities?" The answer again is Yes!** But the jobs that are being torpedoed by automation are, of course, not those which are being created by automation. They are jobs in a different place, at a different time and for different people.

Changing Job Mix

The government keeps statistics about all the people who work in the country, through the Bureau of Labour Statistics and the Bureau of the Census. All employment is broken into 12 categories, which in turn are in two groups one of four and one of eight. For purposes of this discussion I call the first group of four the wealth-creating occupations

and the second group of eight the wealth-using or wealth-consuming occupations.

The first group of four consists of :

1. Agriculture (which includes forestry and fishing)
2. Mining (which includes quarrying)
3. Construction
4. Manufacturing.

The jobs in these four categories are those in which people apply their energy, skill, intelligence and know-how to the resources of the earth, out of which things are made for people to have—from the dingle-dangles the girls wear on their ears up to and including the most massive facility that man ever has made.

The second group of eight consists of :

1. Trade and commerce
2. The professions
3. Transportation and utilities
4. Government at all levels
5. Banking, Insurance, Real Estate (the financial functions of society)
6. Business consultation and repair services
7. Personal service
8. Entertainment of every kind.

These are the jobs in which people use their energy, skill, intelligence and know-how to do things for each other that make life more convenient, comfortable, agreeable, amiable—but no new wealth is created: in fact, these jobs exist by virtue of the existence of the wealth-creating jobs in the first group.

Completely Interdependent

Do not misunderstand me. I am not saying that the wealth-using or wealth-consuming jobs are less essential to the society. Of course not! Petroleum extraction and refining is wealth-creating work, but it could not exist without the wealth-using or wealth-consuming functions in the society. As one example, an education system produces an oil geologist. Another : people with leisure time drive automobiles, which creates a market for petroleum products. In every area of wealth-creation, the occupations are sustained and supported by the wealth-using functions even as the wealth-using functions are able to exist because of the wealth-creating functions. My purpose is not to indicate a cleavage but to emphasise a mutual support relationship.

Let me here pick up again the "working with material" jobs and the "working with knowledge" jobs. Until the last decade most people found employment in the first group of four wealth-creating occupations. Now the most jobs, and the needed new ones, are found in the group of eight wealth-using or wealth-consuming occupations. We are actually living through the time of transition and the rapid increase of the "working with knowledge" jobs.

Allow me to select agriculture—the first of the four wealth-creating jobs—to illustrate the problem of output in relation to old economic notions. Agronomy and animal husbandry are very advanced; more is produced than can be sold. Here we have a shortage of what the economists call "effective demand" to take the farm products off the market. This means some people are without enough money to spend—a shortage of purchasing power.

About one-fifth of all Americans are still undernourished, while some nine billion dollars worth of food and fiber is in dead storage, which costs more than one million dollars a day just for the storage charges. Every day we lose some two million dollars worth because of rats, mildew, insects, water and fire spoilage and other destructive forces.

Farmers Down, Output Up

The number of people on farms has been going down, while the farm output has soared. Early in our country's history one farmer, working as hard as he could, produced enough food to keep himself alive and to provide one-third the food needs of another person. Three people had to work at food production merely to keep four people alive. A recent report of the Department of Agriculture reveals that now one farmer produces enough food, fiber and

tobacco for himself and for 21 other persons. With modern technology the work of three farmers can keep 66 people alive and furnished with products of the earth.

The phenomenon here is not that agriculture is so much more productive than industry; as a matter of fact it is not! Industry, with its technology, is really much more productive than agriculture. The difference is that a farm cannot be shut down but a factory can be. A farmer must fulfil the harvest cycle but a factory owner or manager can shut down, lay off workers, create a business cycle which feeds unemployment. The fact is that on the average about one-third of our potential industrial capacity is unused most of the time.

When we buy food and put it in storage to hold up income for agricultural people and when we allow factory owners to reduce output and shut down production, taking their profits from higher prices on lower output, we are sabotaging the technology. I remind you here that when President Kennedy yelled "Stop Thief!" at some steel corporation officials he added, in the small type that didn't get so much publicized, that **if the steel industry wished to make more profits they should do so on higher utilisation of their facilities** and the production of more steel products at truly competitive prices—instead of using the technology to lower their break-even point, then shutting down, laying off workers, and making as much or more profit by higher administered prices.

In the naturally low-cost, high-profit industries, wages can be increased, prices can go down and corporations can still make big profits. Thus petroleum refining and petrochemical industry is one of these, In fact this industry can raise wages and reduce prices and still make too much proft.

There are other industries, however, which are naturally high-cost, low-profit — where a substantial amount of direct labour costs with less technology in being does bring a cause-effect relationship between wages and prices. The laundry and dry cleaning business, the food cooking and serving business, the shoe cobbler, the barber's job—these are the kinds of occupations where there is a large amount of direct labour costs in the product or service and where wages do have a significant relation to selling prices.

Mutual Collective Bargaining

An increasing number of the questions which automation and computer technology throws up for examination and decision are those which cannot be solved by collective bargaining alone. I do not write off collective bargaining; it is the indispensable function of the labour movement. However, my friend EE Phelps, Research Director for the Oil, Chemical and Atomic Workers Union has, in a communication to me on the subject, raised some relevant points which I should like to pass on to you:

> "OCAW would welcome the opportunity to act in a statesman-like role in the necessary adjustments brought about by automation. However, all too often in the oil industry, management insists on treating this matter unilaterally. **Management cannot expect unions merely to perform the role of anaesthetist while they indiscriminately perform amputations on their own employees.**
>
> "Many of the oil companies DO have comparatively decent severance and early retirement plans; but here again, they never let the union be a full-fledged partner in discussing their application. There is a need for a continuing and long-term approach toward working out adjustments in the progress of technological change. Where true and honest collective bargaining can create confidence and co-operation, with each side having an understanding of the other's point of view, many of the knotty problems about Management Rights and Work Rules would fade away.
>
> "OCAW people want jobs — the chance to work. We as a union seek to perform the full obligations of collective bargaining by representing the workers in fulfilling their hopes and aspirations, as well as the attain-

ment of job security. We would desire that management would join with us in honestly trying to make collective bargaining a device to administer fairness in the framework of our industrial society . . ."

Close Up, Move Away

One of the most important matters involving employment security is the case of workers who have given their lives, their most desirable years, to an enterprise, then management decides to close up and move away, or merge, leaving the workers and the community stranded. Such a situation prevailed in the meat packing industry. Armour and Company, during five years, closed exactly one-half of their existing meat-packing plants, leaving workers stranded in 16 out of the 32 communities where this corporation had operations, most of them for decades.

The terror of that situation produced the agreement whereby an amortization fund for people was set up by collective bargaining between Armour management and the two unions involved. This was a constructive effort to match amortization that corporations have always operated for depreciation of plant and equipment. The Armour programme has functioned for retraining of the dumped employees. The results have not been a howling success, but the programme constituted a series of intelligent first steps, out of which experience is being acquired to go on to essential next steps.

At the end of two years operation of the Armour-Union programme, one location of which was Oklahoma City where the plant was closed in July 1960, the in-charge committee of management, unions and professors signed a report which stated :

> "Collective bargaining by itself cannot solve these problems. Most important of all is the rate of economic growth which depends on a combination of private initiative and public policy. This growth mus be fast enough to absorb the currently excessive unemployment, the rapid additions of the labour force, the workers displaced by modernisation in an increasing number of industries, and the increasing productivity of workers not displaced. Growth adequate to meet these needs is the essential prerequisite to the orderly social development of the nation."

Who Are the Unemployed ?

Unemployment in the United States today is upwards of four million, which is some five and one-half per cent of the work force. This is a figure so high as to be dangerous to the economy. There is an acceptable unemployment, up to about three per cent which is what's known as "frictional unemployment". In a country as big as the United States, with a work force approaching 80 million, there can be without harm, a couple of million unemployed persons at any one time. These represent persons who are between jobs, pretty largely of their own volition, or in situations where, when they are ready to go to work, they can do so — after holidays, repair work, change of residence, travel or other activities undertaken at the end of one job before taking up another.

A major consideration about the present unemployment is the one and a half million or more persons who are the "hard core" of unemployment. This hard core consists of five categories of people :

i. Negro people who regardless of their self-reliance, initiative, skill and ability are refused employment just because they are coloured.

ii. Women in the labour force who often suffer discrimination just because they are female. Many women are primary wage earners : widowed or divorced, working to support themselves and their children. .... some women are secondary in the labour market. They take employment when jobs are available and drop out when they are not .... Women also are in the labour market because of their primary value to the society. Their training and abilities make them essential business employees, teachers and technicians, doctors and nurses, hospital workers and so forth.

iii. Physically handicapped people. I was accosted by a young man in Norman one day, who asked me to take him in the car to Oklahoma City. He was a muscular dystrophy sufferer and was looking for a job as a dishwasher. A young man he was, 20 years old, intelligent but physically deferred. There are many physically and mentally handicapped persons, who have some competence.

iv. The aged persons. These are not hired because employers don't want a man or a woman beyond a certain chronological age, even though there are many older workers who have experience and skills which should not be wasted.

v. Young people who are dropouts from high school and college. These constitute a new personal and social tragedy, pretty largely because — untrained and uneducated — they have a long life ahead of them. Formerly they worked as bowling alley pin setters, elevator operators, and on other jobs where a human body had to be present for the function of the work. These jobs no longer exist, at least not to the extent that they formerly did, and even those that are still around are rapidly disappea ing.

Note that sometimes the same person is in three of these classifications : an aged Negro woman, for instance. Here is real suffering.

Unemployed .... Uneducable

Two serious problems are present with respect to this "hard core" group of unemployed persons. The first, of course, is their unemployment, consequent lack of income, and the cost to maintain them and their families as living persons on inadequate welfare arrangements (often of a sort which further downgrades them). These things are highly visible.

The second problem is not so visible, in fact is hardly noted by the public, is realized only by a few more penetrating observers. This is the matter of bringing these persons up to as full as possible usefulness to themselves and to society. The responsibility of these persons is for each one to make his or her own personal effort, which in most cases will be very limited because the involved individuals have been discriminated against, rejected, undernourished, and down-trodden for so long that their "divine spark" has been all but extinguished.

The society as a whole must fulfil programmes specifically aimed to reach these people — not alone to educate them (many are uneducable in the traditional sense and method), but to rehabilitate them up to the point where they can be educated and made more nearly self-sustaining. An American society which has not yet accepted the idea of federal aid to education for the educable must take still another tep for rehabilitation of the presently uneducable. To do less is a continual degradation of this large group of men, women and children, but more, it is a great loss to our society as a whole.

Any society which does not provide the opportunity for every member of it to attain whatever may be each person's highest fulfilment of his capabilities is not only failing for the involved people, but failing for itself as well. In a previous time, excuses may have been valid that such a rehabilitation and education programme could not be fulfilled, but **today the wealth-creating potential of our automation-computer technology outdates such excuses. Now we only lack the will to do what for the welfare of each and everyone of us must be done.**

Many New Entrants

Future employment problems arise not only because of the people whose jobs are being destroyed by rapidly advancing technology, but also because of the new entrants into the labour force. About a million and a half additional persons each year enter the labour force. This is a net figure. The number will rise to be two million a year by the end of the decade. Economic growth is needed, not only to supply jobs to those persons who are no longer needed because of technology but also because of these new entrants. The AFL-CIO Research Department has set forth after careful calculations that the American

economy must have 75,000 new and additional jobs each week for the next 10 years in order to have full employment! The resultant 3,900,000 a year is just about the number of the currently unemployed.

Where are these jobs coming from? They are not to be found in the traditional four wealth-creating occupations where fewer people are needed each year to turn out a constantly increasing volume of goods. These new jobs have to come pretty largely in the second category of the eight wealth-consuming or wealth-using functions.

Private enterprise is not able to supply the jobs; there must be a vast infusion of public investment and public enterprise to create the new jobs and to provide the necessary economic growth rate. The things which private enterprise traditionally has done are not the things that the society now most needs. The most important needs of our people now are in the area of public enterprise. They are four in number:

i. **Education**—buildings, teachers, textbooks, laboratories, even Computer Centers. I visited OSAGE at Norman last week.

ii. **Health and its protection**—hospitals, clinics, medical schools, health and research laboratories, more physicians, dentists, nursing schools and nurses. Emphasis has to be on the preservation of health and the prevention of disease, instead of letting people get sick and taking profit on their sickness, as is now the case. The doctors themselves have fancy $ 2.00 words for these concepts: PROPHYLACTICS (which means don't get it in the first place) and THERAPEUTICS (which means if you do get it there will be an awful cost in suffering, time and money trying to cure it)

iii. **Slum clearance, public housing and metro-reconstruction**—Our cities are filthy places, in most cases. Unlike the cities of Europe where river banks are for people, our river-side areas are full of industrial and transportation trash and dirt, and the river water is polluted. Our cities are strangled with traffic, polluting the air also and creating nervous frustration. We lack the cultural centers in sufficient number and variety which give meaning to living. The new concept of living, instead of only working for a living, is possible with the new technology.

iv. **Natural resources preservation and development**—All wealth is the raw material in the earth and the people who process it. Our greatest resource is people, but we must preserve the raw wealth in the earth and develop new basic resources. The United States with six percent of the world's population uses 50 per cent each year of the world's developed natural resources. Our new technology provides new ways to increase natural resources. The United States is rapidly becoming a have-not nation in many important raw material areas. But research with the new technology can overcome losses of and the using-up of former easily available raw materials.

Public Investment

These are the four areas in which public enterprise must function. There must be a vast infusion of public investment in these things. They are necessary for the continued growth of the United States. I repeat, **private enterprise will not and cannot do these things but when they are done by public enterprise, private enterprise benefits and flourishes.**

The Federal government, out of the necessities of the situation, has more and more been required to do the things which business cannot do and which State and local governments are impotent to do. This movement into Federal government activity has come with the opposition of those people who are more seriously afflicted with the cultural lag, about which I spoke earlier. We do a kind of zig-zag, back and forth movement for progress which in the end is less effective and more expensive than if we would be direct and forthright about making the changes the technology requires and which the people need.

Public opinion is handicapped by inadequate and insufficient information, largely because of prejudices of newspaper publishers

who are primarily businessmen—not educators. This lack of information requires us to make "progress through tragedy" such as the tragedy of unemployment, the tragedy of lost production, the tragedy of human inconvenience and suffering

The AFL-CIO looks to government programmes in the area of economic growth and full employment because these are things which fall into the four categories I have just mentioned, the things which provide for the well-being of the whole people, and promote the economic activity and growth the country must have. We are opposed in the Congress by other forces in the society; yet in the end we win our legislative programmes out of the necessities of the situation. But the legislation is usually meagre and late; the cost to individual citizens and to the country from the delay is very great. **One of the things we must face upto is that the rapidly developing automation-computer technology makes even more necessary more rapid institutional change.**

Computers Government-Created

I should interject right here the fact that the wonderful computer apparatus by which you do your information-processing was all originally government-financed. Big private enterprise picked up for development and profit the hot-house plants which public enterprise and the Federal government conceived and brought into being. Eckert and Mauchly, as professors at the Moore School of Electrical Engineering at the University of Pennsylvania, did their first work under contracts financed by the Aberdeen Proving Grounds. The Military establishment certainly needed the development thus paid for with tax money. When ENIAC and EDZAC came into being, the government probably got its money's worth. Between EDZAC and UNIVAC, these competent gentlemen started their own company which later became part of the giant Remington-Rand outfit.

There is a similar story about the development of the MARK series at Harvard, from government-financed contracts of the Naval Ordnance Laboratory, on which IBM went forward.

The fascinating FOSDIC apparatus was developed by government employees at the Bureau of Standards and the Bureau of the Census. If I understand correctly, the operations of this still infant creature will have new and far-reaching effects in future data-processing and information-retrieval functions—another contribution of public enterprise which will benefit and profit private enterprise.

The point I am making by reviewing this history is that we must not draw back now from continuing public investment in those things which are made necessary by the new technology in order that the benefits of it may flow to the whole people. We did not draw back when government investment was made in the first computer development; we must not draw back now.

Modified Economic System

Government at national level will be, must be, more involved in our economic life. Such involvement is not new. A great deal of government involvement has been necessary in the past because of the piratical and anarchistic practices of businessmen and financial barons.

The first Federal government control arose out of the depredations on farmers and small businessmen by the railroad corporations, which became so severe that the Inter-State Commerce Commission had to be created. In a later time the Securities and Exchange Commission had to come into existence because of similar injury of people. A long list could be compiled of such police power of the national government having to be exercised because of economic tyranny of particular groups and practices ... "Laws are made for the lawless", wrote St. Paul

Technology has required government involvement for the good of business and the whole people. The Federal Communications Commission in our government and the International Civil Aviation Organization in the United Nations are necessary to set up and

enforce rules for the use of radio and television channels and for the movement of aircraft, in the absence of which absolute anarchy would prevail.

Better Attitude Towards Government

We must accept it as a rule that the more highly complex the technology is, the more involved the public interest must be, and the more Federal government power must be exercised. The Federal Government is the only institution by which the whole public interest can be determined and fulfilled.

We may not like this development, but there appears to be only one alternative, which is for private business and institutions to operate in such a way that government does not need to step in. Such self-policing has not yet developed, and there is little indication that it will develop. In a democracy we all can, however, control government by using our liberties to preserve them. This means we all must consider government more positively, be more responsible for its proper functioning and NOT try to corrupt it, or like the people of the John Birch Society just stand and scream against it.

So I come back to the four areas of public enterprise and public investment which I suggest will provide the needed economic growth and full employment. These public programmes will fertilize and benefit private enterprise.

Biological Terms

The kind of private-public enterprise we seem to be moving into may very well be described by a biological term : SYMBIOSIS. I pick up this word because businessmen and newspaper publishers have so often referred sarcastically to government operations and government workers as PARASITIC people who "never met a payroll", "have their pig's snout in the public trough", and as being "tax eaters and tax spenders".

The word symbiosis means "the living together in more or less intimate association or even close union of two dissimilar organisms, in which . . . the association is advantageous, or often necessary, to one or both, and not harmful to either."

Where there is public enterprise and public investment for nationally necessary programmes, private enterprise will benefit by the new business which is generated. For example the construction of necessary new schools and other educational structures to the extent we really need them would be a tremendous fertilizing of business for contractors and for all the material and supply corporations and equipment manufacturers, at the same time it would provide new employment and new capital wealth to the country.

In fact, four things would follow:

i. The country would get essential needs fulfilled, which can be fulfilled no other way.

ii. Businessmen would have orders which would make possible greater production, sales, profits and dividends.

iii. There would be employment for the entire American work force.

iv. The increased wealth creation would provide additional tax revenue by which the investment could be liquidated and additional monies made available for still more growth investment.

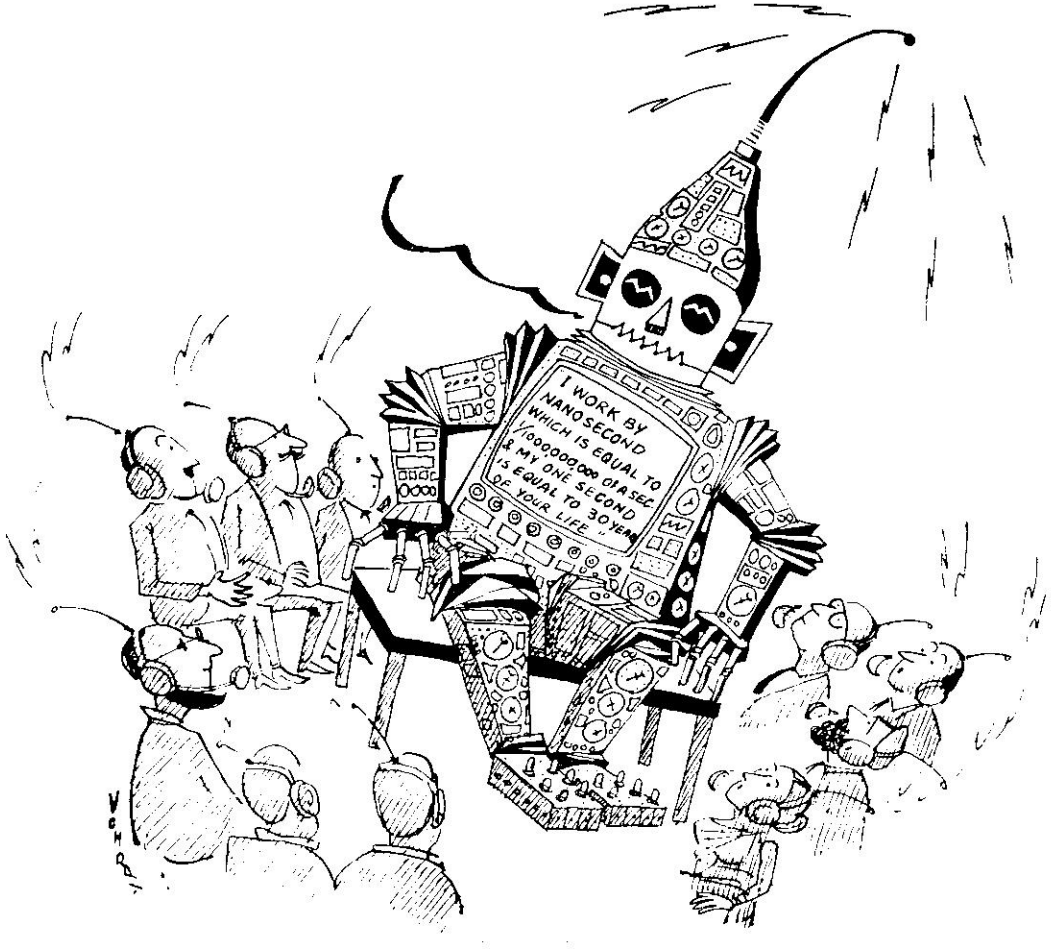
Now There Can be Enough

Let me close by calling your attention to the fact that, in all human history, essential human needs have never been able to be satisfied—until our own time. The present generation in our country is the first to live in a society where every necessity can be supplied. This situation is true because of the tremendous technology of which the electronic computer is a part.

The computer not only has the capacity to help us with information about production. It has also the potentiality to help us with information about distribution and consumption. The computer is an apparatus which produces and processes that for which man has

need without end: information. We may be able to produce a real surplus of some commodities, but there could never be a real surplus of information, education and knowledge. We have in this marvellous, almost miraculous, electronic computer a magnificent servant by which science and technology can fully be put to use in the service of mankind.

The challenge is not a little one; we can understand it only by determining its dimensions and operating our society in that rational pattern, that logic, which we must use in operating the computer itself. Again I must say : the computer has no brain, it makes no independent decisions. People make decisions . . . and we are the people ●●●



Impact of Computer on Organizational Structure

B Hartmann*

In the Spring Issue on Computerization, Dr. B. Hartmann, Professor at the Technical University, West Berlin, examined in brief the immediate impact of computerisation on the traditional organisation system. Actually the computer and the commercial EDP represent new organization systems; and the clash of the computer with the traditional organisational structure was, in the author's opinion, unavoidable. Nevertheless, it was part of a natural historical process; and further, the cost reducing implications of the computer would enable it to pay for itself; and because of its expansive possibilities it need not cause any unemployment or lack of utilisation of the special staff employed on systems analysis and programming; they could in fact be kept usefully busy as long as the computer was used. In the article printed below, the author continues the elaboration of his thesis printed in the last issue of this journal.

IN LITERATURE DEALING WITH EDP WE FIND too much reliance on traditional approaches. It is generally known now that EDP means a new organisation system; but no new system has been developed yet scientifically.

EDP literature is characterised by an overemphasis on hardware, programming and certain examples of applications which the author found occasionally. There is an underemphasis on general creative system design, literally called a lack of theory. EDP must be amalgamated with the organisation structure in theory and in individual application of the business firm. So the organisation theory and also the information theory must be augmented by EDP.

There are reasons for the situation mentioned above. Our present business organisation structures are affiliated with our industrial development (so-called 1st industrial revolution), i.e., specialisation of labour in the administrative departments. Manufacturing a product is a complex work involving the following steps :

(a) Division into standardized works like boring, lathing, milling (for metal products) ;

(b) Performing the work for the decomposed operations of processes by taking each kind of work together on a certain machine, for instance boring-, lathing-, milling-machine ;

(c) Combining the decomposed operations and pieces together into products.

This concept of performing physical work was also adapted to business work. So similar functions were put together in departments

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like accounting, selling, purchasing. The organisation was built around these special functions. The routine work was achieved by specialised machines in the functional department, for instance, typewriting, computing-, copying-, book-keeping-machines. The present stage of development is characterized by the clash of requirements of EDP technology with the traditional organisation system.

EDP prescribes an integrated process of routine work. The organisational criterion of EDP is a data field which is processed in an integrated way, for instance, purchasing is affiliated with inventory and production planning and control and also with book-keeping and payment of liabilities which will close the administration cycle for purchasing.

The selling data are affiliated with inventory control of products, book-keeping and payment of receivables, time scheduling of receivables, forecasting of production programme and many statistical data for sales analysis.

The EDP system has to realign the compartmentalised structure of traditional business organisation concerning all routine work.

Research work of EDP in business administration should deal with organisation models referring to main branches (industry, banks, wholesale, traffic etc.) and also to the size of the firm.

Organisational Advantages

The computer eliminates many routine functions by creating new particular jobs for system analysis and design in applying the computer to management science. In consequence the computer is improving decision making by management : (a) Directly by operations research methods which need computers for complicated mathematical problems, and (b) Indirectly by spending less time on fact gathering and by thus giving more time on using available information and on creative operational management. Of course, the computer's performance of all routine work is exact, costly and timely.

The amalgamation of EDP with business administration may be explicated in the scheme shown at the end of this page.

Organisational changes

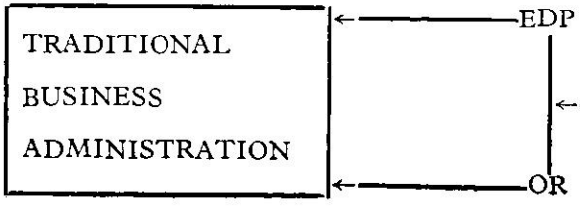
The facts mentioned above (under Fundamental Organisational Criteria) affect the traditional organisation structure in certain fields :

1. The computer department itself, also the methods department for preparing new and improved computer applications. An optimized organisation chart for this new function has to be designed, adapted to the firm. Especially the methods department is to be stressed and increased in a high degree. The organisation of methods section is made referring to data-fields which will be operated by computers in an integrated system. The organisation has to be made highly sophisticated for keeping the staff of experts busy in the most efficient way.

2. The optimal place of the computer and methods department in the organisation chart.

Volume in Business Administration

	In Science	*In Application*
EDP	little	high
O.R.	extremely high	very little



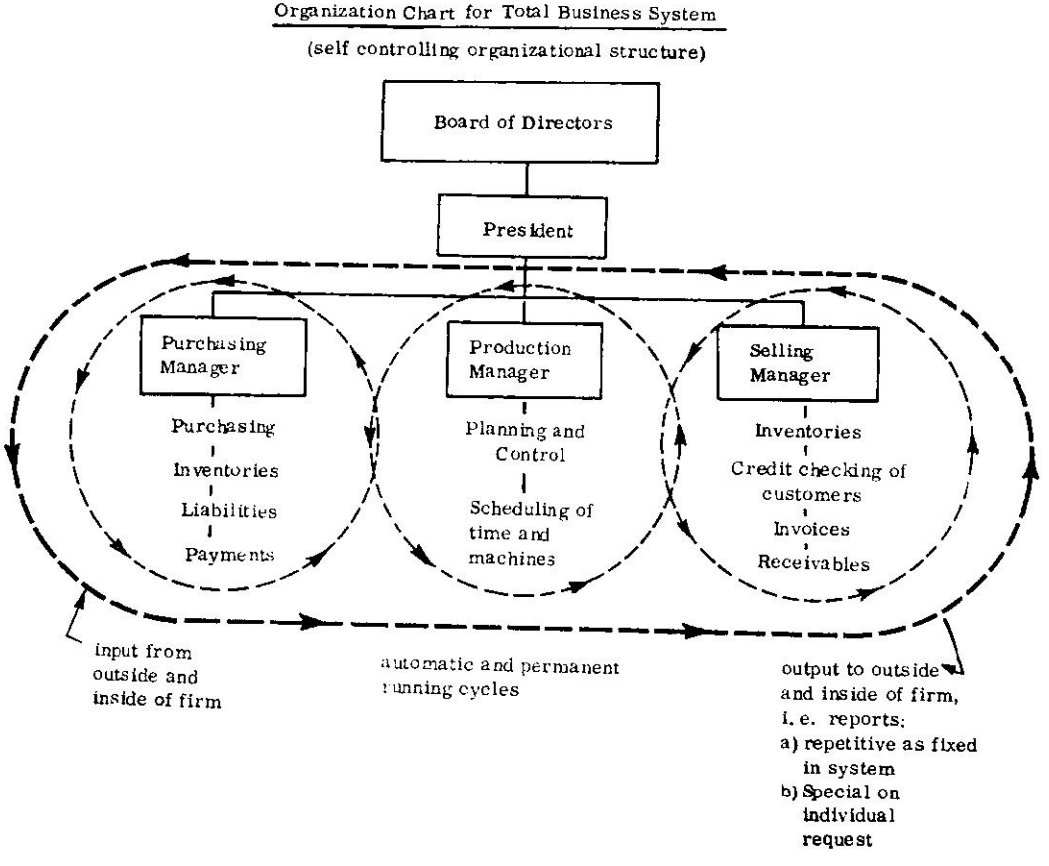
Primarily the EDP centre is not a service implement for certain individual works or for certain departments, but an efficient control network.

All the various functions like checking work and reporting have to be fabricated into the operational system for the entire firm. (It will be necessary to break up the conservative organisation structure especially in middle and lower management; also some of the departments have to be upgraded and most of them downgraded)

The position of EDP in the organisation chart is not the organisational element which most uses the computer (to-day accountancy), but outside of accountancy because operations research methods, production control and scientific research work have also to be performed by computers.

Going to the extreme, EDP tends to fall into the hands of staff specialists. These specialists would have too much responsibility for information systems and operating managers too little. In the beginning of EDP business applications it was inevitable that specialists gained a dominant role in developing EDP departments, for they had to make the work, of course.

The first rule of organisation chart is that each manager is controlling a certain number of staff beneath him, in turn he is reporting to a single authority above him. So organisation charts usually have a pyramid structure, authority and responsibility flowing upwards



into fewer and fewer hands. By EDP a new method of organisation chart has to be developed. The idea is many years old, but up to now no precise definition of what the problem is in details and what solutions are possible have been given yet. On the other hand a manager who is supervising the EDP will be tempted to give top priority to the processing of its own work. Moreover, if the computer would remain in a certain department, resentment among the other departments would soon arise. Therefore a separate EDP department with full authority, providing better all-round service, is advisable. So EDP affects the organisation of the whole firm. EDP will contribute to improvements of the organisation scheme.

Members of the committee are the EDP manager and managers of those departments which are mainly using the computer. The committee authorizes : (a) Planning of the installation and additional installations. (b) Planning of new applications (deciding what? how? and when?) The committee has to develop and elaborate the organisation system of the firm 5 to 10 years ahead.

3. Changes of organisation structure of non-computer departments. The computer by its nature is suited for centralisation into a large unit : it will absorb work from other departments; human beings by their nature tend to decentralise into small units.

A balance between the principles of centralisation and decentralisation should be established concerning the individual firm.

Consequences

The first step is removing all administrative routine work out of departments and concentrating them in EDP department. Second, either cancelling of sub-departments of former organisation scheme or reducing them to unavoidable interaction work or individual decision-making. Third, adaptation of organisation scheme to cancelled or reduced departments by (a) simplifying organisation structure and communication network, (b) downgrading of reduced departments.

4. Changes of information system (flow of output data-records). The information system is to be developed in certain stages comprising total business systems (computerised cybernetic systems of business administration).

Traditional business runs on vertical line, relying almost solely on superior-subordinate relationships. Orders and instructions as mentioned above go down the line; reports and requests go up the line. But EDP technology, including integrated data processing has enforced its very own organisation system: that is, the computer cuts across superior-subordinate relationships, affecting the jobs of people in different areas, stages and departments. The new organisation structure (see chart) has developed not so far by creative research work but by computer technology. ●●

Youth Revolts of 1968

...There was never another time in history in which the brightest kids in every nation on earth looked around them at the same time and said the hell with all of it...

...They are giving the razzberry to their elders in communist Poland, capitalistic America, fascist Spain, Socialist India; and in black Africa, white France and yellow Japan ; in Catholic Italy, Protestant Germany and atheist Russia; in rich Sweden, poor Guatemala and in comfy old England, too...

...Any political or philosophical discussion among 25 kids in the Movement is sure to run into an immediate, 25-way shambles.

—Richard Boeth, in the Detroit *News* of Oct. 20

A Mainstream Approach to Management Control

Robert Taylor*

The brief, explosive history of the computer has raised problems of adjustment among management in industry and commerce. And that history has shown that only when a computer is harnessed to the 'mainstream' problems of a business — those areas having the major impact on profit — can it make its maximum contribution. It has also shown that the computer will only be successful in the hands of craftsmen — management fully adjusted to and appreciative of the computer's needs and capabilities.

IN THE BEGINNING THE COMPUTER WAS used to reduce mountains of commercial paperwork. It was used to save money. Today the computer is being used as an aid to decision-making — a means of making money. The emphasis is now upon more sophistication of computer users rather than more sophistication of computer equipment. A properly used electronic data processing system speeds up the business. Everything moves more rapidly when decisions need not wait on paperwork; management is able to plan better, both in the long and short term, and this helps to reduce the peaks and troughs of business cycles and employment. In general terms a computer can help management make better use of all its resources and run its business more intelligently and more profitably.

Electronic data processing has developed through four eras. In the first of these, computers were used for mundane and obvious tasks, such as statistical compilations, billing, payroll, general accounting and limited scientific chores. The second period, coinciding with the availability of solid-state hardware, extended the reach of computers into sales forecasting, inventory, and production control and advanced scientific work. Subsequently, the computer was applied to sophisticated management techniques such as PERT, operational research, simulation and linear programming.

We are now entering the fourth stage — the development of "totally integrated systems" or computerised information systems that embrace and integrate all functions of an organisation. It is in the context of such a system that a data processing centre with an electronic computer can become the very heart of the business. As new orders come in, the centre can automatically allocate material and labour requirements, schedule production and delivery, send out invoices, make payments, project changes in market demands, and supply compact, accurate and timely reports to management—all in one continuous flow. Men still determine policy by the instructions

*Director, Industry Management, Honeywell

they feed into the computer, but the machine will implement it.

When developing business information involving mainstream problems, it is essential to examine the information procedures of the company **as a whole.** This 'total' approach makes it possible to capture, process and report all data necessary for the operation of a business. However, this does not mean that a system should be introduced as a complete package all at once. Major functions should be added to the existing computer applications by a gradual, evolutionary process rather than by sweeping innovations. Each application fits into an all-embracing master plan, but organisational dynamics make it impossible to carry out this plan in one step. If, on the other hand, there is no integrated master plan, the system will contain duplication of data being fed into the computer and resulting in duplication of information. Inconsistencies and extra cost will further mar its efficiency.

The true nature of an information system is often obscured by emphasis on techniques. Unless there is understanding of the basic elements of the system, the mastery of techniques is wasted. Many businesses have grown to considerable size without accepting that the creation and handling of data and the development of information constitutes a specialised function. Many have assumed that the specialists engaged in the traditional areas of sales, finance, engineering and manufacturing are able to absorb the responsibility of designing systems and day-to-day operating methods in their off-duty moments. This assumption is the cause of a jungle of paperwork and of mounting costs in handling data and developing management control systems.

A successful approach to an integrated information system must include a top-level management services staff, responsible for the critical analysis and evaluation of all existing procedures with the aim of producing information which will serve all management functions of the organisation. This analysis should define what was **supposed** to be done, how people **thought** it was being done, how it was **actually** done and then how it could **best** be done. All improvements should be measured against three objectives — improved managerial control, improved customer service and reduced clerical expense.

Such a staff will soon realise that the production processes of an organisation have two major outputs — the product and its related paperwork. The nerve-centre of an organisation is in production control; this starts with the preparation of the customer's order and goes through the determination of material requirements, scheduling delivery and monitoring progress through production, to the shipping of goods to the customer. The accounting applications that have hitherto occupied computers are by-products of this production control system. Effort should therefore be directed towards developing a system which also embraces the functions of sales forecasting, parts explosion, determination of machine and manpower requirements, maintenance of stock lists, scheduling work loads and recording labour and materials used for costing and progressing purposes.

Basic to almost all these functions is the need for documents specifying the materials and operations required for production of each item. Operations should be classified by department and machine centre and show standard time allowances and the equipment needed. Before these documents can be prepared, product and parts numbering systems have to be created, along with labour and material standards, departmental numbers, machine groupings, tool numbers, master operation numbers and so on. This groundwork for a computer system involves the combined efforts of the design, methods, industrial engineering and accounting departments as well as the specialised systems staff.

Only top management can ensure that systems are planned on a company-wide basis. Key executives must therefore be responsible for the EDP application, and for establishing the objectives of the system. With objectives and procedures defined, a master plan should be developed that covers step-by-step what is to be done and when. Even though it is not known how far the system can go, the plan

should have its ultimate objective in the complete interweaving of information flow through all departments.

Throughout the design of the total system it must be recognised that electronic data processing facilities offer the greatest benefits in the area of decision-making. Computer routines must include appropriate decision rules predetermined by top management. When routine and decision rules are locked into the system — with, of course, the opportunity for manual intervention on an exception basis—the whole concept of control is strengthened and a disciplined enforcement of both policies and procedures is exerted upon the entire organisation.

To manage by objective, using decision rules, requires complete knowledge of what constitutes useful information. Computer appreciation is also necessary to know what decision questions can logically be programmed and, conversely, what questions or situations require management intervention. It is the responsibility of the systems staff to know what data has to be taken into account and perhaps extracted, how often this must be done and in what format the results should be presented. Properly constrained, the computer will provide management with control information rather than voluminous data. Once management has indicated direction and established for the entire organisation the common objective of an improved management information and control system, the efforts of the systems staff turn to developing and designing the system and co-ordinating to completion the changes within the organisation necessary to fulfil the master plan.

One of the major areas of management decision-making hinges on sales forecasting. This could, therefore, become the nucleus of a master management plan including long-range objectives and the direction and implementation of all activities. By applying mathematical techniques to computer-generated records of past sales and incoming orders, forecasts can be made by product lines, by individual products and by market. Such forecasts may be modified by sales and market managers to include new products for which there is no sales history or information or conditions applying to specific items.

Another 'mainstream' problem in any manufacturing organisation is the co-ordination of the design and production engineering departments. The design engineers prepare complete product specifications including bills of material and drawings. Production engineers then determine the departments and machine centres for assembly or fabrication, the equipment required, the operations to be performed and the labour standards applicable to each operation. A computer can consolidate these vital specifications into a single product information file, on magnetic tape and therefore immediately accessible as a whole or in part.

Once the computer has been applied to these two basic problems of sales forecasting and a master product information file, the mainstream approach can then be extended to the explosion of a periodic sales forecast against the product information file. With decision rules based on management policy written into the system, this will establish quantitative controls for stocks of finished products and components in anticipation of customers' orders.

The controls established are those which determine what products and components should or should not be stocked, safety stock levels, order points and economic order quantities. The explosion process produces the input control information for inventory programmes and an equally valuable byproduct in the form of manpower and machine requirements, listed by plant, department and machine centres. If the sales forecast is an annual one, or covers an extended period of two to five years, the information may be used for facilities planning and capital budgets. If the forecast is prepared monthly or quarterly, the information produced can determine whether additional equipment or manpower is required, or what portion of the production plan should be subcontracted or otherwise modified.

Another mainstream application is that of sales order processing. With the provision of the sales forecast and the necessary input



Sales processing by computer



Computing material and labour requirements

controls for inventory programmes, receipt of a customer's order triggers the system. The computer will then supply list prices and trade discounts for each item ordered, perform a check on the customer's credit and determine the availability of the order from finished goods stock or the need to manufacture to special order. It will then print acknowledgements and delivery schedules for the customer and branch offices, printing and releasing a shipping order when the goods are available. When the order is shipped, the computer will prepare invoices and update the records of open customer orders and sales history files.

The next application in the progression towards a total system could be the production of material and labour requirements subsequent to the sales order processing cycle. Orders on the finished goods stock together with 'special make' orders, both generated by the computer, would be exploded against the product information master file into the various sub-assemblies, component parts or raw materials required. Labour and machine hours required by each department and operation would also be established. Processing by the computer in this phase provides for the updating and precise control of requirements in the inventory records, the preparation of production schedules, and the printing of assembly, fabrication and purchase orders.

On completion of these three mainstream applications it is only natural to extend the use of the computer into inventory control, one of the most vital problems of all. The sales forecast explosion can be used to establish weekly usage rates, minimum and maximum stock quantities, order points and economic order quantities at both product and component level. These then become control points in the inventory records. Exploding incoming orders against the product information master file gives the requirements for components and raw materials and the daily manufacturing cycle generates receipts into stock as well as withdrawals. All these transactions can be used as input to a master inventory file on magnetic tape which can be processed by the computer to determine what items should be re-ordered, in what quantities and when, which items should be re-scheduled for earlier or later delivery and which items should be cancelled. In this way stocks can be controlled within the prescribed management policy and decision rules.

The ability to keep a product information master file completely up-to-date permits the extension of the mainstream approach into the development of accurate standard costs and actual costs of products and components. The capacity capabilities and speed of computers now make it possible to employ proven techniques for making mass changes of engineering and manufacturing specifications in magnetic tape files. The application of wage rates and work loads by work centre, and prices of purchased raw materials and components, to the data on the products information file permits rapid and economic development of standard costs for each level of manufacture, including the end product. The ability to record, at high speed, the materials and labour consumed by each operation, provides the link to actual costing. The availability of such details make it possible to analyse the variations between standard and actual costs and determine which products are profitable, which are merely absorbing work and which are loss items. By this means industrial and methods engineers can focus atttention on problem areas. Such analysis is the essence of profitable selling and competitive pricing.

A computer will carry out any instruction given it, but the degree of effectiveness and rate of return depend heavily on the most perceptive choice of application. The highest returns will be in the mainstream areas of management control.●●●

Computer-Based Business Systems

Roger C Guarino, Sr*

Most recent reports indicate that there are some 40,000 installed computers in the United States. Further than that, this number is likely to double within years if current delivery rates of new computers are maintained and most experts think that they will be.

It comes as no surprise, therefore, that the U.S. currently retains a wide lead over the rest of the world combined in regard to the number of computer installations. One may logically suppose that the U.S. has some degree of a monopoly of knowledege of tested and true management principles uniquely pertinent to the data processing function of the enterprise and ancillary activities such as systems analysis, programming, and project management. This is *possibly* true but difficult if not impossible to prove since there seems to be no useful method of comparing progress in this regard from one nation to the next.

ON THE AVERAGE, AMERICAN FIRMS ARE not reaping the economic benefits from the use of their business-oriented digital computers that their managements had expected at the outset.[1] There are a great number of reasons for this, including the likelihood that **most** top managers **have not known** what to realistically expect from their computer because they have had no opportunity for exposure to systems and data processing during their personal career development. This particular problem is prone to solution only with the passage of time as a new era of managers rise to the top. In the United States, this can be expected to occur in five to ten years.

Fortunately, there are several other areas which do lend themselves to current solution and in fact, it has been noted during the past two or three years that many companies have evolved towards common principles in the management of their systems and data processing functions. This is evident from even the most casual review of the extensive trade literature and attendance at professional seminars.

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1. Recent independent surveys by three noted management consulting firms all confirm this point: Booz, Allen and Hamilton Inc, Diebold Group & McKinsey & Co., all of New York City.

Finally, everybody seems to be talking the same language. Hopefully, then, we can expect great progress in the effectiveness of our business systems in the U.S. during the next five years.

The three main management principles that deserve mention are: **System planning, The Project Team,** and **Project Management.**

We will draw upon experience at the Kelsey-Hayes Company in discussing these principles individually.

System Planning

It has been frequently reported that the major cause of failure in attaining the original objectives of a computer installation or of an individual application (such as inventory control, cost accounting, shop scheduling, etc.) is the *lack* of participation in the process of planning for the computer by **top management.** Yes, top management! Because the computer field is so new compared to the traditional business functions of engineering, marketing, manufacturing, etc., top management is likely to not recognize that systems and data processing must be given both the organisational status and attention usually reserved for the traditional functions. This is simply because systems and data processing is the **one** business function that crosses all others, i.e. it **must** if it is to efficiently and economically integrate the otherwise redundant files, processes, and procedures of the heretofore "independent" departments or functions of the enterprise.

But, is top management ready to extend equal status and attention to systems and data processing? For a number of reasons, some previously alluded to, no, at least not in the U.S.

Therefore, until this situation changes, it is the obligation of **systems management** to find ways and means to draw top management into the system planning process for it needs top management's understanding and support to identify, initiate, and install computer projects that are truly meaningful to the firm's mainstream of business activity.

Fundamentally, systems management must sell to top management the need for establishing a top management "Systems Steering Committee". Membership in this Committee would be limited to the plant manager as Chairman, the controller, and other key executives who report directly to the plant manager, such as the director of manufacturing, director of engineering, director of quality control, sales manager, etc. Ideally, the systems manager is also a committee member.

The basic function of the Committee is to evaluate proposed projects in terms of estimated tangible or intangible return to the plant. Usually, more projects are identified than the available manpower resources can cope with. Therefore, a related Committee function is project prioritization.

It was observed by Booz Allen and Hamilton in regard to project selection that the American Companies that they rated as having the highest effectiveness in their use of business computers tended to emphasise computer usage in "main-line" activities such as distribution, production, and marketing. On the other hand, the "lowest effectiveness" companies emphasized computer usage in accounting and finance.

In other words, the Steering Committee ought to examine where the highest costs are because that is where the greatest operating improvements can be effected by the computer.

As to project prioritization, there are two factors that the System Planning Committee must consider in establishing the priority sequence of the identified projects.

First, the individual projects must be **logically** sequenced so that the data "captured" on the computer as a result of one project directly supports (i.e. provides the input for) a subsequent project. Note that this requirement is quite independent of the direct benefits to be achieved. For example, assuming that the real goal is lower inventory costs as a result of an improved material planning system,

it is first necessary to automate the Bills of Materials **even though we may not expect any direct benefits as a result of the latter.** In a manufacturing enterprise, a typical project sequence might be :

1. Sales Forecasting
2. Order Entry
3. Product Structure (Bill of Materials)
4. Shop Routing
5. Work Center
6. Inventory Control
7. Requirements Planning
8. Capacity Planning
9. Purchasing
10. Shop Scheduling
11. Shop Status and Control

Secondly, there should be **a careful Committee assessment of the benefits to be expected after system installation and debugging.** And it must be recognized that there may be **no benefits (possibly even negative benefits) until a major proportion of the identified projects are completely operational.** Break-even analysis, if done objectively and realistically, will usually reveal that the firm will not realise benefits in excess of system development costs until about three years after systems effort was initiated on the first project. However, thereafter, the annual return on investment may very well be incredible.

If the Committee truly considers all aspects described above, then it will be providing much needed direction to user,[2] Systems, and Programming personnel and will be acting as a bridge between the plant manager and the detailed execution of each individual project.

The decisions of the Committee regarding project selection and prioritization should be documented in a book called a "System Plan" which, for each project, would identify :

(a) General Description
(b) System Objectives
(c) Proposed Reports
(d) Key Departments and Personnel Involved
(e) Man-Hour Estimate by Task[3] and Month for Systems, Programming, and User Personnel
(f) Anticipated Benefits and Return on Investment Analysis
(g) Proposed Schedule
(h) Priority Sequence

The Plan would be continually updated to reflect the needs of the plant as can best be estimated three to five years into the future.

Thus, the Systems Plan becomes **top management's direction** to the systems manager and to User management regarding what system objectives are to be met, **when** they are to be met, and **how,** (i.e. with what resource allocations) they are to be met.

The Project Team

So far, we have attempted to describe top management responsibilities in the fundamental process of system planning. We have said that the System Planning Committee must select and prioritize the projects. But they must also have a method for directing and monitoring system development activities on each project.

This may be accomplished by the appointment by the Committee of a User Chairman heading a User Committee. The individual chosen, in terms of his normal job function, should be connected directly with the primary objectives of the project. Aslo, it is desirable that he be relieved of at least 50 per cent of his normal duties during the system development period so that he has sufficient time to engage in project activities.

[2]The term "User" is intended to describe the "customer" of the systems department, that is the ultimate user of the system after it is operational. For example, in a shop scheduling project the "User" would be the Manager of Production Control and his key personnel.

[3]Definition of the term "Task" is described subsequently.

The basic job of the User Chairman is to plan and direct the activities of the User Committee members whose primary concern is to **quantitatively** define their requirements such that the Project Team can evolve a specific system design that meets those requirements. He selects the User Committee members and assures that each member is given sufficient time to meet the commitments delegated to him. It must be noted that User Committee members are not usually people skilled in systems and data processing but, presumably, they are skilled in the various functions which are central to the stated objectives of the project.

Experience has indicated that most user personnel are adverse to change and generally more inclined towards the *status quo* than to major changes in the *modus operandi* of their functions, organization, and procedures. This is too often alarmingly true in new computer projects because the changes to be wrought are frequently of major significance to plant operations as a whole. Thus, one of the major jobs of the User Chairman is to motivate the members of the User Committee to **want** these changes. An educational process is implied whereby the users will begin to understand how the new system will help **them** in the day to day performance of **their** jobs.

Thus, it can be said that the primary purpose of the User Committee is to openly, candidly, and in a spirit of cooperation, develop specific requirements which, in effect, are the design specifications for the new system.

But it is a truism to say that users cannot by themselves develop the kind of integrated systems that will yield the benefits to the plant as a whole that had been contemplated by the System Planning Committee. This can only be done by professionals trained and experienced in the complex morass of modern computer technology.

The development of a computer-oriented management system is a very difficult and trying task partly because **manual systems die hard.** New system development is a process requiring great ingenuity, creativeness, innovation and judicious use of behavorial science and group dynamics. The *status quo* must go — we must find a valid reason for everything that we are currently doing and come to an explicit decision as to whether or not we are to continue doing it.

The day to day development activities require the formation of a Project Team consisting of professional systems and procedures analysts, computer programmers, and, last but not the least, one or more user coordinators whose membership on the Project Team will assure that the requirements of the User Committee are met in the system design and final installation. A Project Manager is designated to head the Project Team. He can be a representative of any of the user departments but he must have a very good understanding of what the computer can do and he must be familiar with the principles of project management as described elsewhere. These prerequisites assume that, as a minimum, he will have served at least once as a user coordinator on previous Project Teams. If no user representative meets these requirements, a very good alternative is to assign the most qualified systems analyst as Project Manager. In any event, the Project Team has certain basic responsibilities, e.g.

Complete empathy with User requirements
High technical quality
Rigid control over progress
Optimum utilisation of assigned resources
Accountability for results

Of course, it is up to the User Committee to see to it that these responsibilities are successfully carried out ; further, the User Chairman must report progress versus plan and related significant problems to the System Planning Committee.

The relationships between the plant Systems Planning Committee, the User Committee and the Project Team are depicted in Figure 1.

Project Management

In American industry, much has been accomplished over the past ten years in the

TYPICAL PROJECT INTERFACES

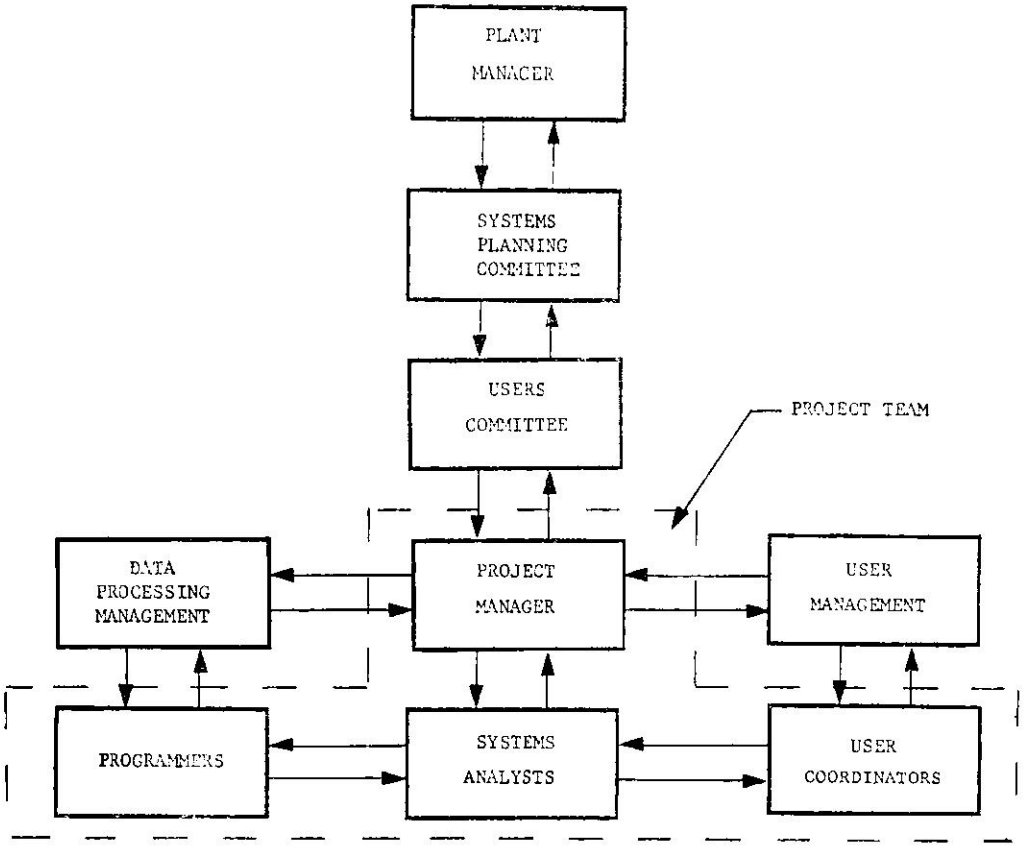


FIGURE 1

development of techniques pertinent to the management of complex projects. Much of the impetus came from the U.S. Air Force where many millions of dollars for aerospace projects (as in the case of the Soviet Union also) had to be controlled with extraordinary measures to assure that expenditures stayed within funding limits established by the Congress. Typically, in U.S. industry, this is an exceedingy difficult problem, because total effort on project (such as a space probe like Project Apollo) tends to be decentralised among literally thousands of companies from the east coast to the west coast of the U.S. Naturally, technical accomplishments must also be completed on a rigid timetable in order that overall project milestones may be met (if they are not met, it is probable that expenditures will exceed authorised funds). Thus, many project management techniques such as Critical Path Method, PERT*, PERT-COST, and Earned Value were developed to serve the need.

It was later found that the underlying principles of project management originally designed for aerospace projects have broad

*Programme Evaluation and Review Technique

applicability throughout commercial industry. For example, there is scarcely a building erected in New York City that is not "controlled" by the Critical Path Method during its construction. It has also been found that many of these project management techniques can be applied to management system projects. In fact, with the complexity of modern data processing, imposing project management techniques for the planning and monitoring of the day to day activities of a Project Team is becoming absolutely essential.

Frankly, to do justice to the total subject of project management would require a very lengthy treatise. We must limit our discussion to a characteristic which is common to all of the project management systems such as CPM, PERT, etc.

This vital characteristic is the necessity to break the total project into **manageable** work packages. Experience has shown that the planning and execution of a complex project become more accurate and understandable to management when it is sub-divided such that each "work package" can be individually analyzed. The first principle regarding a work package is that it be aligned in a manner compatible with the way work is actually approached and accomplished.

At our company, the need for logical work packages has evolved into a structure of "Standard task" which are equally applicable to **all** systems projects, in particular those involving electronic data processing as a primary tool.

Every systems project is organized around the task structure so as to provide a common understanding among users, analysts, and management regarding the mutual commitments that are necessary in the conduct of the work. A Corporate Standard entitled "Phases of a Systems Project" was prepared and published in our Systems and Data Processing Standards Manual which is distributed to all plants. The thirteen standard tasks that we use are shown in the right-hand column. It is not our purpose here to discuss in any depth the definition and content of each of the thirteen Tasks, although this is covered in detail in the Corporate Standards Manual.

THIRTEEN STANDARD TASKS

1. **Feasibility Study**
2. **Systems Requirements**
3. **System Design**
4. **System Specifications**
5. **Programme Logic**
6. **Coding and Testing**
7. **System Test**
8. **User Training**
9. **Conversion Planning**
10. **Conversion**
11. **System Installation**
12. **Post-Installation Audit and Followup**
13. **Project Management.**

It is important to point out, however, that each of the tasks is made up of one or more work packages. The following characteristics of a work package can be described :

(a) A work package is a logical break up of work typical to a systems project, i.e., it is representative of the manner in which work is actually accomplished.

(b) Each work package lends itself to the production of a tangible output, without which we cannot say that work on the package is complete.

(c) An approved estimate of man-hours for each work package is prepared.

(d) A specific start date and finish date for each work package is coordinated.

(e) Responsibility for effort on each work package is clearly assigned.

(f) Technical direction and progress are minotored and controlled at the package level.

(g) "Credit" is awarded for a work package 100% completed not partially completed.

(h) The work to be done can be readily described in works. This is referred to as a "Statement of Work."

As was stated previously, no attempt will be made to define all of the tasks listed on page 194. However, it seems useful to make the point that it is primarily during tasks 1 and 2 that users and the systems analyst must work together most inti mately. It is during this process that the users' requirements are transferred to the analyst; also during this period the analyst is playing Devil's Advocate with both the *Status Quo* and the user's stated new requirements. Often times, the analyst raises the users' sights by bringing to his attention things that the computer can do for him that he didn't realise previously. The analyst prepares a System Requirements Report which receives the official approval of user management.

With this work done and approved, the analyst indeed is able to "design" the system (Task 3) which is not to say that he does not communicate with the users during the process. On the contrary, he must ultimately get their approval on a System Design report which typically consists of a new system flowchart for both the clerical and computer portions of the system, detail definition of required forms and reports, an outline of required supporting procedures, etc.

Based on the approved system design, the analyst examines the computer portion of the system and thus prepares System Specifications (Task 4) which are his means of communicating to the computer programmer.

Thus, in the early phases of the project team effort, the major role of the users is to **identify system requirements** and to **provide data** that is required by the analyst to perform the design function. The role of the analyst can be likened to the architect who is retained to design a structure that will fully meet the owner's (user) requirements.

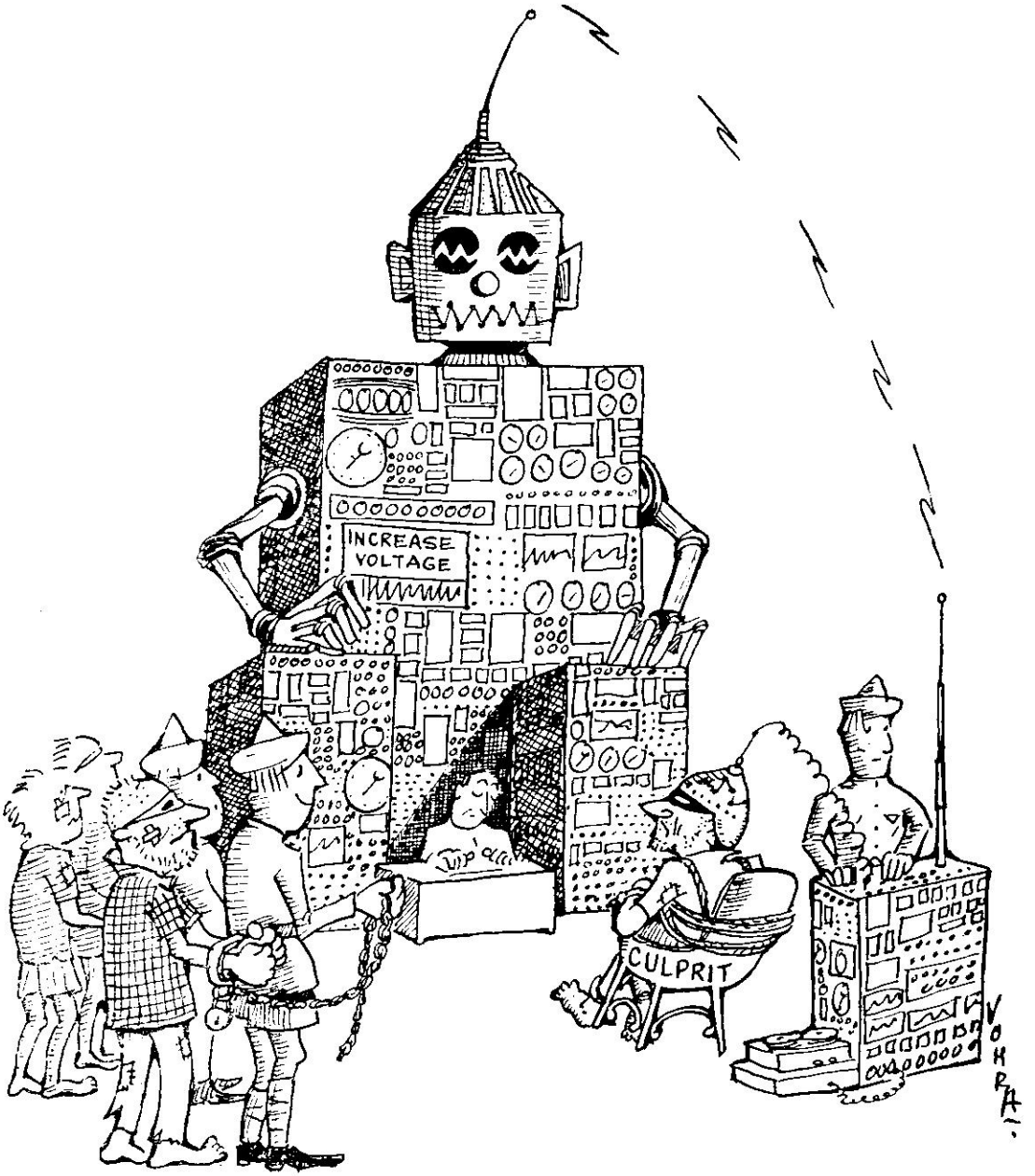
Impact of the Computer

There can be no doubt that the computer will have important sociological effects within the enterprise, particularly in developing nations. This is because, as the computer is brought in initially, there may be a labour displacement resulting from the fact that the computer will take on many clerical tasks heretofore done manually. On the other hand, many of the clerical workers thus displaced have had the opportunity to enter an entirely new challenging and rewarding field. That is, many clerical personnel have become computer programmers or systems analysts. At a certain point in time, one passes entirely through this initial phase of labour displacement or clerical reduction. For example, in an expanding economy such as in the United States, it is found that the greatest value of the digital computer **no longer is** in clerical reduction. Rather it is in effecting such operating improvements as reduced inventories, improved customer service, increased utilization of plant equipment, better yield per dollar of factory cost. These operating improvements mean increased productivity, which means increased profit.

Need we point out that increased profits will result in greater capital investment thus more jobs and other opportunities? We cannot pretend to understand that which we know very little about, namely the social customs and needs of nations which we have not had the opportunity to visit. But, doesn't it seem likely that we must face up to the short-term difficulties incident to the conversion to modern management systems if we are to achieve long-term productivity gains which are for the benefit of all?

Even in the United States, the Personnel Director of one of our largest corporations has had to point out that ".....one place where we have not distinguished ourselves is in preparing employees for the changes that have evolved out of the rapid growth of data processing equipment utilisation and accompanying system development and modification..... familiar symptoms are involved...including fear of the unknown, resistance to change and the negative, defensive behaviour generally associated with these systems."

We can only suggest that if we are to meet our professional responsibilities as users, management analysts and programmers—we must at all costs avoid being management dropouts in the computer age.●●●


INCREASE
VOLTAGE
CULPRIT

Electronics and Management

John P Wilson

Modern business organisations are turning increasingly towards electronics, not to replace management skill and judgment based on training and experience but *to supplement these fundamental assets* **with quick and easy access to data related to day-to-day decision making and forecasting of trends. Management also looks at electronics for stock control, process control, such general data processing functions as payroll accounting and customer billing, in which it can improve efficiency and cut costs.**

WITH THE READY AVAILABILITY OF SUITABLE equipment, there is really no excuse to dodge the problem of whether or not to "go electronic". Such a decision has to be faced today, and it must be made purely on commercial considerations. We are all familiar with the **situation of a few years ago when some companies installed computers at high capital cost with little idea of how to use them.** Utilisation of only a few hours a week on simple routines may have saved a few staff, may have eliminated a few errors, but a careful look at the pre-computer organisation may in all probability have produced a similar result with no capital expenditure at all.

Nevertheless, we should be grateful to those pioneers. If in the early days they got little value in real terms from their installations, they at least recognised that electronics would give **a pay-off eventually** and that **the best way of learning how to exploit the new tool was to experiment in using it.**

Transformed Situation

The situation has now been transformed and management need have little fear in moving into the "automation age". **Systems manufacturers sell equipment today on hard economic facts, not on mere promises or the prestige value to a company of having a computer at its head office.**

Computer technology has always advanced at a faster rate than management technology in the general sense that facilities made available have been greater than management has been able to exploit successfully. The tools have been available but we haven't yet learned to use them fully. But this situation is changing fast, with **manufacturers and specialist organisations now having libraries of programmes on an endless variety of activities** compiled from experience in the field.

In Britain, one of the most potent forces in encouraging the use of computers is the National Computing Centre (NCC)[1] This is a public company sponsored by the Ministry of Technology (Mintech) and charged with

[1]The National Computing Centre, Quay House, Quay Street, Manchester 3, Lancashire, England

removing barriers to computer usage, the co-ordination of existing work to prevent duplication, methods and systems development, and education. It is a partnership between Government and Industry financed by a grant-in-aid from Mintech, by subscriptions from member organisations and by fees for special services.

Two Computers

The NCC has two computers for its own use—an ICT 1904[2] and an E-E KDF9[3]—but does not operate as a computer bureau. Most of its work comprises studies in depth of computer applications in commerce and industry, although some work is done on "hardware appreciation", that is investigation of new processors and peripherals, as they become available, information on which is passed to members.

The NCC Programme Index contains details of computer programmes from a wide variety of sources and a Current Awareness Service informs members on a selective basis of new programmes of interest being originated or added to the list.

In effect, the NCC is a general clearing house from which much information can be gleaned from a single source. One of its current activities is an examination through a Working Party on problems in distributive trade. Short-term aims are to disseminate information on techniques and hardware in use or being planned and, through the trade associations concerned, to develop standard codes and modular systems. Practical encouragement is being given to the standardisation of invoice formats in the food manufacturing industry.

In the Manufacturing Industries Department of the NCC, work is currently concentrated on production and stock control problems. A two-pronged approach is being made in which, first, the existing work is collated and co-ordinated with the object of finding expedient solutions to pressing problems and second, the experience gained is used to develop longer-term solutions. The NCC makes available much of its work through publication of reports, such as "Computer Aided Production Control, a Brief Survey of Practical Experience in the United Kingdom" (price 10s. 6d.)

Co-ordinator of Computer Ventures

Another way in which the NCC helps the user is by co-ordinating computer ventures where the workload may be insufficient to justify the installation of a machine by a single organisation but where joint use with others makes the operation financially viable. One collaboration project of this nature now under study is a venture by the four New Towns of Cumbernauld, East Kilbride, Glenrothes and Livingston, in Scotland.

In specific industries the NCC is investigating computer applications in the textile industry. The first phase of this project is the development of simple programme modules for production and stock control in collaboration with the Management Services Centres of the Wool and Allied Textiles Employers Council. These will then be put into use for practical experience and evaluation in the plant of a NCC member in England. Phase two will be to make the programmes available to other sectors of the wool industry and to launch an educational programme. Phase three will be to build up a library of programmes from which individual companies can select those that satisfy their particular problems.

The NCC has been discussed at some length because it represents a determination to appraise computer technology in detail and its applications in every aspect for the small company as well as the larger enterprises. In this work it complements the activities of British computer manufacturers. These firms have developed a new order of expertise in both design and manufacture of equipment and the development of severely practical operating programmes which are really cost effective.

2. International Computers & Tabulators Ltd., ICT House, Putney, London, S.W. 15

3. English Electric Computers Ltd., Computer House, Euston Centre, London, N.W.1

New Models

The two largest of these manufacturers have just introduced new computers, one a huge commercial/scientific machine, the other a small but potent unit for industrial use. The ICT 1906A[2] announced in late October 1967, is a powerful computer now operating in prototype form with first deliveries scheduled for 1969. With over twice the power of the British Atlas computer, it will cost between £500,000 and £1,500,000, depending on the configuration ordered. It is fully compatible with the existing 1900 series (of which 900 have already been sold) and can be used in a hiearrchy of interlocked computers coupled together by data links.

The other new computer is the E-E M-21-40[4] which has already been ordered by the electricity supply industry for power station control and by the steel and processing industries.

Both machines exploit the potentialities of integrated circuits in providing increased reliability and packing greater computing power into a given space. These new models complement the wide range of established British-made machines which are being bought by users all over the world.

Direct Communication

The new trend is for direct communication between management and a remote computer: practical demonstrations of this development were given at the 1967 Business Efficiency Exhibition at Olympia, London. One demonstration was of a video terminal at the exhibition hall, coupled by data link to a computer at the manufacturer's factory[3] nearly 150 miles (240 km) distant.

The so-called video terminal is a cathode-ray tube display with a small keyboard which enables an executive to request instant data from the computer. The display is in alpha-numeric form and bright enough to be read in ordinary lighting. If a hard copy of the data is required this can also be written out automatically on demand by a "receive-only" teleprinter. Such **real time systems giving instant data,** and the linking of computer to computer and of computer to executive, are setting the general pattern of the future. Some systems of this type are already in operation and many are in the planning stage.

Unusual Application

An example of how a computer can be effectively used in seemingly unlikely circumstances is provided by a British rose-growing firm. This company lists some 150 varieties in its catalogue and has sales of several millions of plants a year.

Roses are planted 18 months before advertising the crop and are lifted six months after the advertising campaign. The first computer job is to list and store all orders, for up to six months before lifting to prepare invoices, and to ensure that orders taken do not exceed availability of the plants. At the same time a daily cash book is prepared with total orders by value and analysis of sales by rose variety, a by-product being a daily stock total of each variety still available.

The computer programme provides a regular comparison of sales by varieties with sales for the previous year and the forecast for the next year; it also undertakes a media analysis of advertising, including a print-out of unit advertising costs for each periodical used. During the plant lifting period, the orders, all of which are in the computer storage, are released in batches of 5,000 for processing.

The whole system was designed by specialist consultants and the work is processed by another firm on an ICT 1902 computer. From this one example it can be seen that even the most unlikely-looking business activity can take advantage of modern methods and that **Britain, by probing into the modernisation of every form of enterprise, is building up an enviable background in really cost-effective solutions to management problems.●●●**

[4]The English Electric Company Ltd., English Electric House, Strand, London, W.C. 2.


SYSTEM HYDRA
BHA
BHA
BHA
BHA
BHA
PARASITES
PARASITES
PARASITES
PARASITES
VOHRA

Simplified Operational Manufacturing Systems*

Jack F Duston[1]

AS INDUSTRIAL ENGINEERS, WE ARE ALL primarily concerned with operating efficiency, and I am sure that none of us questions that a properly designed and implemented total manufacturing information system can improve it. Achieving a successful total system is extremely difficult; however, any total system must be carefully tailored to the specific needs of its users. **In the absence of proper planning, what often happens is that the system becomes more complex than necessary, its cost far exceeds its benefits and its own inefficiency is so great that the user's total efficiency actually deteriorates**—without planning, a total system can worsen what it was designed to improve. What is suggested here is that any total system should be built from the ground up. The first step would be to develop a simplified operational manufacturing system to improve the efficiency of an organization's production activities — one that provides immediate benefits at relatively little cost and can be incorporated ultimately into a manufacturing information system of greater scope if desired.

To illustrate the role of a simplified operational system, I will begin by briefly analysing the typical flow of a manufacturing operation. Of course, the manufacturing and information flow through an organization should be continually reviewed during the development of any system to insure that the effort is always directed toward the desired long-term objectives. Oversimplifying, the manufacturing flow can be classified into four major areas as illustrated in Figure 1 : order entry, planning, manufacturing, and evaluation.

The order entry area covers all areas of processing the orders that help to generate manufacturing requirements, summarising them in the form of sales history, and combining them with management knowledge or estimates of future orders and trends. These inputs are all processed to develop a forecasting system directed at development of realistic planning schedules. The planning function itself entails breakdown of all bills of materials to obtain total detail parts requirements and the continuous analysis of production and inventory to determine the scheduled availability of these detail parts. As each new planning schedule is developed, its requirements are netted against what is already available in stock and in process to determine what must be produced and how much.

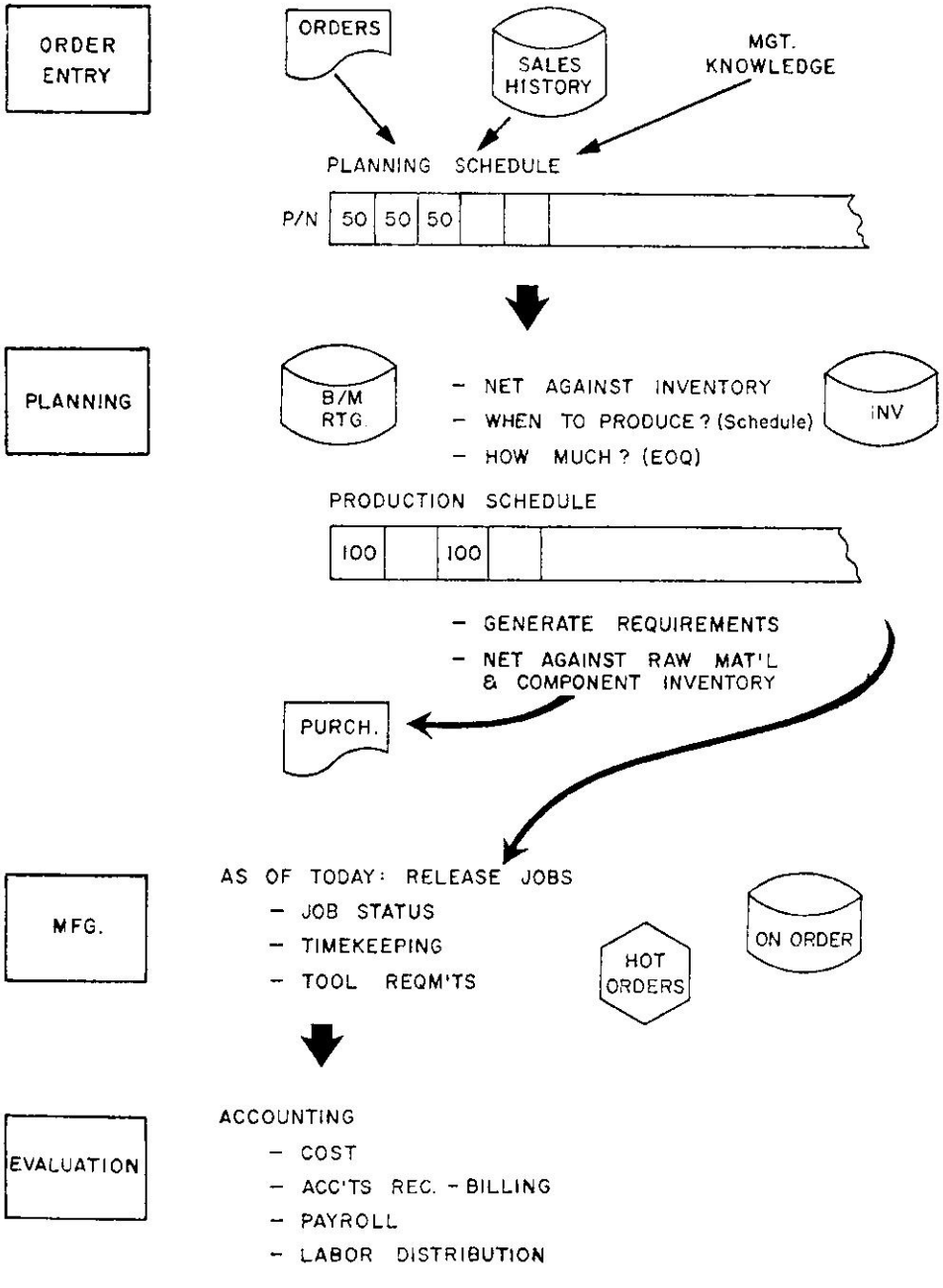
The next area, the actual manufacturing of goods, is the one covered by the simplified operational system I am suggesting. What jobs must be accomplished is known. It now becomes the duty of manufacturing to perform these jobs, **keeping track of what is being done,** making sure that the proper tools and equipment are available, **absorbing hot orders and changes,** and so forth as necessary to meet the planned schedule. The simplified operational system would be used to generate daily status reports; these would be working reports that enable management to make day-to-day manufacturing decisions. For example,

*Published by the courtesy of the American Institute of Industrial Engineers. Proceedings of the 19th Conference, May, 1968.

1. Manager, Computer Systems Services, Logicon Inc. Calif., U.S.A.

Figure 1

MANUFACTURING FLOW



the reporting of excessive scrap might cause management to release additional orders so as to meet the planned schedule.

The last area, evaluation, consists of the after-the-fact activities of the manufacturing flow: analysing cost, summarizing expenditures incurred, and calculating the payroll and distributing the labor. This area also includes various management and statistical analyses made for historical purposes.

In further analysing the manufacturing flow, we can see that it is one continuous cycle in which every single activity has far-reaching effects. An engineering change can affect as many as 10 functions and 24 data files, for example, while even a simple change in the production schedule can affect at least the following functions and data files :

Functions	Data Files
Production control	Production schedule
Material control	Bills of materials
Manufacturing	Work in process
Purchasing	Engineering change status
Accounts payable	Routing or operation sheets
Cost accounting	Shop load status
	Manpower availability
	Machine availability
	Open requisitions
	Accounts payable ledgers
	Cost accounts

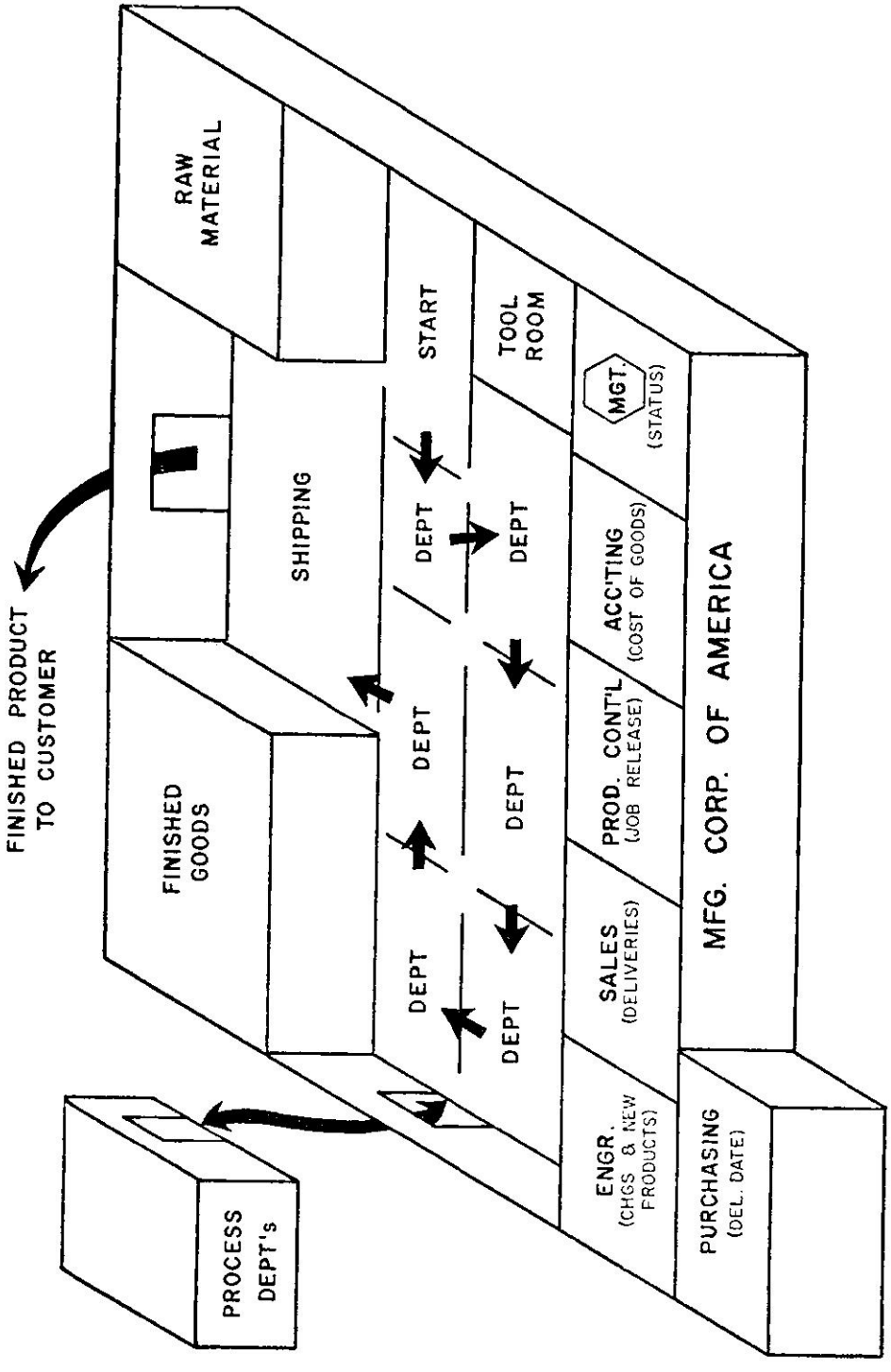
Now these information files are of varying types ranging from formal document or card files to informal desk files or possibly information kept in the head of a key employee. It is vital that all affected data files be notified and changed correctly each time an activity takes place; if they are not, the result is that various departments are working with outdated information. Thus the smooth functioning of the manufacturing cycle relies on both the accuracy of the data generated in each of the four major areas and on the assurance that these data are transmitted to all who need them. I am suggesting that **the manufacturing area is the one in which to begin the development of a total manufacturing information system** because it is in this area that accurate data are the most difficult to obtain.

Consider the hypothetical Manufacturing Corporation of America (Figure 2). The plant covers a large area, and raw material inventory, finished goods inventory, and process operations take place in buildings separate from the main plant. Jobs are being moved from one department to another, inventory is being utilised by various departments, parts are being scrapped or reworked; some jobs are waiting for tools, parts, or manpower or machines, causing them to become behind schedule, critical, and finally, sent ahead partially completed; but work is being done, indirect labour is being expended, and all departments and operational functions are generating information and providing this information to other departments. Time cards are sent to accounting. Job moves are reported to floor management. Inventory utilization is reported to production control. Waits for tools are reported to floor management and sometimes forwarded to manufacturing engineering. Each of the departments on the receiving end of information keeps track of the data it utilises in performing its specific functions, but there is no assurance that it is receiving all useful information or forwarding all information that would be useful to others. For example, if the department responsible for releasing orders to the floor has not been informed of parts that have been scrapped, delayed, sent ahead so that a hot-order situation could be covered, or just plain lost, it is unable to compensate for these situations when releasing future orders.

In other words, what the Manufacturing Company of America lacks is total floor coordination through communication between its departments. It is perfectly possible for them to implement control of floor activities and procedures for handling the many changes that occur without going to overly expensive equipment or a complex system ; in fact, they have no need for sophisticated systems until they know what is happening in their day-today production activities, nor are they in any

Figure 2

THE COMPLEXITY OF TOTAL FLOOR COMMUNICATION AND COORDINATION



position to develop or use them. What they do need is control, and the way for them to get it is to establish a single control center and provide it with prompt and accurate production data. Disciplined input and central control are absolutely necessary no matter what the complexity of the operational system they ultimately desire. With a small computer to process the daily activity and produce the appropriate reports these two ingredients will make it possible for them to develop a simplified operational system that provides them with much of the information they need and **the ability to react efficiently to order changes, engineering changes, scrap and rework, hot jobs, parts shortages**—these are the exceptions to the normal manufacturing plan and, **as we all know well, manufacturing is one long series of exceptions.**

The beginning point in insuring that the necessary information is obtained is to require that it be recorded by the employees in a standard format, and an excellent way of making sure that the information recorded is accurate is to use cards prepunched with as much of this information as possible. While the use of prepunched cards on a manufacturing floor is often thought to place too many extra documents in areas of activity, the following example shows that such cards do not really require any floor activity beyond that needed for manual recording systems presently being used in most industries. What they offer is a **standard, disciplined approach to the recording of data** that, combined with the prepunched data already contained on each card, allows far greater accuracy.

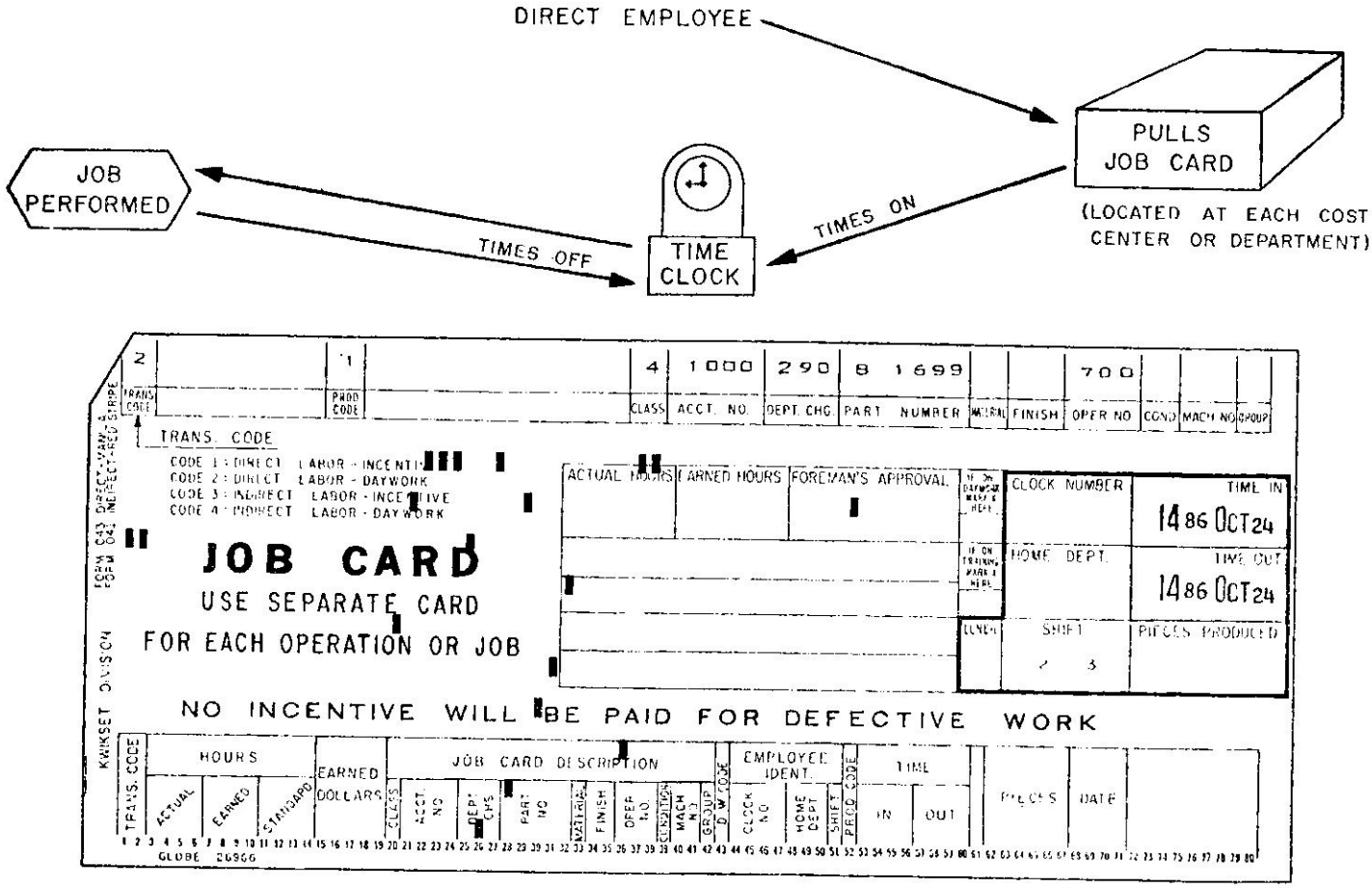
Prepunched cards have been used by the Kwikset Division of the Emhart Corporation in Anaheim, California, for more than six years to provide input to their time-keeping and incentive payroll systems and their labour distribution and performance analysis programmes.* Kwikset has a high-volume production of many different parts, and as many as 180,000 cards are on the manufacturing floor at a time, located at some 30 different stations and being used by 300 direct employees. As shown in Figure 3, the prepunched cards contain part number, operation number, performing department number, general ledger account number to which the labour is to be charged, and miscellaneous production information. Upon being assigned to a job, the employee extracts the appropriate card from a file of prepunched cards, which is maintained either in part number or operation number sequence, and stamps it with a time clock. Upon completing that job or at the end of the day, the employee time-stamps off and manually records pieces produced, man number, home department number, and so forth. Every day the completed cards are sent directly to data processing for key-punching of the time and manually recorded information, which requires approximately 4 hours for an average daily volume of 1,800 cards. The completed cards are then processed by a computer to prepare various time-keeping and employee performance reports ; one of the most useful, as far as the industrial engineer is concerned, is an operation report showing standard *versus* actual operation time.

To return to the simplified operational manufacturing system I am suggesting, the completed prepunched cards would be delivered to a control center at frequent intervals rather than being sent directly to data processing at the end of the shift or day. The control center could use the cards in various ways to keep track of each order on the floor and to implement changes to them. One way would be to have the control center receive a card notification of ech order being released to the floor. This master job card, which would depict all operations to be performed for the order, would be filed in a visible rack according to the department in which the first operation is to be performed. Upon receipt of a completed prepunched operation card from the floor, the control center clerk would note this status on the master job card and move it to the rack designated for the department in which the second operation is to be performed. Thus any order on the floor could be found

*The information contained here was obtained through the courtesy of Chad C Julian, Kwikset Data Processing Manager.

Fig. 3

PREPUNCHED SHOP CONTROL CARD



by going directly to the control center, which, in addition to its floor locator function, would also provide an excellent source for quick analysis of department load. The control center clerk could perform several other functions in addition to posting the cards. If the proper quantity is not reported after each operation and he has not been notified of the reason, he could immediately resolve the discrepancy by calling the latest reporting department and asking for supporting input ; and if part of a job is to be sent ahead to expedite orders, he could annotate the master job card and create a new one for the sent-ahead quantity, in effect splitting the job into two.

Each night, the completed prepunched cards delivered to the control center for use in locator control and floor change activities would be processed and summarised by **a small card oriented computer to produce significant daily operational reports such as job status, behind schedule, departmental production and remaining load, scrap and rework, and so forth.** A daily report such as that illustrated by Figure 4 could be provided to each department manager showing the part number, job number, and operation number of each job currently in his department or performed on the previous day; and the quantity reported against that operation, its status, the man numbers of employees working on it, and the calculated expended time for each. The report could be run in several different sequences, such as by part number for locating particular parts or jobs and by man number for performing quick analysis of employee performance. Finally, the report would also serve to point out errors, including those that might have got past the control center; these errors would be resolved the following day.

On such a simplified operational system a more sophisticated system can be built with the assurance that it will be provided with accurate input data and in this regard, at least, capable of functioning successfully. **In the ultimate total manufacturing information system, all areas amenable to data processing would be computerised, using a large, on-line, disk-oriented computer**

Fig. 4

DAILY REPORTING AUDIT
DEPT. 102

PART No.	JOB No.	OPER. No.	QTY.	STATUS CODE	MAN No.	TIME EXPENDED	ERROR CODE

MAY ALSO BE DESIRABLE TO RUN
IN MAIN NUMBER SEQUENCE

STATUS CODES

1. PARTIAL
2. COMPLETE
3. SCRAP
4. REWORK
5. SENT AHEAD
6. INDIRECT

ERROR CODES

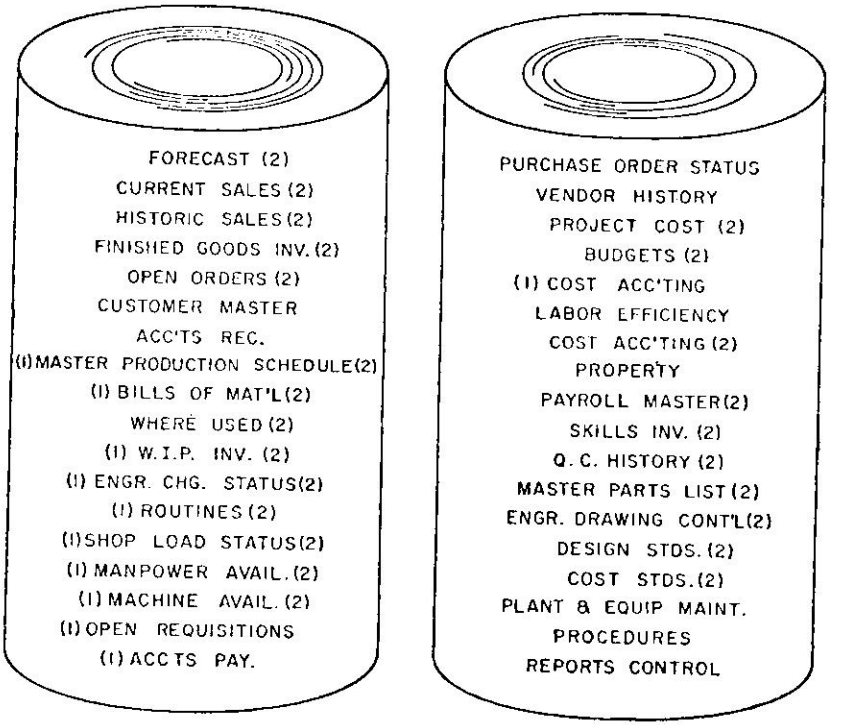
A. QTY. INCONSISTENT
B. INVALID JOB No.
C. INVALID MAN No.

CORPORATE MANAGEMENT

(2) MKT. PLANNING	(2) MARKETING	SALES ORDERS
A/R	(1) (2) MFG.	(1) MAT'L CONT'L
(1) PROD. CONT'L	(2) I.E.	(1) PURCH.
(1) A/P	GEN'L ACC'TING	PAYROLL
(1) COST ACC'TING	(2) PERSONNEL	PROPERTY MGT.
PLANT MAINT.	Q.C.	(2) RESEARCH
(2) ENGR.	(2) PRODUCT PLNG.	(2) MFG. ENGR
(2) PRODUCT ENGR.	SYSTEMS & PROCEDURES	(2) FIELD SUPPORT

MANAGEMENT INFORMATION

TYPICAL DATA FILES



(1) PRODUCTION SCHEDULE CHG.
ENGINEERING CHANGE (2)

system in place of the card-oriented system and also using data collection equipment on the floor in place of the manual system previously described. Th computer itself would function as the control center, receiving all transmitted data and answering any enquiries. While the total system would have vastly greater capabilities, its implementation would be both far more difficult and far more expensive. The following rough comparison illustrates the basic differences between the two systems in terms of initial implementation and continuing operational costs, savings made possible by elimination of various production support personnel, and applications of the two systems. This comparison, which would of course vary greatly from company to company, is based on a manufacturing concern with 600 employees and a yearly gross sales of $25 million involving 10 to 20 thousand different part numbers.

	Simplified System	**Ultimate System**
Implementation Cost	$30—50,000	$120—250,000
Monthly Operational cost:		
Equipment rental	3,000	14,000
Data processing personnel	3,000	13,000
Miscellaneous	500	1,000
Control center personnel	200	..
Total monthly cost	$6,700	28,000
Savings	Timekeepers (2—5)	Same, plus
	Expediters (1—7)	Parts Analyzers
	Production Staff (2)	Purchase order personnel Accounting personnel
Applications	Job status reports Timekeeping and payroll/ reports. Simplified inventory control Statistical reports Scrap Rework Indirect labour Employee performance etc.	Same, except on line: Order entry Forecasting Requirements generation Shop scheduling Order release Purchase order release and control Inventory control Cost accounting.

I would like to point out that the question of the concern's previous data processing experience does not enter into the comparison. Whatever such experience may be, **implementation of a total system is an almost overwhelming undertaking**. For one thing, the total system demands much of management's otherwise-committed time to communicate company operations and management needs to those doing the implementation. For another, **implementation of the total system requires extensive systems, programming, and data processing skills**. The current (and ever-increasing) **shortage of qualified personnel has caused implementation of many a total system to flounder,** and **the few successful total systems in existence today were not developed without considerable pain.** But with the development of a simplified system such as the one I have suggested, not only does the company gain immediate operational benefits, it also develops the computer system and working experience required for the implementation and use of a larger system and allows management ample time to become familiar with the type of support required of them. Thus the simplified operational system can provide a company with the direct benefits to be gained from better input and job control and the fringe benefit that the necessary personnel skills and management undetstanding are being developed within the organiztation. ●●●

FUTURE
PRESENT
PAST

Computers and Supervisors*

Keith E Thurley†

THE DEBATE ABOUT THE IMPLICATIONS AND consequences of automation for industry, society and the individual is now very familiar to us all. We may quarrel about the terminology used (automation or cybernation?) or about the need to trace automatic developments back to the industrial revolution or beyond, but the plethora of international conferences and publications in the last ten years have at least established automation and the use of computers as a **problem**—or a set of problems—of major importance. Underneath the debate there often seems to be a deep-rooted anxiety. Although scientific and technological advance offers us power and mastery over our environment, —as Edmund Leach has recently said—**"Men have become like gods, but instead of rejoicing we feel deeply afraid."**[1]

"Cybernation creates changes in our social system so vast and so utterly different from those in the past that it will challenge to its roots our present understanding about the viability of our way of life."[2]

Main Questions

1. the effect of the introduction of computers on supervisory functions
2. the problem of adapting the existing supervisors to new techniques and problems
3. the question of training and retraining for any changes in roles demanded by the new technology.

As with other aspects of the automation debate, there is a visionary view of the problem which promises radical change and exciting developments. There is also the cautious and more cynical view which disbelieves in the likelihood of the predicted changes occurring at any speed. Those who take the former view may go on record **querying the possible need for supervisors under conditions of sophisticated process automation. "The foreman's position tends to become equivocal.** If he possesses sufficient technical skill and knowledge, he may act as a **roving technical adviser;** and if he has also the necessary personal qualities, he may become the accepted leader of an integrated team. But, however good he is at managing men, unless he has extensive technical knowledge and experience, he is **apt to find himself a fish out of water, merely keeping records and arranging rotas.** Where there is a qualified engineer on each shift, it is doubtful whether there is a place for him at all."[3]

Leavitt and Whisler argued further in their study of management in the 1980's, that **middle management would be replaced by overall co-ordinators,** systems analysts and programmers.[4] Management controls

*Italics ours, throughout, unless otherwise mentioned.

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[1]Leach, E: A Runaway World, Men and Nature, *The Listener*, p. 621, 16 Nov. 1967, Vol. 78, No. 2016.

[2]Michael, D: "Automation, The Silent Conquest", Vintage Books, New York, 1962. (quoted by J. Rose "Automation, its uses and consequences", p. 117 Oliver & Boyd 1967).

[3]Crossman, ERFW: Automation and Skill. Problems of Progress in Industry, No. 9, D.S.I.R., H.M.S.O., London, 1960, p. 51.

[4]Leavitt, H and Whisler T: Management in the 1980's Harward Business Review, Nov./Dec. 1958.

would be centralised at more senior levels, the autonomy of departments would be broken down and **lower level management decision-making would then be subject to programming and rationalisation.** The rump of independent areas for decision-making left to foremen after the recent growth in specialist functional departments might finally then be eliminated by the creation of an integrated computer-based production control and planning system.

Against such predictions one can quote the evidence of the ILO Report on Automation and Non-Manual Workers on the effect of the introduction of computers on administrative hierarchies.

"The same studies note, however, that in the early stages of computer operations **middle management is very busy with the practical and organisational problems involved.*** Other studies have not confirmed the prediction that middle management jobs will substantially diminish. Rather they indicate that, although the functions required of middle managers change under office automation, the need for them remains"[5].

As Professor Zalewski argued in the Geneva Conference of 1964 on Employment Problems of Automation and Advanced Technology, it is equally possible that supervision will not be made redundant but will become more crucial.

"Co-ordination of specialised tasks will become the prime function of the supervisor, while subordinates will be expected not only to supply information and report progress, but to identify problems and initiate proposals for their solution. Apart from giving orders, the supervisor will supply the general information that enables subordinates to direct their specialised activities towards the fulfilment of organizational objectives."[6]

Zalewski sees the necessity for upholding the authority of supervisors "for it is his function of co-ordinating diverse efforts towards a common goal that entitles him to make responsible decisions at a policy level".[7] This argument finds some support from a case study of the introduction of a computer-controlled production control systems in an English factory:

"For example, the foreman has **now no responsibilities or worries concerning the planning of the work** in his section for weeks ahead; neither is he responsible for ensuring that the materials, tools, blueprints, etc. are physically available before he issues the work to a specific operative; nor to see that the sections responsible for prior operations are, in fact, keeping up to schedule, in order not to invalidate his own programme. All these facets are now part of the total scheme and no work authorities are issued to him unless all these prerequisites are satisfied. On the other hand his function as a manager of a team of men has been re-emphasised*; his responsibility to see that they are adequately trained and competent for the tasks in hand,† to ensure that machine tools are maintained and to assist in the continued effort to improve methods of manufacture. In all levels of management there exists, in differing degrees, **this tendency to anticipate difficulties, to be concentrating on tomorrow's needs** rather than the immediate problems of the day. Now the foreman gets a completely detailed work plan for two weeks ahead; the superintendent knows

*This would really mean that the position of foremen under a computerised system would be transitional

—Editor

[5]Labour and Automation Bulletin No. 5, Automation and Non-Manual works, ILO, Geneva, 1967 p. 21.

[6]Zalewski, Andrzej : "The influence of automation on management". Employment problems of Automation and Advanced Technology, An International Perspective (edit. J. Stieber) MacMillan, St. Martins Press, London and New York, 1966, p. 358.

[7]Zalewski, ibid p. 358.

*This is just beating about the old bush!—**Editor**

†Rather the problem would be for the management to train the supervisors in the smooth working of a computerised system.—**Editor**

the plans for a month ahead; the production manager has the next four months under completely detailed analysis and review; the works manager has a whole twelve months' plan before him. Each in his turn has to make appropriate appraisals and decisions to ensure that plans laid down by top management are carried out."[8]

The main issues at stake appear to be, therefore:

(a) The degree to which centralisation of decision-making is demanded by the introduction of computers to assist managerial planning of production schedules, controls of scrap loss, maintenance programmes etc.

(b) The degree to which supervisors find their total functions restricted to organisational and leadership functions.

(c) The degree to which the necessity for direct supervision of operative behaviour is eliminated by changes in the role of operators; i.e. by the development of complex man/machine **production systems in which "operators" themselves are supervising and monitoring** the results of closed loop process control system.

With these problems, as with the other supposed effects of automation and computers, it is **desperately important to avoid yet another speculative debate.** We need further clarification of our hypotheses and we need detailed factual evidence. There is, unfortunately, very little systematic and objective data on supervisory roles and behaviour in the now extensive literature on automation. Fragmentary information can be gleaned from published case studies. Much more data is no doubt available within companies that have experienced the introduction of ADP and other types of computerbased systems. We can hardly hope to dispose of our problems with our current amount of data. It is, however, important to consider the types of factors influencing supervisory behaviour under various technological systems, as this may provide some detailed clues, as to the **possible effects of the introduction of computers.**

II. RECENT STUDIES OF SUPERVISORY ROLES

It was argued in a previous paper,[9] that much of the research into supervision conducted by social psychologists was limited in its usefulness by its exclusive emphasis on leadership style. Researchers have been concerned to demonstrate the correlations or lack of correlations between varying aspects of individual supervisory behaviour and operative productivity and morale.[10] Recent studies of foremen roles in Sweden,[11] the Netherlands,[12] Finland,[13] in the United Kingdom,[14] and

[8]Grant, J.W. : Production Control System for Letchworth Factory, The Electronic Data Processing Symposium 1961, p. 43, Pitman, London, 1963.

[9]Thurley, K.E. : Changing Technology and the Supervisor. Employment problems of Automation and Advanced Technology—An International Perspective (edit. J. Stieber) MacMillan, St. Martins Press, London and New York 1966, p. 334-353.

[10]RL Kahn & D. Katz : "Leadership Practices in Relation to Productivity and Morale (from Cartright D & Zander A Editions) Group Dynamics, Research and Theory, ch. 29, p. 554—570, Harper & Row 1961.

[11]Wirdenius, H: Supervisors at Work, P.A. Council, Stockholm, 1958.

[12]Hesseling, P : Strategy of Evaluation. Research in the field of Supervisory and Management Training, Van Gonum, 1966.

[13]Lehesmoa, M : (See Wirdenius, H : *'Formani arbete'*, 1961)

[14](a) Thurley, K E and Hamblin, AC : The Supervisor and His Job. Problems of Progress in Industry, No. 13, H.M.S.O., 1963.

(b) Kelly, J : The Study of Executive Behaviour (by activity Sampling) Human Relations Vol. 17, 1964, p. 277, No. 3.

(c) Pinschof, Maria : Notes on the Role of the Production Foreman in one case study. Journal of Production Engineering, Vol. 3, No 3.

Japan[15] have tended to use observational and questionnaire methods in attempting to describe and analyse supervisory functions in a more comprehensive manner. A common objective of these studies appears to have been the attempts to obtain realistic information about training requirements and many of the researchers have adapted their techniques from work study practice as well as psychological and survey research. One result has been the gradual compilation of case studies of supervisory behaviour in different types of technology. It is useful here to try to summarise the main characteristics of the supervisory role as described in such case studies.

1. **Supervisory Systems:** Analysis of individual supervisory roles is greatly enriched by considering the inter-relationships between roles as a "supervisory system of control" over some or all aspects of a production system, i.e., plant, materials, men and general process conditions. Membership of a supervisory system could be established by checking the degree to which the individuals concerned were directly and personally involved with shop-floor problems and were recognised by operatives and mangers as carrying authority and status in their role, above that of the ordinary operatives.

2. **Levels of Supervision :** Supervisory systems thus vary from the single role to the multi-focal type. The levels show a gradation from roles which are semi-operative to those which are semi-managerial.

3. **Supervisory Tasks:** The tasks performed show an enormous variation in content. **The supervisory role is an "empty box" which is filled according to the situation.** There are no necessary common tasks for all supervisors. There may be, however,

(a) essential tasks necessary to meet minimum production requirements and which can only be performed by supervisors,

(b) tasks essential to the production system which could be performed by supervisors or by others,

(c) tasks which are not essential but valued by managers, supervisors or operatives.[16]

4. **Types of Supervisory System:** Systems can be classified according to functions performed or by the shape and complexity of the role system or by the degree of role specialisation and inter-dependence between roles. Another important charactersitic of each system is the degree to which the boundaries are defined and mutually agreed. Two crucial variables are the **degree of formalization of the role system** and the **level of skill and discretion shown by operatives being supervised.** These two factors can be combined as in Fig. I to show four ideal types of supervisory system.

Types of Supervisory System

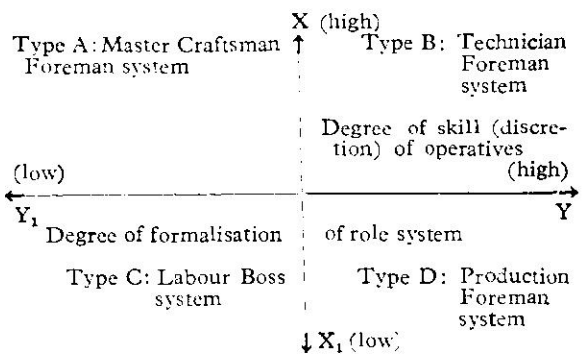


Fig. 1

5. **Supervisory Functions :** These vary with the influence of many factors (see below) but they can be classified by the extent to which they involve predictable activities and tasks. Certain types of organisation and environment provide numerous contingency problems which demand action by those within the supervisory system. Contingencies might include variations in the production process, shortages of raw materials or components, unpredictable

[15]Thurley, K.E. : The Foreman Problem in Japanese Industry, Industrial Training International, Oct. 1967, Vol. 2.

[16]Hamblin, AC : The Nature of Supervisory Tasks. *Sociologie du Travail*, p. 225, Vol. 5, July/Sept. 1963.

variations in performance by operatives, faults or breakdowns in plant, shortages of space and so on. *The actions taken by supervisors to deal with contingencies appear to be the most critical parts of their role.*‡ Although adequate planning may make it possible to avoid certain types of problem, in reality it is beyond the influence and power of supervisors to affect the causes of many contingencies. Reactions to problems arising out of the production system are thus crucial.

6. **Typical Organizational Problem :** Difficulties experienced by supervisors with their roles reflect situations of "role stress" as well as that of "role ambiguity."[17] **Supervisors operate in situations in which the correct performance standards are not decided; in which opinions differ as to priorities, and definitions of authority; and in which the main stimuli to action may come from requests and demands from a whole variety of persons—managers, supervisors and operatives. A supervisor is found to respond to a number of "messages" sent to him by persons in his role set. These messages may be contradictory and in this case the supervisor is** involved in the problem of conflicting expectations as to what he will do or should do. Gaps certainly exist between the perception of the supervisior's tasks by senior management and the tasks perceived by supervisors themselves or observed to be typical. **They don't want to acknowledge any non-stan dard corditions, which we have all the time".** (Superintendent quoted by Kahn et al).[18] Such a gap reflects a blockage of upward communication from supervisors to management which appears to be widespread in large industrial organizations. Recent studies of supervision confirm that despite this, the most crucial role relationships for supervisors are with each other and with various managers. Relationships with their subordinates appear to be less significant or vital to them.

III. DETERMINANTS OF SUPERVISORY BEHAVIOUR

If these characteristics give us a broad picture of the supervisory role, can we go further and explain variations in role system behaviour patterns and attitudes?

In the paper quoted above[19] we discussed the relationship between the type of technology and the type of supervisory system. The conclusion was reached that there was no direct correlation but that many of the factors that were directly affecting supervisory behaviour, for instance, the incidence of plant breakdowns or changes in planning schedules, were themselves partly created by the type of technology. We are dealing here with types of "socio-technical systems", in which technical, social, cultural and economic factors are inter-dependent.[20] One way of establishing the extent to which non-technological factors are contributing to supervisory behaviour is to examine similar technologies in differing cultures. A recent study[21] of supervisory systems in Japan contained one observational study of a steel tube making shop which was compared with a study in a British factory making tubes. Superficially the supervisory systems were not too dissimilar. (Fig. 2).

‡Italics author's.

[17]Kahn, RL, Wolfe DM, Quinn, RP, and Snock JD: Organisational Stress, John Wiley & Sons Inc., New York, 1964.

[18]Kahn, RL, et al. ibid p. 342.

[19]Thurley, KE : "Changing Technology and the Supervisor", ibid p. 349.

[20]Emery, FE & Trist EL: "Socio-technical Systems" Proc. 6th Annual International Meeting of the Institute of Management Sciences. London and New York Pergamon Press 1960. Management Sciences, Models and Techniques Vol. II.

[21]The research is being reported in a series of articles in *Sangyo Kunren Zashi* (Industrial Training) Japan Industrial and Vocational Training Association, Tokyo, May, 1967 onwards.

Supervisory Systems in Japan and the United Kingdom (Steel Tube Manufacture)

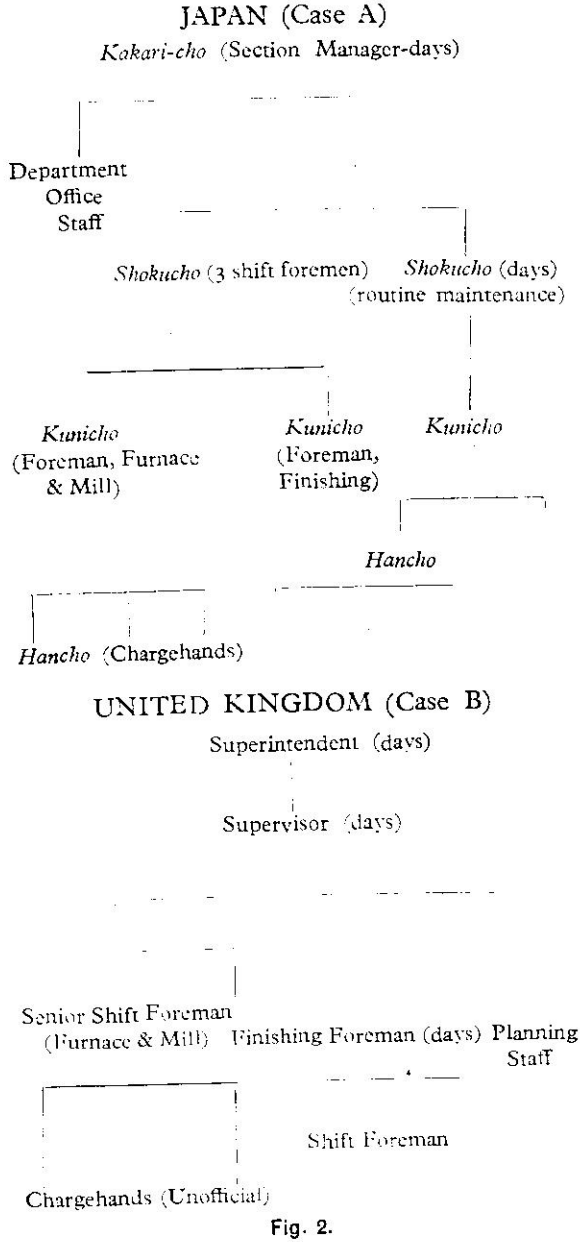


Fig. 2.

If the location of work activities are examined (Table 1) the importance of office work in the Japanese case is underlined.

Table 1

Location of Work Activities for Supervisors in two Tube Mills

(Avge. % of time at work)
(Tour Method)

	Own work area (Shop Floor)		Office	
	Japan	U.K.	Japan	U.K.
Shift Foreman (Mill)	31	66	53	18
Chargehand (Mill)	60	74	18	2

Much of the observational data, however, showed considerable similarities in the proportions of time spent, for instance, on routine tasks or on meeting contingencies of various types (Table 2).

Table 2

Average Percentage of Time at Work Spent in Routine Tasks or in Meeting Contingencies

(for supervisors in two Tube Mills)
(Tour Method)

Percentage of time spent in	U.K. (Mill Foreman)	Japan (Kunicho)	U.K. (Chargehand)	Japan (Hancho)
Routine Task	43	47	49	59
Contingencies :				
(a) Problems given to supervisor	..	6	1	4
(b) Minor variations in plant, components or human behaviour	9	13	7	6
(c) Major variations & breakdowns	11	3	6	1
(d) Problems due to introduction of new methods	4	8	..	1
(e) Problem due to shortages of materials or men	1	3	..	1
(f) Problems of communication failure	1	3	..	1

The figures for observed contacts, which are shown in Fig. 3, also have many similarities, although contacts with workers appear to be more numerous in the Japanese case.

Can we conclude (on the basis of these similarities) that technology determines the shape of supervisory role behaviour? They may well be used as *prima facie* evidence that "essential tasks"—demanded by the technology, exercise a strong influence on the nature of supervisory work. The interview, questionnaire and discussion group data, however, showed that perceptions of role and attitudes varied considerably between the two systems. Broadly speaking, the Japanese supervisors showed a certain contrast between the *Kumicho* who were largely over 40 years old and who perceived their role as monitoring events for senior management and the *Hancho* who were younger, better educated, far more self confident and much more identified with the shop-floor workers. The confidence of the mill foremen in their own authority stands out by contrast, as well as the extremely limited formal responsibility of the chargehands. In terms of Fig. 1, one could say that the U.K. supervisory system tended towards Type A whilst the Japanese case was nearer that of Type D. A general conclusion from their, study and from the other nine companies studied in Japan was that the Japanese supervisory systems showed a great deal of deliberate organizational design by management, in contrast with the reliance in Britain on traditional social patterns of foremanship. In Japan, the status levels of lower and middle management and management development systems show more signs of a common traditional inheritance than the foreman systems, which were often confused after much organisational reform.

This digression, therefore, teaches us that supervisory role behaviour is determined by a balance of influences arising from:

(a) The production system and its demands,

(b) The beliefs and plans of management for its supervisory control system,

(c) The relative importance of traditional supervisory role systems in a particular industry's occuptational system,

(d) The social composition and characteristics of the workforce itself (education, aspirations, political beliefs etc.)

Observed Communication Network for Four Selected Supervisory Levels in Two Tube Works in Japan and the U.K.

Average Percentage of Time Spent **(Tour Method)** (face to face contacts)

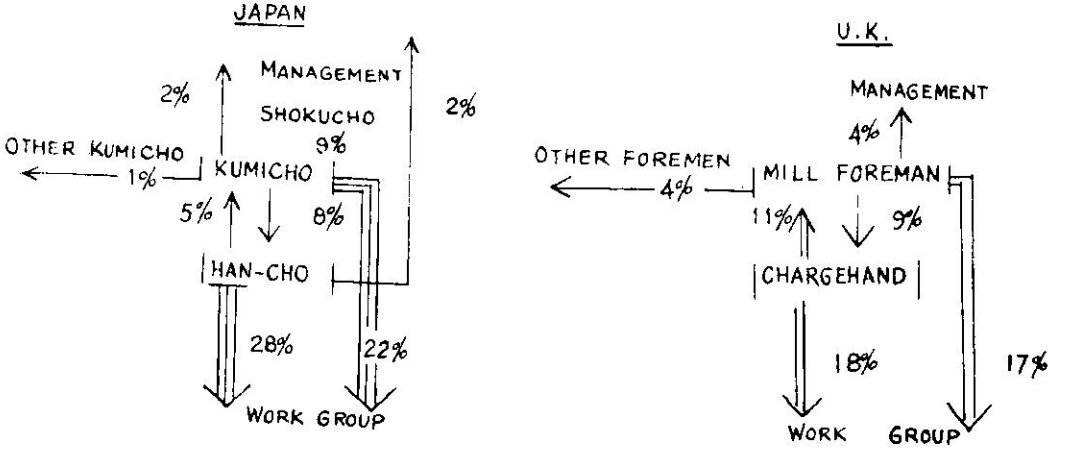


Fig. 3

IV. DECISION-MAKING AND PROBLEM SOLVING FOR SUPERVISORS

If dealing with contingencies is important for supervisors, it is necessary to look at how they are dealt with. We can use a simple problem-solving model to clarify the activities involved (Fig. 4).

This has been used to examine a number of cases of problem-solving by construction site agents, foremen and contracts managers on six building sites in the U.K. Three conclusions stand out from this study—

i. the importance of previous experience in shaping the type of problems recognized, in perceiving alternatives open and in learning appropriate strategies,

Problem Solving for Supervisors[22]

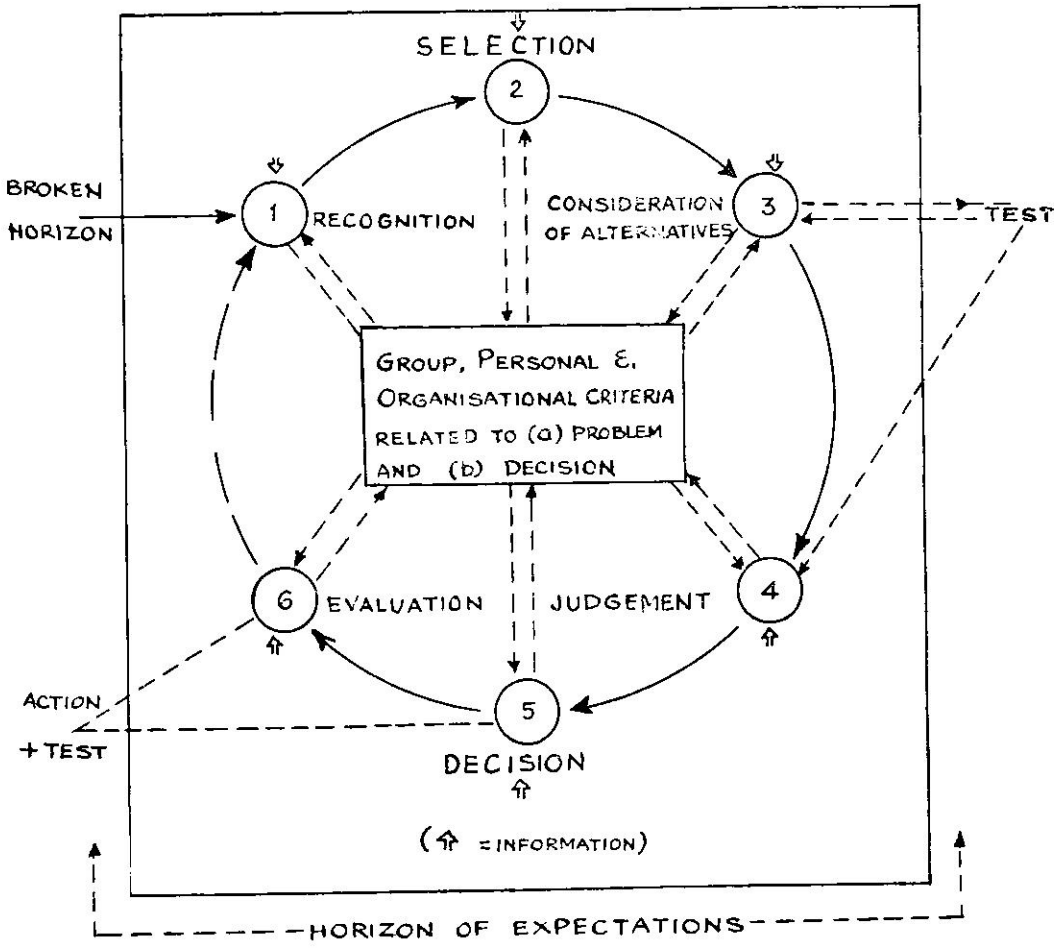


Fig. 4

[22]Deeks J, Majid, SA, Pinschof, Maria & Thurley KE: 'Problem Solving Behaviour in Construction Project Management', Paper given to Anglo Swedish Conference on Human Factors in the Construction Process", Sept. 1967.

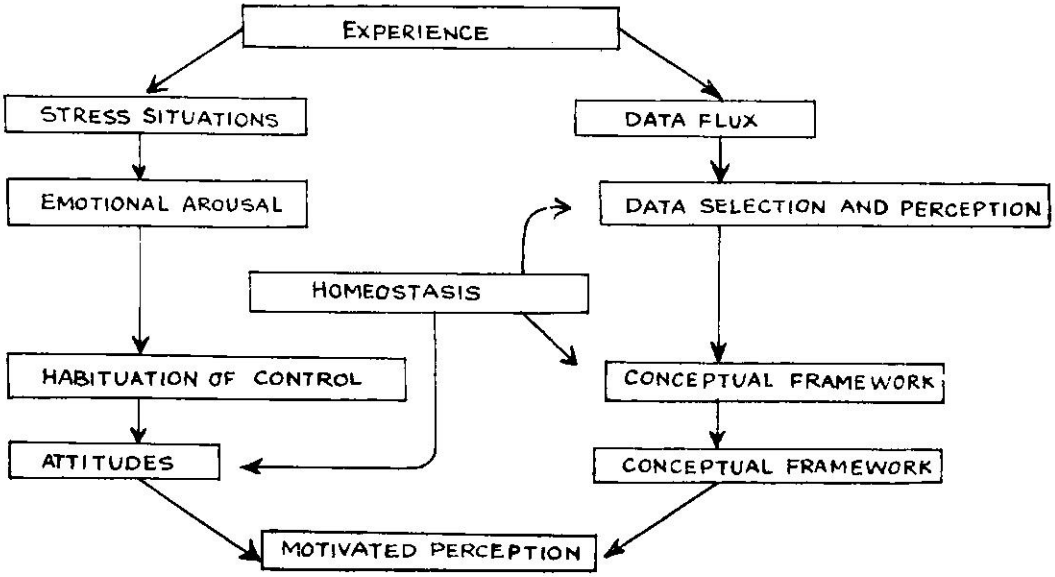


Fig. 5

ii. the importance of the attitudes of supervisors towards search procedures of any type, and

iii. the importance of the type of goals or objectives actually accepted by supervisors as relevant for their particular situation.

These points are elaborated by Will Howells' model of perception as modified by experience[23] (Fig. 5).

We can say here that there are tendencies for attitudes, ways of thinking and facts perceived to be connected. If supervisors have learnt how to choose strategies entirely or largely from observing other supervisors, if they feel that judgment from "experience" is superior to "academic" techniques of data collection and if they are not expected by senior management to produce results from their problem-solving (because managers do not expect or believe supervisors to be capable of decision making)—then we can readily understand why such problem-solving is often ineffectual. The construction study showed many examples of supervisors "patching" problems and trying to find temporary solutions which got them out of the immediate problem. In any fundamental difficulty, however, the problem remained unsolved.

Recent work by psychologists analysing the various types of methods of thinking have underlined three separate approaches.[24]

(a) Use of memory to perceive relationships between variables,

(b) Use of patterns, (extrapolating from one set of relationships to another set),

(c) Use of an operational strategy to test relationships between variables.

What we are saying is that supervisors in the U.K. construction study showed much evidence of stereotyped thinking or the use of deductions by patterned thinking, rather than operational thinking. The results of these strategies were satisfactory if the problem conformed to type and was a familiar one, e.g.,

[2] Howells, W : Managers and Systems; Journal of Management Studies, Vol. 3 No. 2, May 1966, p. 150-162.

[24] Dienes, ZP : Thinking in Structures, Hutchinson, 1965.

allocation of work. In any new situation, or where the problem had to involve others across the boundary of the supervisory system, the response was usually quite inadequate. We can summarise our supervisory theory at this point by saying that supervisory effectiveness would seem to depend on how far the "essential" supervisory tasks and problems arising from a given production system can be performed and solved by the supervisors with their **particular set of skills and attitudes, methods of thinking and objectives. Where the rate of change is fast or where there is much variation in such production demands it requires the acceptance of operational strategies by supervisors and the support of management in their problem-solving role.**

V. INTRODUCTION AND APPLICATION OF COMPUTERS

Generalisations about the implications of automation or about the effects of using computers are frequently sterile because of the lack of precise definition of terms and the fast increasing variety of possible applications. Probably the best starting point is to take Prof. Crossman's definition of automation **"as the replacement of human information processes by mechanical ones."**[25] This enables him to build up a taxonomy of automation[26] based on nine characteristics of information processing (see Fig. 6), as under :

1. Type of input data (digital, analog or patterned)
2. Use of feed-back (open or closed loop) for input data
3. Source of programme (fixed, pre-loaded, adaptive or learning)
4. Type of programme (open chain, branching, looping or heuristic)
5. Determining of programme (determinate or probablistic)
6. Size and type of memory (storage of current data)
7. Size and type of memory (storage of permanent data)
8. Type of output data (digital, analog or patterned)
9. Timing of output data (either in step with input (real-time) or independent (off line).[28]

Another useful classification of types of computer control system is given by J. Rose[29].

Information Processing[27]

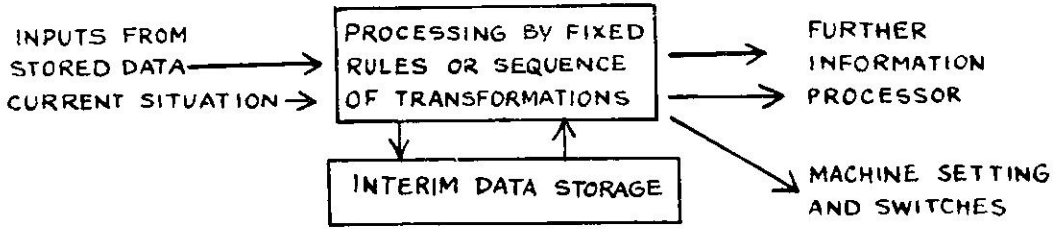


Fig. 6

[25]Crossman E.R.F.W. : "European experience with the changing nature of jobs due to automation." The Requirements of Automated Jobs. N. American Conference Final Report, p. 161 O.E.C.D. 1965 (Italics author's).

[26]Crossman E.R.F.W.: "Taxonomy of Automation—State of the art and prospects." Manpower aspects of automation and technical change. European Conference Supplement to Final Report, p. 75, O.E.C.D. 1966.

[27]Crossmann, 1966, ibid, p. 81.

[28]Crossmann, 1966, ibid. p. 83.

[29]Rose J, ibid, p. 8-9

He distinguishes between systems designed at stabilising, control, optimising a steady state system or optimising a transient state system. The latter (as found in batch production of chemicals) is the most difficult to design and operate. These classifications are useful in allowing us to distinguish types of computer application and to identify precisely what aspects of information processing are being handled on the computer. They present generalisation from particular cases and the illusion that total automation of management information systems is just round the corner (Dearden[30]). In this article, Dearden argues that computers are best used when the data deals with inter-acting variables, and comprised accurate values. Where there is need for speed and where operations are repetitive, it is probably also true that computer investment will be most worthwhile as an economic investment. Otherwise, there are many barriers to the use and development of computers ystems. As Emery remarks "Decision making and judgment cannot be reduced to the narrow band of formal logical structures to which computers are restricted".[31]

VI. SUPERVISION AND THE COMPUTER

Coming back to our first and central issue, can we say that supervisors are handling information processing, are operating faulty control systems; carrying out heuristic problem-solving procedures in a limited and unsystematic way? Certainly. There could be many case studies showing such limitations. Are supervisory tasks capable of being handled automatically? The answer here seems to depend on the nature of the problem and task. Allocation of work and planning almost certainly could be handled in this way, inspection may be eliminated by the feedback controls in the process itself and even disciplinary action could perhaps be expressed in a computer programme. It is more difficult to see how action to increase work motivation or the improvement of job methods could be dealt with by the computer. Nevertheless, there are few aspects of supervisory work that **theoretically** could not be assisted and perhaps transformed by the automation of information processing.

We do not really get to the heart of our problem until we consider the value to an **organization** of possessing a discrete set of roles and norms which we call a supervisory system. Collectively, within the sub-culture built up among the foremen there exists a complex memory of previous situations, actions, successes and failures, earlier referred to as experience. The virtue of possessing such a memory store immediately at hand to production developments is the possibility of quick response based on local information (real knowledge of shopfloor conditions). As argued previously, the shape of supervisory systems has up to now depended largely on historical accident, social conditions and the type of technology. In Britain at least there is some evidence that the traditional systems are becoming disfunctional. Yet in complex technologies, where plant becomes increasingly interdependent, the need for accurate and operational thinking close to the area of operations becomes even more important. "The time span of the supervisor's job is considerably extended in correspondence with the sorts of variability with which he is normally coping."[32] Work on the application of computer-controlled planning systems to building contracts in Britain at the moment is clearly recognizing this point. The systems are usually planned to increase the amount of data available for site agents to take their decisions on weekly programmes. In many cases of developing automation, the emphasis has been placed on the importance of the know how of the design

[30]Dearden J : Can management information be automated? Harvard Business Review, March/April 1964, p. 128.

[31]Emery F.E. & Marck J : "Some Socio-technical aspects of automation" Human Relations Vol. 20, No. 3, 1967.

[32]Emery FR & Marck J : Some Socio-technical aspects of automation" Human Relations, Vol. 15 No. 1, 1962.

and Systems Engineers.[33] The problem of communication between th eanalysts and supervisors and local management is commonly noted. It should be clear that we face grave difficulties in trying to develop designs for integrated control systems in ignorance of the "memory" of operational strategies built up inside the traditional supervisory system. The actual strategies, themselves, of course, may be inappropriate to a new production system. The point is that in the processes of developing the design and of gradually pushing forward with the objective of optimising the methods of running the system, the earlier supervisory system can serve as a model and an indication of problems likely to be encountered. The arguments all point to the necessity of developing integrated teams of systems engineers and supervisors utilising the experiences of the past for the current and future design activity.

VII. CONCLUSION

Implications for personnel policies

1. There are no inevitable consequences of the use of computers on supervision, because of the variations in such uses and in the types of supervisory system and behaviour in existence. We can only underline the types of choice open for personnel policy makers.

2. On the question of organisation, it is possible to keep a traditional system of supervision in existence alongside teams of systems analysts and computer engineers. In this case, the role and functions of supervisors will certainly be restricted to personnel functions and even these may be minor in character.

3. An alternative is to try to develop teams of supervisors and engineers partly concerned with design, partly with optimising the system. Such teams may eventually include operators as well, at least for part of their time. There would seem to be more possibility of developing such teams within Japanese industry than in the English case, if only because of the flexibility built into Japanese supervisory roles and their personal attitude to technical change.

4. The training implications are fundamental if the course of action under 3 is favoured. *Supervisors have to be helped to develop an operational method of thinking and the appropriate attitudes towards search procedures, change and measurement.*† This would require on-the-job training and probably the use of group problem-solving exercises off the job. In Britain and probably throughout western Europe, some type of sensitivity, and group training will be necessary as well. In Japan, the training may require the reverse emphasis on individual work; the development of individual skills and thinking.

5. **Organisationally, managers would have to plan for a system of collective supervisory objectives,** e.g. types of improvement, if the supervisors are to be supported in any new problem-solving role. It's clear that this would be disturbing in both the Japanese case and the British, for different reasons.

6. *Training of the systems analysts inevitably follow match personnel policy decisions.*† Probably they need experience in case study work and in management exercises and projects in order to develop their self understanding and communication skills.

7. A final and crucial point for personnel policy lies with the future selection and development of supervisors. It is unlikely to be true that traditional selection and promotion systems can be tolerated, if the other policies are carried out. As the size and nature of the supervisory problem expands, however, (as with an integrated production system) the status of the supervisor as a "shop floor" job could change radically. In this case **one can conceive of supervisory jobs being merely types of managerial work which most managers would experience at various stages in their career.** A project system of organisation would certainly make such a change more feasible. ●●●

[33] Laden HN & Gildersleeve TR : System Design for Computer Applications. John Wiley & Sons, Inc., New York, 1966.

†Italics author's.

Planning Computer Centres in Universities and Colleges*

Winfred L Godwin[1]

Computers have enabled States and their higher institutions to solve or to make manageable, complex problems associated with the planning, development and conduct of higher education. Administrators, teachers, scientists and engineers utilise a wide range of computer techniques to cope with the enormous detail of research and administrative records. Increasingly, computers are being used in imaginative ways to present effective instruction to students. University computer centres are serving communities by analyzing complex data and producing information vital to the economy of the states in the region.

WHILE COMPUTERS AND COMPUTER APPLICATIONS are of increasing importance there is at the same time a serious shortage everywhere in industry, in government, and in academic institutions of personnel trained to programme and use computers. There is an even greater gap in personnel trained to make proper and effective use of computers in the solution of problems and to develop the emerging academic-technical field of computer science. In addition, there is an acute shortage of management personnel to direct the activities of computing facilities.

This shortage of computing personnel must be faced by the educational system. But computers pose for education not only the problem of developing computer scientists and users but also a variety of opportunities in the whole range of academic instruction and research. They are changing the approaches to many disciplines; they open new areas of research; they provide more information about complex phenomena; **they help solve problems which would otherwise be unmanageable.**

In the past year, many institutions of higher learning have become aware of the problems and opportunities which the computers present. The number of computer installations at colleges and universities increased markedly. There are now about 200 computing centres at U.S. colleges and universities with equipment ranging in size and cost from the smallest to the largest available. The general tendency is to integrate the use of computers into the educational framework and to establish special and new curricula for students who wish to enter the computer field directly. Wherever a computer has been introduced, its use for instructional, research, and administrative purposes has expanded rapidly and usually beyond all expectation.

*This publication has been really prepared by a cross-section of the Southern Region's leading computer centre directors.

1. Director, Southern Regional Education Board, Atlanta, Georgia, U.S.A.

Services Rendered

The computing center of a major university can serve not only the full range of academic departments but also provide the staff and laboratory facilities for the emerging discipline of computer science which is concerned with the training of computer specialists of various types.

As an illustration of the diverse fields which a computing center may serve, the active users' list of one university computing center now includes over 200 projects distributed over the fields of biology, business, chemistry, economics, engineering science, education, physical education, English, food and nutrition, geology, government, home economics, library science, mathematics, meteorology, music, oceanography, physics, psychology, social welfare, sociology and statistics. Other universities having schools of agriculture, law, or medicine have numerous computing projects from those fields. People in any discipline can use a computing center to advantage as an aid in processing the current literature of their field for purposes of information storage and retrieval.

In many universities, major portions of the book-keeping and payroll activities of the business office and the registration procedures and student record keeping of the registrar are being carried out with the aid of computers. They are used, for example, in determining and printing student schedules and in printing class cards. The result is a great-saving of faculty and staff time once required for tedious clerical work at registration time.

The new discipline, usually called 'computer science', which the existence of a center with adequate staff enables the university to offer has not been precisely defined. It is, however, interdisciplinary in nature and involves such topics as the theory and application of computer programming, problem-solving techniques, methods of applying computers to various fields, logic and algorithms, information storage and retrieval, automata theory, design of computers, and information theory. Several institutions already have computer science departments or other departments which embrace part of this material. Any school should include in its long-term planning the possibility of offering this interdisciplinary subject of computer science whether it does so in a separate computer science department or through other departments of the institute.

In addition to serving the several academic disciplines, to facilitating administrative operations, and to providing the opportunity to offer training in computer science, a computing center provides a number of important fringe benefits.

It helps, for example, in the procurement of able students for fields in which computing has become a significant element. Students interested in such fields are likely to inquire not only whether a school has a computer but what kind of computer and whether it is used in instruction; and they may even want to know what courses make use of the computer.

The history of computing on college campuses shows that students profit in many



ways from access to a computer. Intelligent students of business administration supplement their training by writing business game

programmes. Physics and engineering students write programmes for nuclear reactor operations and for meeting design requirements for structures. Students in programming courses write new assembly and compiler programmes, and some students even write programmes to compose music on a computer. Although their work may be amateurish, students use computers to exercise creative intelligence, to develop planning of work as a habit, to analyze theories—studying the complexities and difficulties and putting them to work.

As the availability of a computer may attract able students, it certainly attracts and helps to hold research men and ultimately expedites and broadens the scope of research. For it drastically reduces the tedium of large volumes of computation which in the absence of a computer may delay the completion of research or even prohibit developments in theory and application. The high-speed computer lifts this burden from the man in research, thus not only increasing his effective life but also permitting him to do research of greater magnitude by solving, in a matter of days, problems which would have been disregarded twenty years ago as too demanding and time-consuming to permit investigation.

The wide variety of non-numeric applications of computers which are now possible makes them effective in an ever-increasing number of fields. The digital computer, for instance, is now recognized as a device for manipulating symbols of any kind, in any way. Research in mathematical logic has already shown that machines of this kind have almost universal capabilities in executing algorithmic processes.

Another fringe benefit results from the fact that the staff of a computing center affects not only the work of individuals but also that of groups. In discussions with research men, computing staffs occasionally point up a community of interest among men in different disciplines, where the knowledge of one supplements that of another, where the method of one complements the method of another, where duplication of effort on small problems can be changed to effective contribution on large problems. A habit of cooperation and communication is established for some of the faculty and results in greater interdisciplinary understanding.

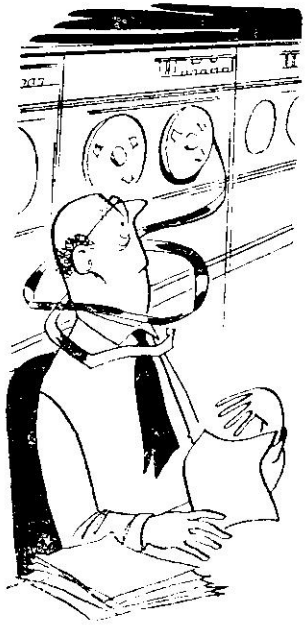
Hardware

The term 'hardware', refers to the electrical and mechanical devices used in the machine-processing of information. Except for small computers, a modern computer system rarely consists of only one physical unit. Instead, a variety of units is usually involved, each of which is interconnected by special cables and serves a special purpose. The heart of such a system is often called the 'main frame', which is also the particular part of the computer specified by the model number, e.g., 'The wonderful 3001'. The main frame includes (a) the control unit, which serves to direct the overall operation, (b) the arithmetic unit, which performs addition, subtraction, multiplication, etc. (c) the main memory unit, in which data and instructions are recorded and (d) the operator's console. In addition, every computer system has to have at least one set of input/output devices, such as a card reader and a card punch, for communication with the outside world.

Although the computer elements mentioned so far comprise the basic part of a computer system, they rarely constitute the computer in its entirety. For practically every system now on the market, a variety of units can be attached to expand its capabilities. In other words, most modern computer systems can be expanded to serve the growing needs of their users. Extra memory modules to increase the capacity of the main memory unit may be added. Special operator consoles (often called 'inquiry stations') or additional input/output devices are available. On occasion, a second central processing unit may be needed and available for parallel operation.

Among the units most frequently added are auxiliary memory devices, such as magnetic tapes, which therefore desever special mention. The main memory unit of a computer is used for storage of the instructions about to be executed and for the corresponding sets of

data. When new information enters the main memory, part or all of what was in the memory is erased and replaced by the new information. The computer's ability to process problems



involving many steps and/or large amounts of data depends on the size of the memory. Auxiliary memory devices are therefore desirable to store excess information to be used only infrequently in the programme.

At the same time, certain types of auxiliary memory devices can act as additional input and output units if the stored information can be removed from the unit and handled elsewhere, away from the system. One such auxiliary memory device is the magnetic tape unit, which resembles the well-known tape recorder. Information is stored in the form of magnetic spots on reels of plastic tape coated with a special layer which has specific magnetic properties. Other auxiliary memory units in frequent use are disk storage units, wherein disks with a magnetic coating are arranged much as the records in a coin-operated record player.

As far as the general user is concerned, the most readily understood output is, of course, the printed page as it comes, for example from modern high-speed printers. In small and medium size computer systems, these printers are directly attached to the main frame. In large-scale systems, they (as well as most of the other input/output devices) are usually controlled by a small separate computer which communicates with the large computer only via magnetic tape.

Programme Library

The importance of the computer programme library, frequently spoken of as the 'software', cannot be over-emphasized. Without an adequate programme library, the computer hardware can be used only by persons well acquainted with programming. Moreover, only in special cases can an institution hope to have a sufficiently large and skilled programming staff to build and maintain by itself a good programme library and at the same time to keep up with the usual daily programming requirements.

A good programme library contains not only a well assorted set of special-purpose programmes (such as those for performing the standard statistical computations) and a well written set of mathematical subroutines (such as those for computing the elementary functions—square root, sine, cosine, etc.), but also even more important programmes for simplifying the programming process itself and for monitoring the execution of the programme on the computer.

The machine language of computers is in most cases extremely difficult and tedious to use. Special programmes have therefore been written for every modern computer which simplify this programming task in a variety of ways and which make the programming language easier to understand, to learn, and to use. The computer is then used to translate these languages into its own machine language. Some translation programmes such as those for the widely used languages (FORTRAN, COBOL, ALGOL etc.,) are usually furnished by the computer manufacturer. ●●●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GRASPING UNIT
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ECONOMICS
MATHS
SOCIAL SCIENCE
VOKRA

Digital Computers*

This article explains briefly what digital computers are in general and how they operate. In contrast to analog computers where voltages or other analog, continuous quantities are used in computation, digital computers deal with discrete numbers (usually binary) represented by pulses which are transmitted either in sequence on the same line (serial computers) or simultaneously on different lines (parallel computers).

THE DIFFERENCE BETWEEN AN ELECTRONIC digital computer and the way a human being solves a problem, can be easily explained. The "IN BOX" ("IN tray") serves to bring the problem to the human. The desk calculator does all of the arithmetic, the pencil and paper serve as intermediate storage and input-output generation devices, the library contains stored knowledge on how to attack the problem and the "OUT BOX" (OUT tray) serves to present the completed problem. The whole operation is under the control of a human being who directs the flow of material and information. If we could replace these elements with devices that operate automatically and at higher speeds, and particularly, if we eliminate the human, we would indeed have an automatic digital computer.

In the Computer, these elements are replaced by certain basic blocks: the control unit, the memory unit, the arithmetic unit, the input unit and the output unit. The way in which these units are interconnected differs from one computer design to another.

Each unit will be discussed separately before combining them into a working system.

A basic concept necessary in understanding digital computers is the concept of the computer **word**. A computer word is a grouping of binary digits (commonly referred to as bits) that conveys a certain amount of information.

The first form can be just an ordinary signed number to be used in some type of computation. The second form of a computer word, called an "instruction" is used to tell the computer what operation to perform next. An instruction is broken down, in many computers, into three parts: the operation part, the address part and the index register identification part (where applicable). The way in which these three parts are interpreted by the control unit of the computer will be discussed later. Some typical instructions common to most digital computers are listed below:

1. Add
2. Substract
3. Multiply
4. Divide
5. Store
6. Bring
7. Branch
8. Conditional Branch
9. Input
10. Output

*Published by the courtesy of the Westinghouse Computer Systems Division

Each instruction that a computer is capable of performing has a unique code which the control unit can recognize and interpret.

From all external appearances data words and instruction words look alike. Both are represented by the same number of bits (word length). The computer can only distinguish between a data word and an instruction word from the locations in which these words are stored.

Memory Unit

One of the basic requirements of all computers is the ability to store information. This ability is one feature that distinguishes computers from calculators. One of the methods of storage used in the earliest computers was an appropriately large array of flip-flops. For the large memory capacities required in computers today, this method is too expensive. Another disadvantage of this method is the complexity and cost required for access equipment. Matrix switches must be provided for each and every flip-flop which means that the access equipment would cost as much as the storage elements themselves.

The problem in devising a memory system is, therefore, not in the storage elements themselves but in providing means to gain access to any specified storage element. All memory systems that are currently used in computers have a built-in access mechanism as an integral part of the storage element. Figure 3 shows four types of memory systems that have been used in computers. The storage medium and access mechanism for these four types of memory systems is listed below:

MEMORY SYSTEMS

Type of Memory	Storage Medium	Access Mechanism
Electrostatic	Potential on Insulating Surface of CRT	Deflection of Electron Beam
Delay Lines	Pulses Travelling Along Delay Line	Time-Controlled Gating
Magnetic Surface	Magnetised Spots	Voltage Induced in Sense Coil by Motion of Spot
Magnetic Cores	Flux Level of Ferrite Cores	Coincident Current Technique

Magnetic core storage systems which are the most common storage device in use utilise a great number of small toroidal pieces of magnetic material, called magnetic cores. These magnetic cores have a square hysteresis loop. The flux level in a core can only be in one of two states. If it is assumed that a core is saturated in the positive direction, a negative current, — Im, large enough to produce a magentizing force — Hm is required to change the flux level from +Bm to—Bm. Any current less than —Im will not change the state of the core. A magnetic core has essentially two windings (See Figure 1). Pulses of current are applied to the input winding. If the

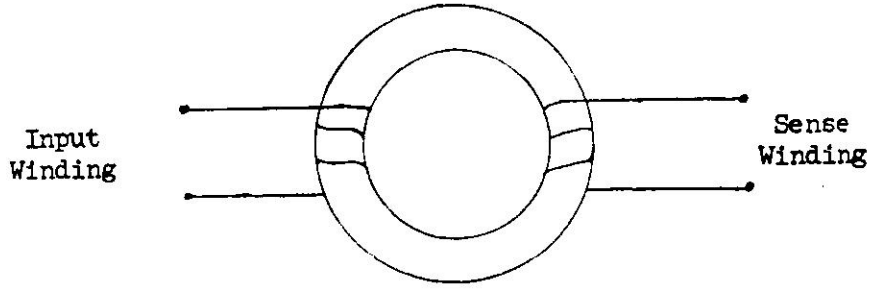


Fig. 1. Magnetic Core

magnitude of these pulses is sufficiently high and if they are in the proper direction, the state of the flux in the core will change. If more than one input winding is used, the sum of all magentizing forces determines whether the core will change its state.

The sense winding is used to determine the state of the core. To accomplish this, a positive pulse of current Im is applied at the input winding terminals. If the core is in the "1" state, the flux level will change and a voltage will be induced in the sense winding. If the core is in the 0 state, no voltage will be induced. It should be noted that in order to sense the state of a core, the information stored in that core has to be destroyed. Thus it is necessary to regenerate the information destroyed.

Figure 2 shows how a number of cores are combined to form a memory system. It also shows the technique used to select any one core in the core array. This technique, known as the **coincidence current** technique, is the most common one in large computer memory systems today. To select any particular core, for example core X_2Y_3, pulses of current $Im/2$ are applied to terminals X_2 and Y_3. This current is not sufficient to change the flux level of any of the cores in column X_2 or row Y_3 except for core X_2Y_3. This core receives two $Im/2$ current pulses which are sufficient to change its state. Core X_2Y_3 is known as a "fully selected" core while all other cores in column X_2 and row Y_3 are "half selected".

The state of any core is sensed by the same technique. The state of the selected core is caused to change from 1 to 0 by applying a current of $Im/2$ to each of the two input lines. If the original state of the core were 1, the change in flux will cause a voltage to be induced in the sense winding. No voltage will be induced if the original state of the core were 0.

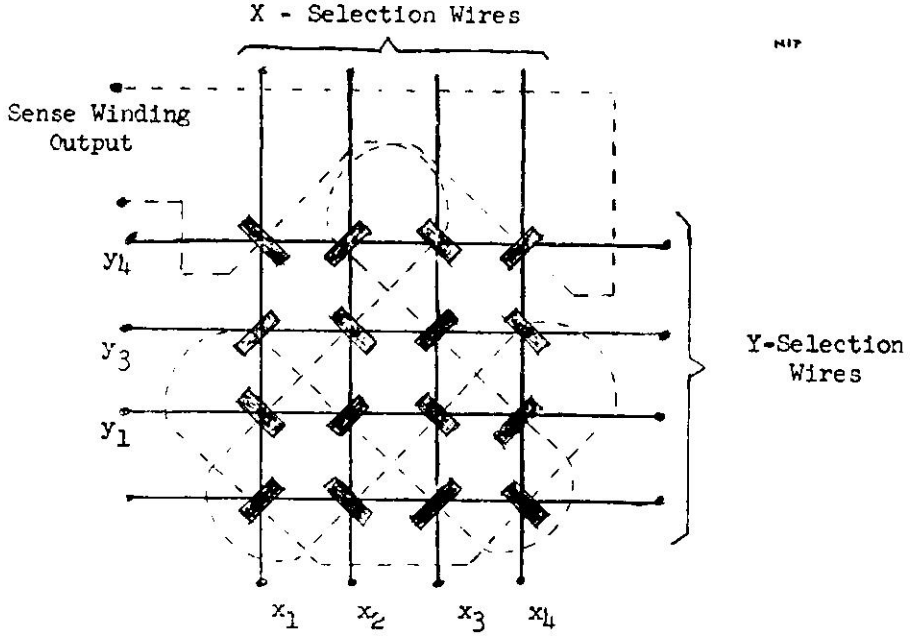


Fig. 2. Simplified Code Memory Plane

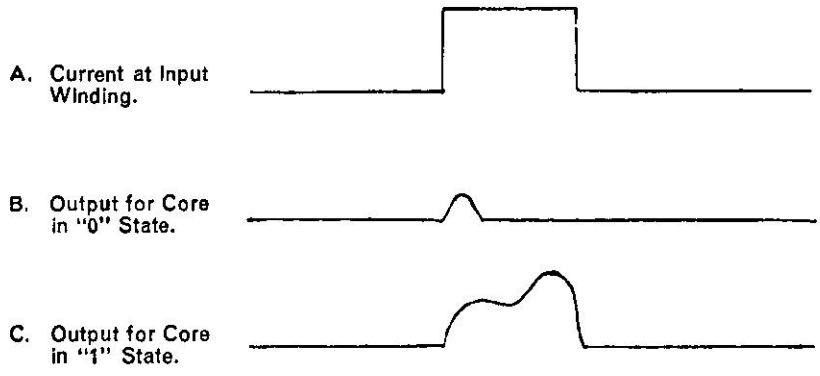


Fig. 3. Output of sense windings

It is thus seen that two distinct operations are involved. First, the operation of writing information into the core, and second the reading of information that has been stored.

A complete core memory system consists of many planes of cores of the type shown in Figure 2. In general there are as many planes as there are bits in the particular computer word. For example, the memory system of a computer with a 30 bit word has 30 core memory planes. The size of each plane depends on the total number of words. The corresponding selecting wires of each plane are connected in series. For example, wire X1 of plane #1 is connected in series with wire X1 of all planes. Similarly, wire Y1 of plane #1 is connected in series with wires Y1 of all planes. Thus, instead of selecting a single core, a whole vertical column of cores (corresponding to one computer word) is selected. Each plane has its own sense winding with a sense amplifier so that when reading, information appears in parallel on separate lines.

Data Register and Memory

Figure 4A illustrates how these planes would be connected and how they would be interrogated or read. This particular core memory would have 16 words since there are 16 cores in each plane. A word would **always** consist of 4 bits.

As an example, let us interrogate (read) the word in position X1 Y4. Upon the signal to read, half select currents are applied to terminals X1Y4. As explained previously, if the core X1Y4 in plane #1 is in the 1 state — these currents will change the magnetic state of the core to the 0 state. In so doing, a pulse is generated in the sense winding (terminal 1S1), is amplified by the sense amplifier, and results in storing a one in the flip-flop of the data register. If the core had been in the 0 state, no pulse would have been generated in the sense winding and thus the flip-flop in the data register would remain in the 0 state. Thus the first bit of the word has been stored in the data register.

It should be recalled, however, that the half select windings X1Y4 are connected in series with the corresponding windings on the other three planes. Therefore if any of the corresponding cores on the other planes is in the 1 state, a pulse will be generated in its sense winding and result in a 1 being stored in its corresponding flip-flop in the data register.

If the world 1010 was stored in position X1Y4, a pulse would occur on 1S1 and 3S1 and no pulse on 2S1 and 4S1. This would result in word 1010 being stored in the data register as indicated in Figure 4A. However, the cores in memory position are now all in the 0 state. This would be fine if it were not desired to make any future reference to this

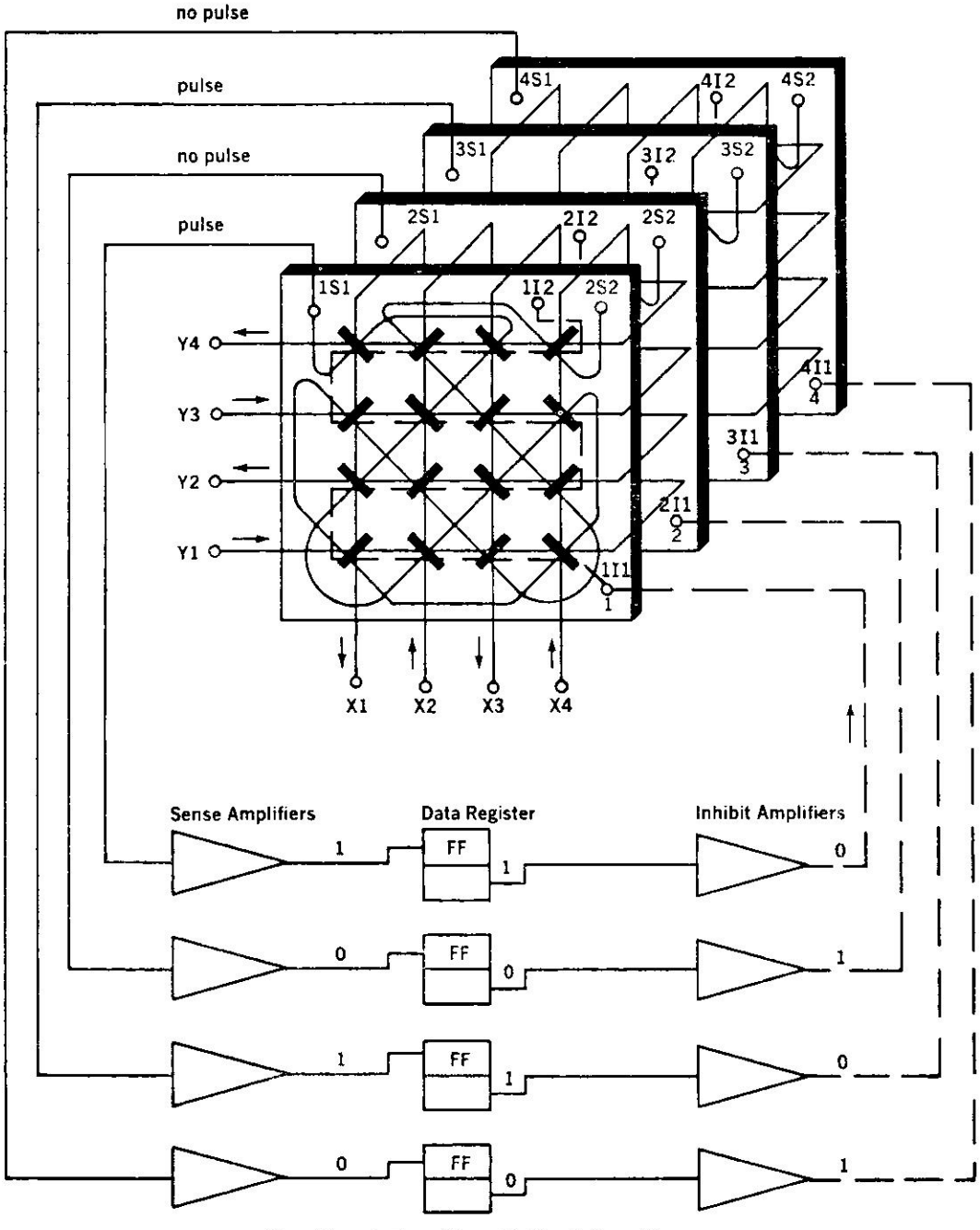


Fig. 4A. A Four-Plane 16-Word Core Memory

information. However, on occasions we may wish to store this information back into memory.

If the polarities of the half select windings are reversed and a pulse applied, all the cores in that word position would change to the 1 state. Thus far only three windings have been discussed. Another winding called the **inhibit winding** is also used. This is to enable us to regenerate or write a word into the memory. This winding is threaded through all the cores on a plane in a manner similar to the sense winding. Thus if the X and Y selection windings each carry a current of —Im/2 each, the inhibit winding should carry a pulse of +Im/2 to inhibit the writing of a one in the selected core.

In order to store the word 1010 back in memory location X1Y4, the half-select currents are reversed and the second and fourth plane inhibit amplifiers turned on. Thus the inhibit amplifiers have the outputs as illustrated in Figure 4B. The second and fourth inhibit windings have a pulse output and the two cores will remain in the 0 state since the summation of currents is (—Im/2) + (—Im/2) + (+Im/2) or —Im/2.

The first and third planes have 0 output from the inhibit amplifiers so the current will equal —Im and the cores will switch to the 1 state. The sense amplifiers are blocked during this write cycle.

Thus the complete process has been to interrogate the core and store the word 1010 in the data register and then to regenerate or write the word back into memory for future use. The data or buffer register and the memory (location X1Y4) now both contain the word 1010.

Address Register and Memory

In the preceding discussion it was not explained how the half-select currents were initiated. This is the function of the address register, decoder matrices and read-write drivers. The address register is simply a group of flip-flops and the decoder is a diode matrix.

The computer communicates with the core memory through two registers (See Figure 4B): (1) The Memory Address Register which is a register capable of containing the maximum number of memory words. This register contains the memory address of the word which is to be read from or written into. (2) The Memory Buffer register which is equal in length to the computer word. This register contains the information read from memory or the information about to be written into the memory.

The same basic sequence of operations is used for both reading and writing instructions. The total time taken by the timing sequence is called the "memory cycle". The memory cycle is an indication of the speed of operation of computers. Medium speed computers have a memory cycle of about 6 microseconds. The memory cycle consists of two periods, namely, the read time and the write time.

The write and read operations will be examined in detail, in reference to the memory cycle and the functional block diagram of the core memory driving system shown in Figure 4B.

The Write Operation

The word to be written into memory is stored in the memory buffer register and the memory address where this word must be written is stored in the memory address register. Two decoder matrices of the "many-to-one" type (one output for each combination of many inputs), are used to select the proper X-and Y-selection windings. When the "read" pulses are applied, pulses of 1m/2 are applied to the two selected windings and the selected cores on each plane go to the "0" state (See Figure 5).

During the read cycle the outputs of the sense amplifiers and the inhibit drivers are blocked and the contents of the buffer register are not disturbed. During the write cycle, the X-and Y-selected windings pass a pulse of —1m/2 each but the inhibit line is on and therefore any flip-flop of the buffer register that

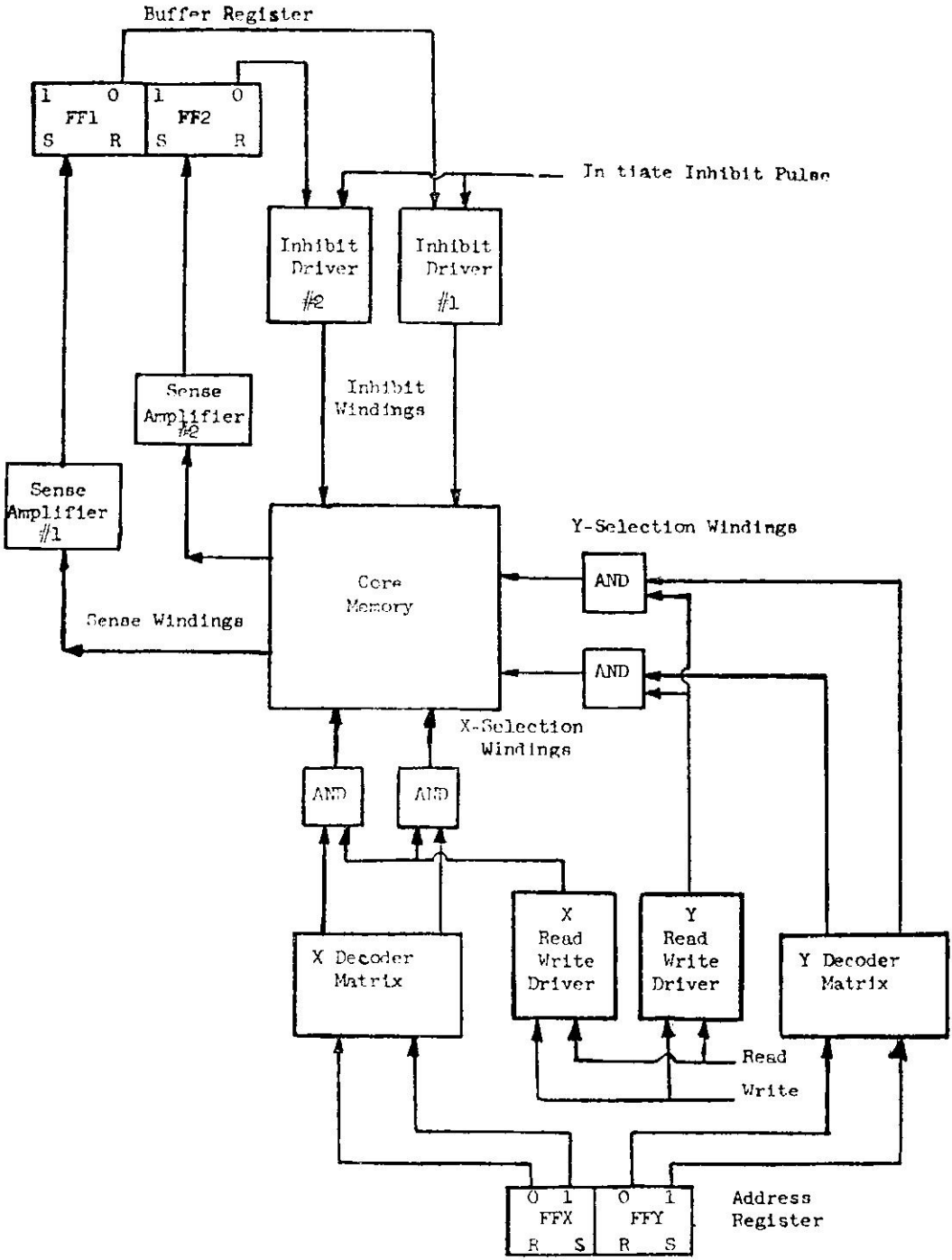


Fig. 4B. Simplified Diagram of Core Memory Driving System

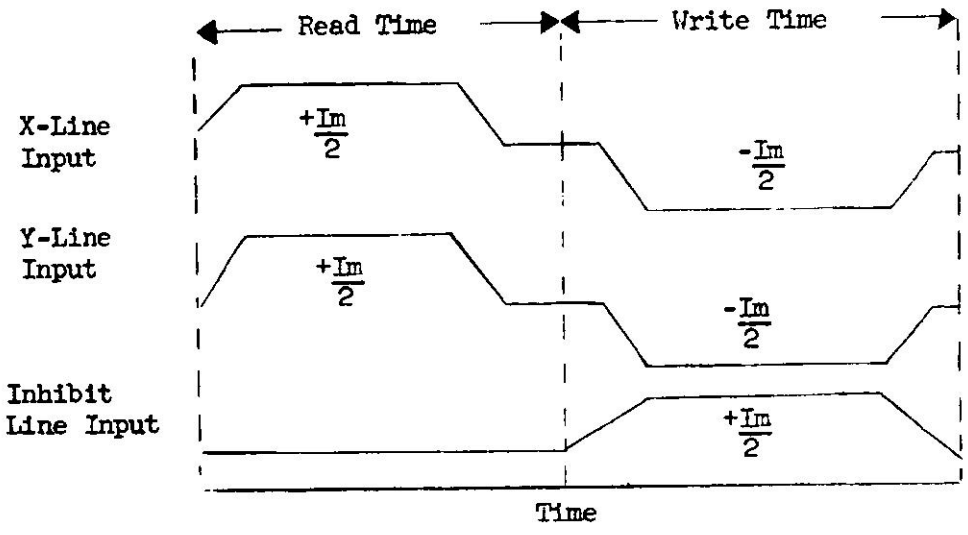


Fig. 5. Timing Sequence for Memory Cycle

is in the "0" stac, will inhibit a 1 from being written into the corresponding plane of cores.

The Read Operation

The address of the word to be read is stored in the memory address register. After the word has been read it is stored in the memory buffer register. The basic timing sequence is the same as that shown in Figure 5. The selection of the proper X— and Y— line windings is also the same. The operation of the memory buffer register differs however. During the read cycle the sense amplifiers are connected to the inputs of the buffer register flip-flops. As the selected cores are driven to the "0" state, voltages are induced in all cores which were in the "1" state. These voltages set the buffer register flip-flops. During the write cycle the inhibit pulse is applied and the word contained in the buffer register is restored in the selected memory location.

Arithmetic Units

So far we have discussed the ability of a digital computer to store into its memory any word that has been placed in its memory buffer register or to bring into the buffer register a word that had been previously stored in the memory. Words from the memory buffer register can be transferred to other registers within the computer. To perform an arithmetic operation a word must be transferred from memory to a special register in the arithmetic unit which acts as a buffer. This register is sometimes known as the arithmetic unit "addend" register. A common way in which a register to register transfer is accomplished is shown in Figure 6.

In addition to the addend register the arithmetic unit of all computers contains at least two more registers, known as the accumulator register and the auxiliary (Q or MQ) register. The accumulator is the register in which all arithmetic operations are performed and where the results of all arithmetic operations are left. The auxiliary register is used in double length operations such as multiplication and divison. In such cases the accumulator and auxiliary registers are treated together as a double length register. Some shift operations also treat these two registers together.

The hardware needed to implement all the arithmetic operations plus other special

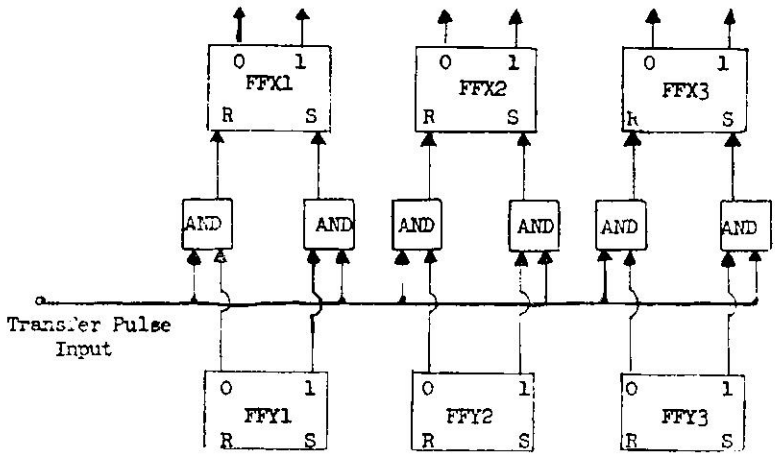


Fig. 6. Register to Register Transfer

operations is rather complicated and depends on the number of instructions that a given computer is capable of performing. Broadly the arithmetic unit works as follows: Prior to any operation the operand is stored in the buffer register of the arithmetic unit (addend register). When the operate pulse (add, subtract etc.) comes from the control unit the requested operation between the contents of the accumulator and addend registers is performed and the results are left in the accumulator. The various operations described have been of the parallel mode type. Many computers use serial arithmetic units where speed is traded for cost or series-parallel units where a compromise is made.

Input and Output Units

The input and output units basically consist of the input and output device, buffer registers that temporarily hold input-output information and proper control signal inputs. A list of common input-output media is given below :

1. Punched Cards
2. Punched Paper Tape
3. Magnetic Tape
4. On line typewriters, line printers, etc.
5. Cathode Ray Tube display
6. Manually set switches.

Command signals from the control units are used to initiate transfer of a coded character or a complete word between memory and input-output buffer registers, and to initiate the actual operation of the input or output device.

Control Unit

The operation of the various elements of the control unit are described by referring to Figure 7 where a generalized computer block diagram is shown. One of the control unit registers is the "instruction counter". The instruction counter contains a number corresponding to the address of the memory location where the instruction to be executed next is stored. Every time an instruction is executed the contents of the instruction counter are increased by one. Thus a set of instructions stored in memory will be executed in sequence unless one of the instructions is a "branch" instruction in which case the computer will branch to a different set of instructions. Note that the computer cannot distinguish the difference between instructions and data words, and therefore, if it is asked to branch to a location containing data words it will most likely function unintelligently.

The execution of an instruction is initiated by transferring the contents of the instruction

counter to the memory address register. The memory unit is directed to select the location specified by this address and to read the contents of that location into the memory buffer register. From there this instruction is split and transferred to the three buffer registers of the control unit, namely the **operation, address** and **index identification** registers. The operation register contains the code for the particular operation to be performed. This information is decoded and fed into an operation timing and control matrix whose outputs are properly timed control signals distributed throughout the computer system. The address register contains the address of the operand. In computers with no indexing the contents of this register are transferred to the memory address register and the memory unit is instructed to deliver the operand to the addend register of the arithmetic unit. Some computers have an "indexing unit". The indexing unit consists of the index identification register, several index registers and an adder. The contents of the index identification register are decoded and are used to select one of the index registers. The contents of the selected index register are then added to the contents of the address register, thus forming an effective address. The purpose of indexing is to facilitate programming. By changing the contents of an index register (instructions are provided for this purpose) the same instruction can be used to operate on many consecutive memory locations.

As an example demonstrating the operation of a digital computer consider the execution of the instruction ADD 500, 1 stored in location 1000. This instruction is interpreted as "add the content of location (500 modified by index register 1) to the contents of the accumulator". It is assumed that the code for ADD is 16, index register 1 contains the number 10, the accumulator contains the number-200 and location 510 contains the number 300. The computer will go through the following steps in executing this instruction.

1. After executing the instruction contained in location 999 the contents of the instruction counter become 1000.
2. The number 1000 is sent to the memory address register.
3. The coded number 16,5001 appears in the memory buffer register and is sent to the operation, address and index identification registers of the control unit respectively.
4. The number 16 is decoded and found to be on ADD operation.

   Appropriately timed control signals are sent to the memory unit requesting that the operand be delivered to the addend register of the arithmetic unit and the arithmetic unit requesting that the addition operation be initiated. As soon as the addition is initiated, the control unit is free and it will start decoding the instruction stored in location 1001.
5. In the meantime the number one is decoded and the contents of index register $\neq 1$ (10) are addee to the contents of the address register (500).
6. The number 510 is transferred to the memory address register and the number 300 appears in the memory buffer register.
7. The number 300 is transferred to the addend register of the arithmetic unit and is address to the contents of the accumulator (—200) to give a sum of (100) which remains in the accumulator. The instruction to follow must store the contents of the accumulator in some memory location.

IT SHOULD BE OBVIOUS THAT DIGITAL COMPUTERS POSSESS VERY LITTLE ORIGINALITY. THEY DO NOTHING THAT THE PROGRAMMER HASN'T ALREADY WRITTEN INTO THE MACHINE. THERE ARE, HOWEVER, SOME EXTREMELY IMPORTANT SUBTLETIES IN THE DIGITAL COMPUTER. WITH PROPER PROGRAMMING A COMPUTER CAN BE MADE TO ALTER ITS OWN PROGRAMME. BY TRANSFERRING AN INSTRUCTION TO THE ARITHMETIC UNIT, AND MODIFYING IT BY SOME

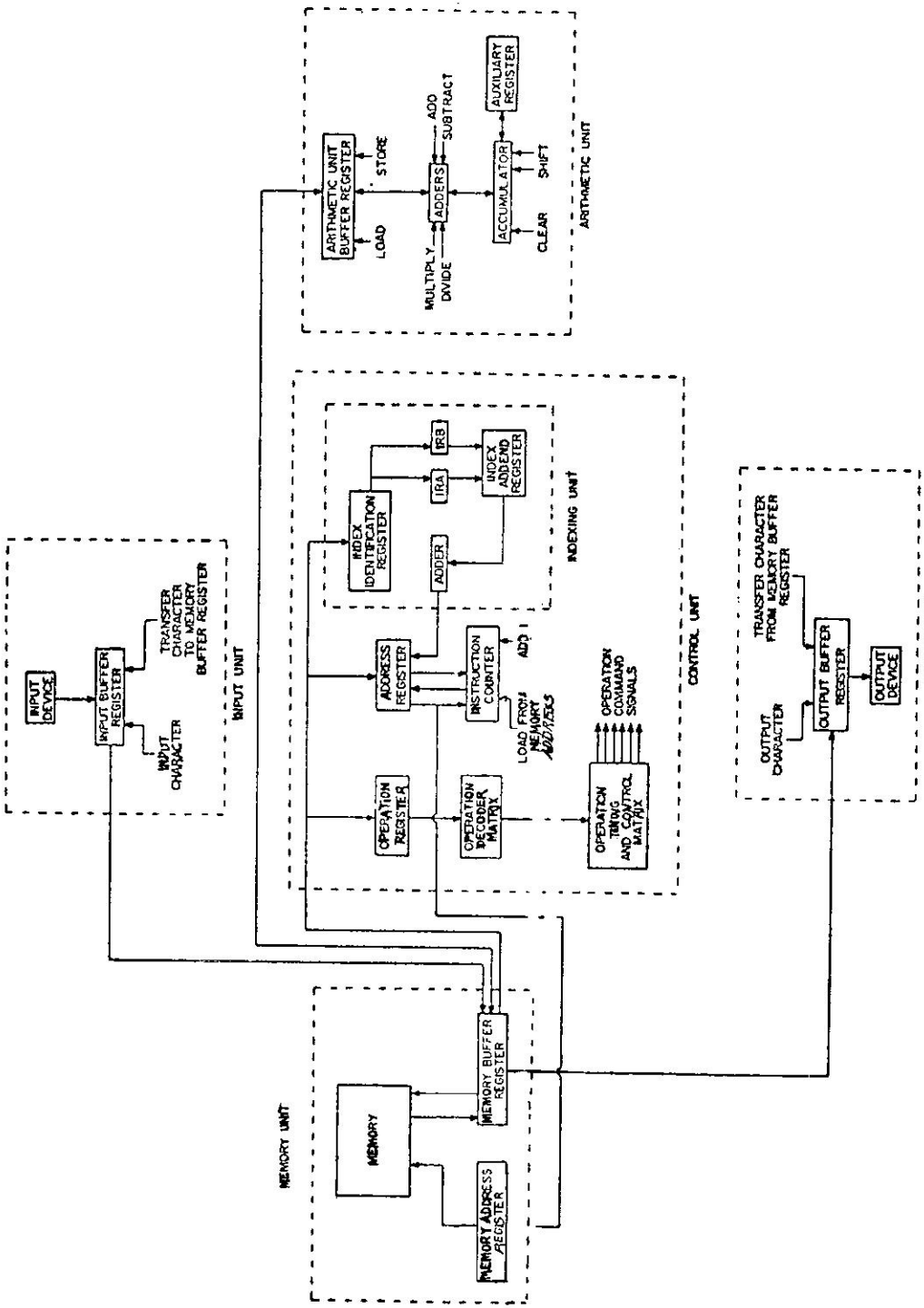


Fig. 7. Generalised Computer Block Diagram

ARITHMETIC OPERATION, THE MACHINE CAN ITSELF FORM A NEW INSTRUCTION FOR LATER USE. THE COMPUTER CAN ALSO MAKE DECISIONS, SUCH AS, WHICH OF TWO NUMBERS IS THE LARGER OR WHETHER OR NOT A NUMBER IS POSITIVE OR NEGATIVE. ON THE BASIS OF SUCH A DECISION, IT BRANCHES TO ONE OF TWO PARTS OF THE PROGRAMME AND IS THUS CAPABLE OF DETERMINING ITS FUTURE COURSE OF ACTION DEPENDENT ON THE PRESENT STATE OF THE PROBLEM. ALL OF THESE "DECISION MAKING" OPERATIONS ARE PUT INTO THE PROGRAMME BY THE PROGRAMMER.

PROGRAMMING AND FLOW CHARTING

Programming

Programming is the process of preparing a sequence of instructions which the computer must execute in order to solve a problem. Unlike many scientific type programmes where any one programme may not run very often, control programmes are repeated minute after minute, day after day, and therefore great care must be taken to minimise execution time and memory storage required. Most control computers operate in a "fixed point arithmetic" mode. This means that the arithmetic unit treats all data as if the binary point, which separates the fractional from the integral part, were fixed (between the sign bit and bit $\frac{1}{1}$). Since the number handled by the computer have different scaling factors, scaling must be taken have different into account by the programmer. Each piece data is assigned a scaling factor, and whenever an operation takes place it is recalled that when adding, the numbers added must have the same scale factor and when multiplying the scale factor of the result is equal to the sum of the scale factors of the multiplicand and the multiplier. Scale factors can be changed through the shift instructions. The alternative to fixed point arithmetic is "floating point arithmetic" where each number is represented by a magnitude (mantissa) and an exponent (binary in case of binary machines) called the characteristic. Floating point mode of operation is available in some large-scale computers as an integral part of the hardware. Its cost, however, is not justified in a control computer with a fixed programme. If the complexity of computation for a specific application demands floating point operation, then special "subroutines" or "interpretive programmes" can be provided which can execute floating point instructions.

A **subroutine** is a sub-programme that is executed several times in the course of running a long programme. Rather than take space to store this sub-programme at every part of the sequence where it is used, this sub-programme or subroutine is stored only once and appropriate instructions are provided so that one can enter the subroutine from different locations and exit to the location from which entry was made.

An **Interpretive programme** examines and interprets each instruction before executing it. These instructions need not be machine instructions. One can define any type of instruction and have the interpretive proggramme interpret and execute it. The penalty that is paid for this convenience is the slow speed of execution of instructions.

A programme written by a programmer is in symbolic form. This means that operations are designated by their mnemonic codes (ADD, MPY, etc.) and addresses are in decimal or some other alphanumeric form. A **Symbolic Assembler** is required that will translate the symbolic language into machine instructions. When using an assembler it is not necessary to define all addresses as absolute numbers. One can express addresses by symbolic alphanumeric expressions and the assembler would then assign an absolute location to each expression. A Symbolic Assembler is part of the large library of subroutines and other programming aids that are usually available with a computer.

Flow Charting

Programming in its broader sense includes more than coding of required operations into machine language. Before a problem can be coded, **the general method of solution must be decoded and the logical steps to be**

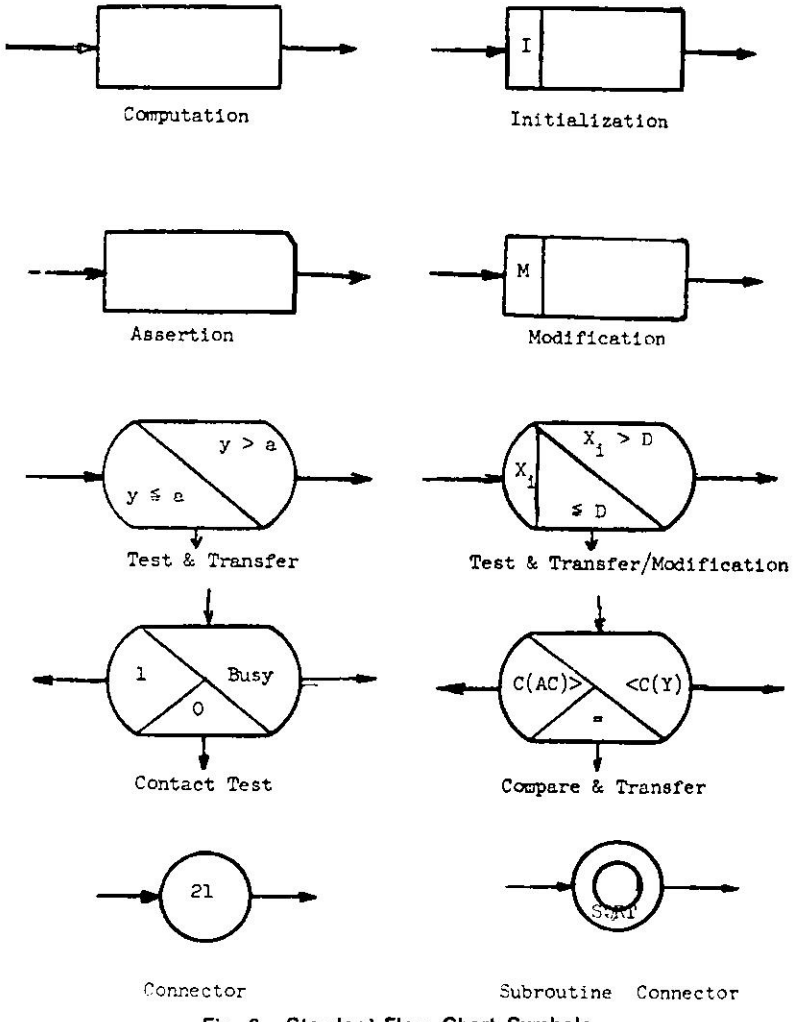


Fig. 8. Standard Flow Chart Symbols

followed as well as all alternatives must be described in detail. This is best done in the form of a flow chart. The ACM (Association for Computing Machinery) First Glossary of Programming Terminology (1954), defines "Flow Chart—a graphical representation of a sequence of operations, using symbols to represent the operations such as compute, substitute, compare, jump, copy, read, write, etc." In actual practice the flow chart consists of a series of boxes connected by lines and arrows indicating the direction of flow.

The types of boxes shown in Figures 8 are adequate for most kinds of flow charts and represent a consensus of what is actually being used by most of today's programmers.

As an example of flow charting a simple scanning problem is presented below :

PROBLEM—Scan 5 input variables when a "scan" pulse is applied. Compare against

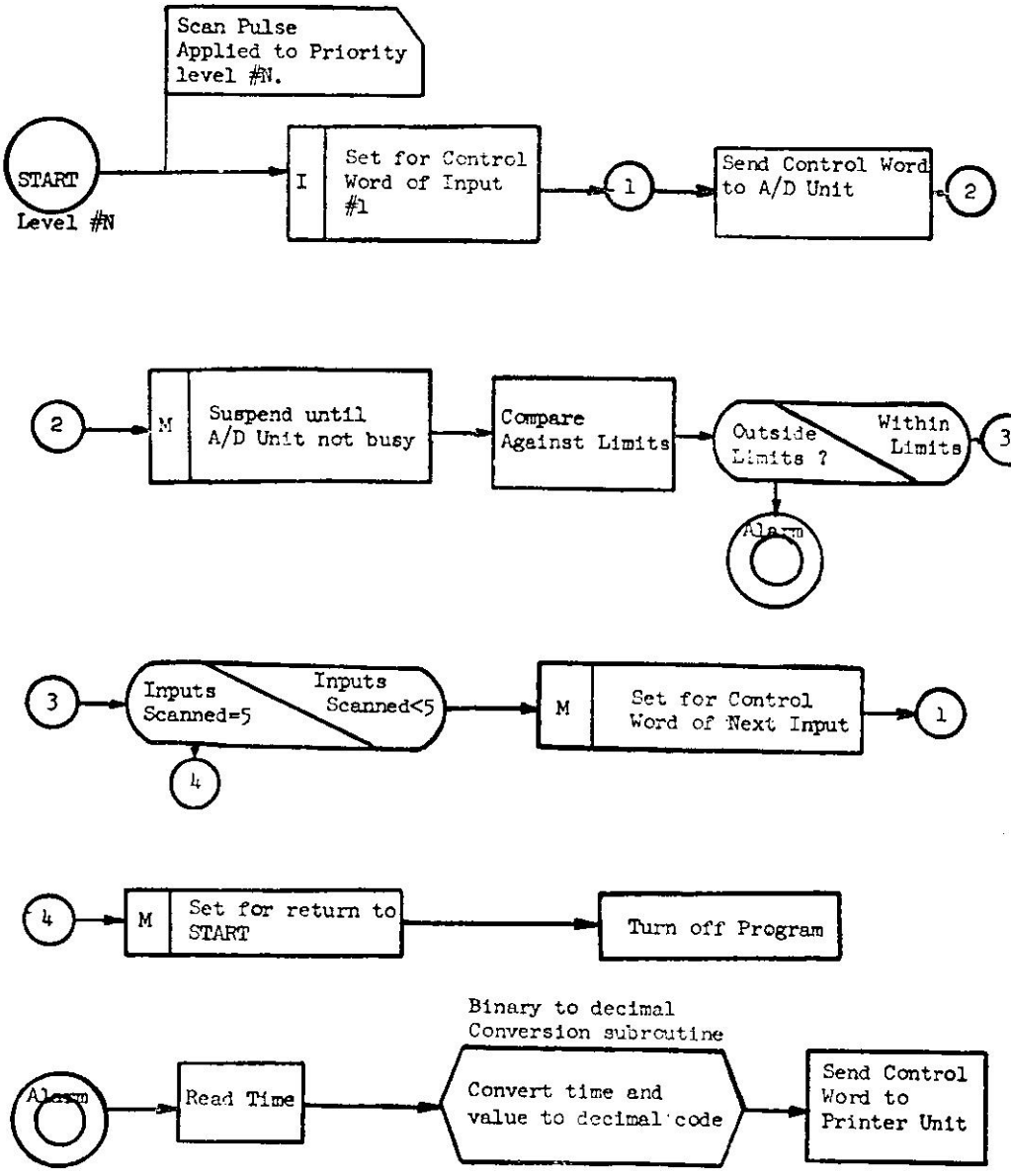


Fig. 9. Flow Chart for Scanning Problem

high and low limits. If the limits are exceeded, sound an alarm and print time and value of variable.

The flow chart outlining the way in which the computer would go about solving this problem is shown in Fig. 9. A skilled coder can translate this flow chart into a sequence of machine instructions.

FUNCTIONS OF A CONRTOL COMPUTER

This section will describe very briefly the functions that a digital control computer is capable of performing. A computer controlling a typical process has three general types of inputs and three types of outputs. The first group of inputs includes all analog variables (pressures, flows, temperatures, etc.) which are read into the computer through the A/D converter. The second group includes all digital inputs from the process such as flow meters, limit switches, contact closures, presence detectors, etc. The third group of inputs consists of all manual inputs which the operator sets on the operator's console. This group includes programmes, process parameters, alarm settings, etc. This information is entered into the computer either through the tape reader or through switches and pushbuttons on the operator's console.

The computer outputs are also divided into three general categories. First there is the periodic logging of system variables and other statistical information for review and evaluation by management. The second type of outputs includes information which the operator can use in supervising the process. In other words the operator is used to close the feedback loop. Operator information includes visual trend displays, alarms, annunciator panel, operational guides, etc. The third type of outputs are analog (obtained through D/A converters) which are used to set control subloop set points. These analog outputs are calculated according to some optimizing control strategy that is part of the overall computer programme.

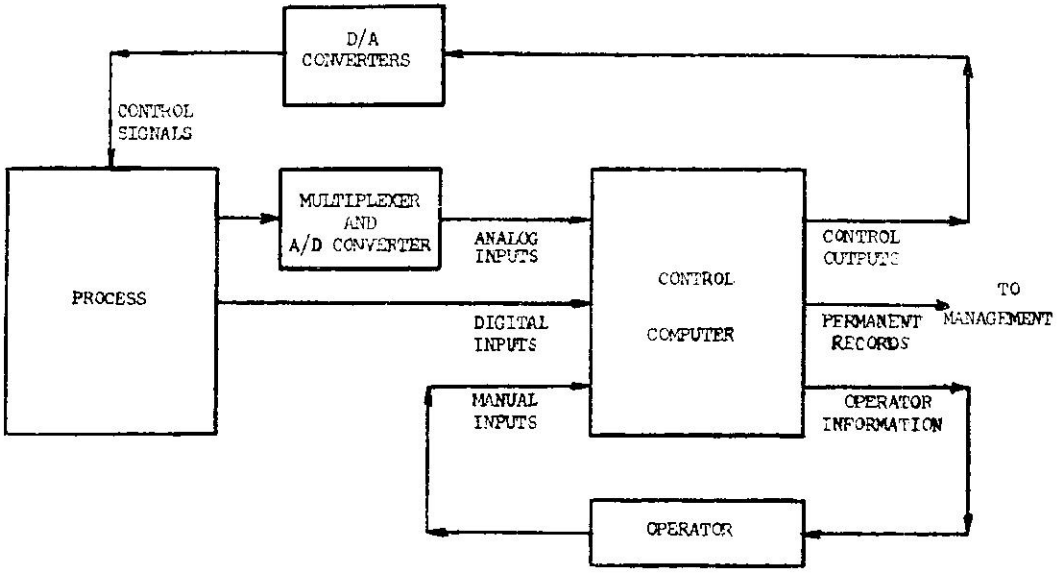
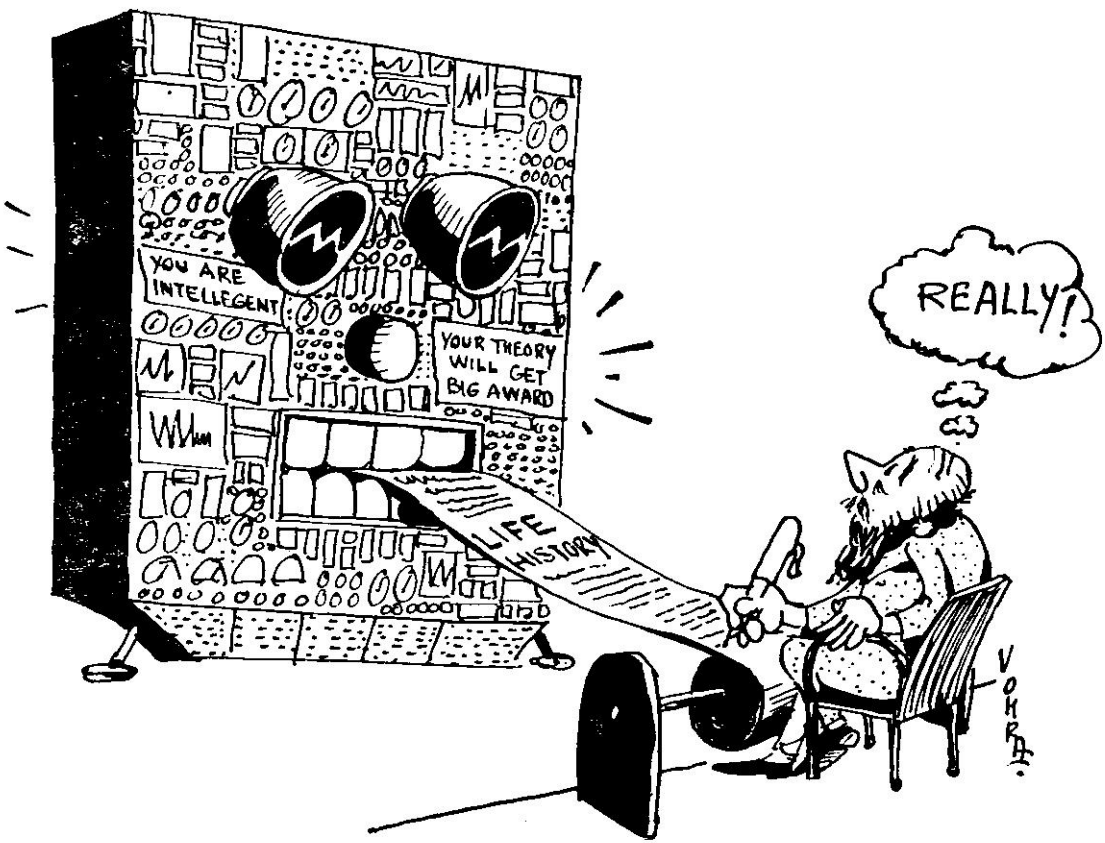


Fig. 10. Block Diagram Showing Typical Computer Functions

The order in which the above three types of outputs have been listed represents the evolution of computer applications. At first the only function that would be entrusted to digital devices was the accumulation of information from the process and the logging of this information for the operator's use and also for permanent record. Soon engineers discovered that digital computers were able to do much more than scan and log data. The small additional cost of a digital computer over a data logging system was justified on the basis of the additional supervising function that a digital computer could offer. Thus the computer was allowed to assist the operator in the many decisions he had to make in order to operate the system. At this stage, however, action was only taken by the operator.

With the accelerated improvement of digital computer components (transistor, core memories) and design techniques, digital computers have proven themselves fast and reliable enough to take up the control function. Today digital computers are used to set sub-loop controller set points and to coordinate the operation of many sub-loops within a system.



Fourth-Generation Software

Ascher Opler*

This article is based on one man's guess about the next generation. The guess is that fourth-generation hardware will use large-scale integration (LSI) logic specialised by micro-programming. Integrated logic chips will be needed to obtain the required fast circuitry and the micro-programmed specialisation will be needed to obtain the required software and user interfaces.

THE ELEMENTS OF ONE OF THESE COMPUTERS might have these characteristics :

circuitry (LSI)	5 nanoseconds
micromemory access	10 nanoseconds (read time)
main memory access	400 nanoseconds

In the most radical departure from present architecture, the computer would have **no order set** and **no data structure.** The computer would be specialised for the various roles it is to play by **replaceable micro-programmes.**

Third-generation microprogrammed computers are delivered with a pre-designed, pre-installed microprogramme of the read-only type. And in most members of the product line, the option of an additional read-only memory carrying a **second** microprogramme set is available. This second set serves to provide full or partial compatibility with the order set of an older computer.

In fourth-generation computers, **many** microprogrammes will be available from the manufacturer. Software and user specialists will also prepare and use their own. This should throw the whole field wide open.

*A noted software specialist, the author was formerly Programming Director of Computer Usage Company; now Executive Director of Computer Usage Education Inc., New York.

To better understand the nature of micro-programming a no-order set/no-data-structure computer, I believe it worthwhile to introduce a new word into our vocabulary : *firmware.* I use this term to designate microprogrammes resident in the computer's control memory, which specialises the logical design for a special purpose, e.g., the emulation of another computer. I project a tremendous expansion of firmware—obviously at the expense of hardware but also at the expense of software.

Microprogramming has, of course, been known since the early days of computing. The principle is simple — build a small microprocessor and drive it with a stored microprogramme.

Take floating-point addition as an example. In the first generation, it was performed with a normally-programmed subroutine. In the second generation, it was implemented in circuitry. In third-generation microprogrammed computers, the floating-point addition is performed using a microprogramme stored in read-only memory.

One major factor making this possible is the ratio between main memory access time and circuitry speed. With integrated circuits (IC) and now LSI, times have **plunged** to 1-5 nanoseconds while the access time of main memory has **slowly** declined. This allows 30 to 70 micro-steps to be performed by circuitry between each main memory fetch or

store. These 30 to 70 steps permit the implementation of third-generation order sets.

The memories are called read-only memories but, of course, the contents had to be written once in order to "load" the memory. Today this is done as part of the computer fabrication process. For the fourth generation, extension to slow-write fast-read (SW/FR) memory is anticipated.

The interface between "normal" programmes and microprogrammes comes via the operation code. In effect, when each instruction is decoded, the operation code calls upon a specific microprogrammed "routine" stored in the micromemory.

To visualise the preparation of firmware, consider special keypunch not available to software and user programmers. This punches 67-column cards (4 x 8 inches) with triangular holes (try that on your keypunch and card reader!). A special card reader loads decks of these 67-column cards into the fourth-generation SW/FR memory. This card reader probably will be locked so that only firmware specialists have access to it!

What Firmware Can Do Now

Even in the third generation, firmware is expanding the capabilities of hardware and software. Its effect on reducing the cost of hardware is central to third-generation economics. Unprecedented production rates with reduced requirements for system checkout and delivery are due to both integrated circuitry and to microprogramming.

Specialised versions of standard product line computers have been prepared primarily by altering the microprogramme in the read-only memory. The most spectacular success has been achieved with all-hardware compatibility via a special microprogramme. The success of the IBM System/360 Model 30 in running IBM 1401 programmes attests to this fact.

Emulation, a combination of software and hardware, operates by using two different microprogrammed features. Basically, an emulator is an interpretive simulator made much more efficient by using a microprogramme to perform the basic interpreting loop—fetch an instruction. decode the address, access the contents of the address and perform the indicated operation. In addition, the op-codes that are most time- (or space-) consuming to simulate are directly executed by microprogramming those orders into the micromemory. Emulation is, of course, required when the micromemory is too small to contain the entire order set of the second-generation computer.

Firmware in the Fourth Generation

Assuming the availability and accessibility of adequate SW/FR memories in the next generation, the entire **hardware/software** interface problems disappear only to be replaced by the more complex **hardware/firmware/software** interfaces.

Secondly, firmware will assume a dominant role in structuring the computer. Manufacturers could (potentially) supply firmware decks allowing their fourth-generation computer to execute the order set of most popular third-generation computers — their own and competitors'. There could be a standard fourth-generation industry-wide order set and data structure.

But an even more significant impact would be felt by software. There is a general consensus that present software is too large, too complex and too slow. It is in the tradeoffs between software and firmware that most price/performance improvement should be obtained.

Third-generation computers require control programmes to resolve and handle interrupts, to control multiprogramming and input/output despatching, and to provide useful services such as resource allocation and protection, etc. The demands placed on control programme by the hardware and by the user have forced the current programmes to swell to enormous size with concomitant reduction in performance.

For fourth-generation computers, the answer will lie in using firmware for major portions

of the control programme functions and in using special features built into the firmware to facilitate other control programme functions.

For instance, one problem that contemporary software must solve is to provide flexibility so that any particular installed configuration can be used with "general purpose" control programmes. Even though "system generation" is used to specialise a generalised control programme for a given configuration, the resultant code often contains lengthy subroutines to handle such functions as resolving device error signals, providing special user error recovery or interrupting the processing routine. The point is this — to provide modularity and flexibility, manufacturers are currently forced to delegate obvious hardware functions to software since this is the only means by which the user of the computer can specialise it for his use.

In fourth-generation equipment using SW/FR micromemory, micropogrammes can be prepared by the firmware specialists — manufacturer, programming company or the user — to carry out the specific interrupt and input/output control function specified by the user. This alone will go far to simplify control programmes.

Further simplification can be obtained by making the data structure and order set work for, not against, the implementors of control programmes. The basic implementation involves techniques of queue management, control block handling, table reference, internal sorting, pointer handling, etc.

Since microprogramming permits extensive data structuring for control programme implementors, it will permit the addition of instructions to enqueue, dequeue control blocks, build search and sort tables of specified structure, etc. These new commands should prove a boon to expediting the running of supervisory programmes.

Time-sharing and multiprogramming both require very fast switching among programmes. Many fourth-generation computer programmes (processors and utility programmes) will be written in the form of re-entrant code. The new hardware must be able to preserve the status of each user's computation and, when re-entrant code is used, to preserve blocks containing variables and other parameters. Currently much of this preserve/restore function is performed by software. Delegating this function to firmware should reduce the milliseconds performance time to microseconds.

Compilers and Firmware

Last year, a paper by Melbourne and Pugmire described the design of a small computer for **directly executing** FORTRAN **statements**. The machine, which was simulated but not built, was "controlled by a microprogramme held in a fixed store." Marketing men can determine the reception of a FORTRAN-only computer—but it is certainly one reasonable approach for the fourth generation. With SW/FR firmware, the FORTRAN microprogramme can be read into micromemory—instead of the order set of a computer.

Short of a computer which executes programming language directly, firmware can add many features to fourth-generation computers to facilitate compilation and execution. Special instructions corrseponding to the POP (programmed operators) of Digitek compilers can be microprogrammed to facilitate compilation. Facilities like the "hardware algorithms" of System/360 Model 91 can operate on object code to permute computational order and even eliminate redundancies. Direct execution of statements in Polish string notation — a technique first used in the KDF 9 and B 5000 — can add to the power of new computers which handle programming languages with unprecedented speed and economy.

It is quite likely that the bulk of programmes run on fourth-generation computers will be written using standard programming languages. These may be run in some multiprogrammed (or time-shared) manner with other programmes on a large computer run as a "power house utility" serving many users—or on small "private" computers, dedicated to a single application use (e.g., message switching) or the needs of a single isolated

user (e.g., small engineering laboratory). The latter may very well prefer to use the FORTRAN-only computer while the user of the dedicated equipment may find it to his advantage to start from scratch and write the central portion of his programme in firmware using normal core (or thin film) storage only for bulk tables and transient storage.

Depending on the ease of preparing, debugging and loading firmware, the whole application area might be radically altered. But it will probably be worthwhile to prepare firmware only for real-time, dedicated, applications where every microsecond (nanosecond ?) counts!

At the present time there is a limited supply of microprogrammers and a **relatively** small demand for such services. The only firmware under preparation is in the shops of manufacturers and is performed under careful supervision of hardware designers. Preparing microprogrammes is considerably different from writing programmes. It requires a more detailed knowledge of the function of circuits and registers.

Automatic preparation of microprogrammes starting with some "higher" level language — like FLOATING ADD A, B — has not been achieved. However, as firmware becomes more important, increased effort to facilitate its preparation will certainly be made. Indeed, if some of the many roles that firmware is to play in the fourth generation are to be realised, a new generation of specialists must be trained and effective tools provided for their use.

Perspective

With increased demand for low-cost, high-performance total systems, the emphasis continually shifts to means of buttressing hardware to make it easier and more efficient to use. The third generation has seen the peak of the effort in software. No doubt the fourth generation will require equivalent effort — but placing much of what was software into the firmware area should go far to prevent some of our current difficulties. ●●●

Specialists Beat Computer

LIMA, (Peru), April 23—Six heart specialists pouring over cardiographs from three patients outdid a computer yesterday in diagnostic study.

But the contest was close. . . .one victory for the specialists and two ties.

"A computer is not as good as an expert", said Dr. Eliot Corday, a past president of the American College of Cardiology. "But a general practitioner could use a computer to good advantage."

The cardiologists *vs.* computer contest was set up at the eighth inter-American Congress of Cardiology, a week-long meeting of some-200 heart doctors from 21 American countries.

The doctors won the first test—studying the cardiograph of a 75-year-old man with a chronic congested heart.

"I believe doctors everywhere should support development of computer diagnosis," Dr. Corday said.

Even though man triumphed, "you have to give one thing to the computer," he said, "It is faster."

"It'll produce a diagnosis in 13 to 15 seconds. We usually take a little longer."—AP.

Fourth-Generation Hardware

Gene Amdahl & Lowell Amdahl

The third generation of computer technology can be characterised as one of unification. An attempt has been made to unify in one computer structure the effective capability to perform commercial, scientific and real-time tasks. Time-sharing is being elaborately analysed, with conversational mode systems in early use. Monolithic integrated circuits are coming into widespread computer use, but with their greatest potential yet to be realised.

TO ACHIEVE SOFTWARE INTERCHANGEABILITY, the concept of upward compatibility has been extended by some to include downward compatibility, giving rise to families of computers differing only in speed and price. Manufacturers such as IBM found that this could be accomplished only by drastic means —design of a totally new line of computers having basic differences from predecessor equipment. The transition to the third generation has therefore been arduous, with techniques such as microprogramming and emulation being employed and with complete new software being required.

Fourth-Generation Hardware : Batch Fabrication

Computer hardware of the fourth generation is anticipated to be most strongly characterised by batch fabrication. In areas of logic circuits and high-speed memory, complex arrays of switching circuits on single silicon chips will be batch fabricated. This is referred to as large scale integration, or more simply, LSI. It should be noted that batch fabrication does not necessarily mean the concurrent fabrication of identical items ; rather, it means the concurrent fabrication of many different items passed through identical process steps. This permits economically produced silicon chips to logically differ. While large parallel computers (such as the proposed Illiac IV) could have many identical chips, small computers would be denied this luxury. Therefore the economic production of many different kinds of chips would benefit the manufacturer of the small computer.

Integrated circuits offer benefits of batch fabrication both in the area of logic circuits and memory. The benefits of LSI for logic circuits will be reduced cost, greater density and greater speed. The limitations of LSI in this use arise in interconnections, heat dissipation and chip complexity. To use LSI, a problem of the first magnitude will have to be solved: the complete automation of chip design. This problem is vastly complicated if yield must be enhanced by adjustment of the interconnection pattern of cellular circuits as a function of test results.

LSI memories can be very high speed and can permit multiple-access use. Because select and sense circuits are fabricated by the same process steps as those used for memory cells, high performance memories are expected to be relatively inexpensive. An economic property of considerable advantage for small memories is the relatively linear cost per bit as a function of size exhibited by LSI memories. But these speed and cost advantages will not apply to large LSI memories. Another factor to be considered by systems designers is the volatile nature of the LSI storage cell, permitting loss of information stored when power is removed.

Other batch fabrication techniques for memories will undoubtedly emerge in each of the areas of wired ferrite arrays, woven plated wire arrays and thin films. Any of these will be suitable for large quantities of lower-speed random-access memories and would not have the volatile characteristics of the LSI memory.

Mass storage still appears to be dependent on electromechanical devices for lowest cost implementation. To a large extent this is due to the fact that batch fabrication is always easier to achieve when detailed structure is unnecessary, and the fabrication of the surface of a disc or drum is indeed batch fabrication of an enormous number of storage cells. However, the feverish activity in the development of static (nonrotating) mass storage will surely result in its use in fourth-generation equipment, particularly for systems requiring rapid information retrieval.

Architecture : An Attempt to Balance

The economic consequences of batch fabrication are expected to have the greatest effect on fourth-generation architecture. Even in the third generation, processor costs are relatively low compared to other system cost factors such as i/o channels, peripherals, marketing and software. In the fourth generation this imbalance will tend to increase, with the system architect offsetting it by greater instruction capability, more processing overlap and parallelism, and additional hardware features for multiprogramming and multiprocessing.

The use of the high-speed LSI memory will tend to impose an additional level in the memory hierarchy. This will emphasise the need for semi-automatic control of memory, perhaps along the lines of paging techniques. We would expect that considerable emphasis will have been applied to this area due to difficulties incurred in third-generation systems. The problem here is to make the memory appear to be a very large and homogeneous virtual memory (techniques which permit viewing main memory as unrestricted by actual main memory limitations), yet without imposing virtual response and virtual solution times.

Basically the computer can only deal with information residing in real memory. It must in some manner be provided with instructions which, during its operation, can cause it to control the transmission of information between hierarchy levels with as much preplanned structure as is possible. In circumstances where preplanning is inadequate, multiprogramming must be able to fill the voids.

Failure to provide any preplanning would raise the level of multi-programming, requiring memory capacity that would be considered excessive even in the era of batch fabrication. The solution time for individual large problems may become excessively long in a multiprogrammed environment, making the system unsuitable for this purpose. Algorithmic control, suited to access characteristics of data sets, will undoubtedly become important. The nature of the control would be governed by programmer specification or by recognition of historical referencing properities as determined by the hardware.

Another area of architecture is the employment of microprogramming to an extent that compiler languages might be optimised. In a campanion article, Ascher Opler predicts a fuller utilisation of this technique in the fourth generation and the emergence of firmware specialists.

The question of equipment dependability will come under careful scrutiny in the fourth generation despite the fact that LSI will offer high reliability. The reason for this scrutiny will be the customer's concern for nearly absolute computer up-time in time-sharing environments. While in the past he was willing to accept turnaround delays due to the computer being down, he will not accept inoperative on-line terminals. Partial redundancy, multiple processors and in-line diagnostics should result from this emphasis. With LSI, redundancy can more economically be achieved than with discrete components.

Software : More Freedom

The role of software has been changing from generation to generation. From an initial

start of freeing man from dealing directly with the computer by the provision of input-output utility programmes, the role has progressed from having to deal in absolute terms by means of symbolic programme assembly, from having to deal in basic terms by means of macro assembly and compilation, and finally from having to deal with space-time boundaries by means of data management programmes and virtual memory. One of the current activities is aimed at freeing man from space and time separation from the computer by time-sharing.

One can speculate as to those freedoms which will be sought for the next generation. A number of likely candidates come to mind, many of which have been started and have varying degrees of progress. Some fairly basic ones are (1) freedom from redundant effort by means of common libraries of programmes and data sets in the information utility, (2) freedom from limited forms of man-machine communication by means of better techniques for the identification, extraction and display of meaningful information, (3) freedom from necessity to recognise the particular machine type being used by software standardisation, and (4) freedom from painful recovery on machine malfunction by automatic detection and by maintenance of user transaction journals.

It is interesting to note that these freedoms contribute to a layer of basic concepts. These concepts relate the more abstract notions o computing to the detailed dynamic activity of the hardware computer. As more freedoms are added which release the user from primitive representation of his problem, he is further insulated from the hardware. This intervening software structure will develop into a capability for self-generation of programmes for specific computational actions. Such programmes will enjoy an existence so brief that they deserve a unique name, for which *bubble-ware* is advanced.

One can deduce that significant overhead will be added in the execution of hardware functions as the user gains freedom in detailed programme declaration. Despite this, the hope for fuller realisation of human creativity will give continued impetus for this trend to greater abstraction.

Beyond the Fourth

It may be inappropriate to speculate beyond the fourth generation, but it appears that the logical conclusion to be drawn is that the ultimate goal must be **freedom from having to deal with the computer at all.** When this level of development has been reached, creative intellect will have burst its final shackles, free to wing to new Olympian heights. ●●●

I was learning electronic data processing in a training programme at a large firm. Our instructor fairly emanated positive thinking. One day when we were discussing a certain procedure, some of us mentioned problems that we had encountered. After listening for a few moments, our instructor exploded, "Gentlemen, there are no problems in data processing—only opportunities!"

After a moment's silence, a meek but audible voice said, "Sir, could you help me with an insurmountable opportunity?"—ROBERT MITCHELL

Information Retrieval

Robert M Hayes*

The computer was originally designed for application to scientific computation and later rapidly found application in business data processing. At an early time, however, other applications were foreseen. In 1947 Vannevar Bush wrote "As We May Think" in which he delineated the capabilities of *Memex*-the computer, but used for tasks such as information retrieval and language translation. Since then, such applications have become increasingly important, and the term "information retrieval" has become a broad one, covering the problems in management information systems, command and control, urban data banks, and dissemination of scientific information.

The purpose of modern "information retrieval" is to use computers, photographic processes, and techniques of magnetic recording, as they have developed over the past 20 years, to provide a capability for solution of problems comparable to that given the scientist in the solution of computing problems.

THE TERM "INFORMATION RETRIEVAL" HAS become so broad that it is useful to classify the several different kinds of systems into three groups: data base systems, reference systems, and text processing systems.

Data Base Systems : The most widespread information retrieval systems are those for data base file management, which process records organized into fields, each containing a type of data in the record. These can be schematically represented :

	$Field^1$	$Field^2$	...	$Field^n$
Record	$Data^1$	$Data^2$	...	$Data^n$
Example of record for a person	Name	Social Security		Birth Date
	J. Smith	123-45-6789	...	12-03-26

A set of these records is arranged in order by a specified field (e.g. chronologically by birth date) and is called a **file.**

In recent years, there have appeared a number of "generalised file management programmes." Table 1 presents a list of some of the generalised programmes now operating or under development. These provide capability for adding records to such files and changing the contents of specific fields of existing records. In this respect they are like typical data processing systems. Of more importance for purposes of subsequent information retrieval, they also provide capability for searching files in answer to requests phrased as **Boolean combinations** (using logical **and, or,** and **not**) of specified values in specified fields. One such request might be : "Find all records with A in Field 1 and B in Field 2 **or** with C in Field 1 **and** D in Field 3."

An example of a data base system occurs in business data processing, in which day-to-day clerical operations generate large quantities of

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TABLE 1

GENERALISED FILE MANAGEMENT PROGRAMMES

Programme Name	Organization
GIS (Generalised Information System)	International Business Machines
INFOL	Control Data Corporation
TDMS	System Development Corporation
DM/1	Auerbach Corporation
MARK IV	Informatics, Inc.
CFSS (Combined File Search System)	Service Bureau Corporation
FFS (Formatted File System)	International Business Machines
ICS(Information Control System)	North American Rockwell

data. **Management information systems** are used to identify these data, store them, and retrieve them for further use, particularly decision-making. Another example occurs in cities and states, where **metropolitan data banks** are used to acquire data from the normal operations of government agencies, store and retrieve them, and analyze them using models of urban development. Table 2 presents a list of some existing efforts to create such data banks. Other examples are the hospitals and medical centres (among them Massachusetts General Hospital and the Veterans Administration) developing consolidated **medical records systems.** The data come from administrative forms (entry, records, test results, prescriptions, etc.), from on-line monitoring of patients, and from direct input by doctors and nurses. They are used to aid in diagnosis, in care of critically ill patients, in research, and in hospital administration. Perhaps the most advanced examples are the systems for **command and control**, used to support military operations. The SAGE system, for example, monitors signals from radar and telemetry, correlates them with previous data, stores the results, retrieves and displays them when needed for evaluation by analysts, and transmits decisions to command posts for continental defence.

Reference Systems : Data base systems handle highly formalized descriptions in formatted records of defined field structure.

TABLE 2

City or State	Purpose
Alexandria, Virginia	Administrative
Boston, Massachusetts	Planning
Chicago, Illinois	Land Use and Transportation
Denver, Colorado	Land Use
Detroit, Michigan	Social Welfare
El Paso, Texas	Land Use
Fort Worth, Texas	Business Development
Little Rock, Arkansas	School Planning
Los Angeles, California	Administrative
Louisville, Kentucky	Transportation and Land Use
Oakland, California	Police Files
Pittsburgh, Pennsylvania	Land Use, Economic Development
Portland, Oregon	Renewal
Rochester, New York	Land Use
San Francisco, California	Renewal
Santa Clara, California	Land Use
Tulsa, Oklahoma	Renewal
Wichita, Kansas	Capital Improvement
State of California	Administrative
State of Hawaii	Transportation and Land Use
State of Michigan	Economic
State of New York	Administrative

TABLE 3

Organization	Use of Reference System
American Bibliographical Center	To Produce index for Hist. Abstracts
American Petroleum Institute — Division of Refining	To Provide a Central Abstracting and Indexing Service
American Society for Metals	To Providea Documentation Service
Applied Mechanics Review	To Produce Word and Author Indexes
Atomic Energy Commission	To Produce Nuclear Sciences Abstracts
Bio-Science Information Service	To Produce Biological Abstracts
R.R. Bowker Company	To Produce Pub. Weekly, BPR
Chemical Abstracts Service	To Produce Chem Titles, Chemical Biological Activities Registry System
Clearinghouse for Federal Scientific and Technical Information	To Provide Federal Scientific and Technical Information
Institute for Scientific Information	To Produce Science Citation Index
Library of Congress	To Produce Machine Readable Catalogue Data
NASA	To Produce NASA-STAR
National Library of Medicine	To Produce Index Medicus and Medlars
Office of Education	To Support the Educational Research Information Center
Scientific Information Exchange	To Provide Reference to Grant Supported Research Projects

The descriptions of many things—photographs, engineering drawings, subject content of books, etc. require much more complex data structures. Information retrieval systems to process them can be called **reference systems,** since they are used to store and retrieve references to material rather than the content of it. Usually, the records include subject terms, as part of the description, which represent the content and provide criteria for selection. Such data are more difficult to search than those dealt with by file management systems, because of the complex relationships among subjects. Reference systems, therefore, must include the ability to handle *thesauri*, describing the structure of the vocabulary of subject terms and indicating for each subject term other terms which are more general, more specific, similar or synonymous, etc. Usually, the files in reference systems become so large that only a portion of the records can be examined for a request. Subfiles and indexes to them are established (at the extreme, one for each subject), so that only the references on a specific subject need be evaluated by the computer.

The earliest reference retrieval systems were for scientific and technical information, particularly in support of projects in federal agencies. Computer produced indexes are published by a number of technical information centers, the largest being TAB by the Department of Defense Documentation Center, STAR BY NASA and *Nuclear Science Abstract* by the AEC. In each case, the data base is available for reference retrieval services to qualified requestors. A Clearinghouse for Federal Scientific and Technical Information was established in the Department of Commerce to provide comparable indexes and reference retrieval services for the general public.

The same technique is used by libraries as a supplement to traditional cataloging. As libraries mechanize clerical processes — circulation control, ordering of books and journals, printing of catalogues and indexes, etc. — data bases have become available for reference search as well. The National Library of Medicine publishes *Index Medicus*, its monthly index to journal articles in medicine, using a computer. The magnetic tapes are then used, in a reference system called Medlars. The Library of Congress is now beginning to produce and distribute magnetic tape records of cataloguing data for books they acquire.

Scientific and professional societies and abstracting services, including *Chemical Abstracts* and *Biological Abstracts* plan to use computers in publication and tapes will be made available for reference searching. Table 3 presents a representative list of reference systems.

Reference systems frequently function as part of **document retrieval systems** which deliver the reports themselves. The output of the reference system indicates where the material can be found and made available to requestor. Historically, most document retrieval systems have stored the reports on printed pages. Over the last several years, however, the physical size of many document retrieval files has become so great that storage in micro-image has become increasingly important. The variety of such storage systems is illustrated by the list in Table 4—a list which by no means exhausts the choices available. It includes microphotographic forms such as film reels, film cartridges, film cards (called microfiche), film strips, and even film plates as well as combinations of films with other forms of data storage. But it also includes micro-image storage in magnetic analog form (the various video files).

TABLE 4

Microimage Form	Characteristics
Film Reels	Of varying length, width typically 35 mm, with images stored at a reduction of 20 × 1.
Film Cartridges	Usually 35 mm wide and 100 feet long, storing 2000 images of pages of 20 × 1 reduction.
Microcards	Cards, usually 3″ × 5″, containing up to 70 opaque positive images of book pages at 20 × 1 reduction.
Microfiche	Transparent cards, usually 4″ × 6″, containing up to 60 or more images of pages at 20 × 1 reduction.
Aperture Cards	Paper cards, usually punched card, stock, with one or more holes cut in them, each containing a frame of 35 mm film with an image of a document or drawing, typically at 20 × 1 reduction.
Video-image Files	Magnetic tape video recordings of document pages, usually accompanied by digital identifying data.

Most recently consideration has been given to the storage of the full text of reports in magnetic digital form, since publishing by computer is becoming so widespread as to guarantee the availability of text in that form.

Text Processing Systems : In computer based publication, text is recorded in machine language, and the programmes then establish page format, hyphenate, and control devices for photo-composition which then produce offset masters ready for printing. Table 5 lists a variety of existing text data bases.

From the standpoint of information retireval the advantage of full text in magnetic tape form lies in the potential of language data processing. An almost classical example is the preparation of a concordance — an alphabetic

TABLE 5

(Extracted from "Literary Works in Machine Readable Form, "Dr. Gary Carlson, Brigham Young University, July 1965)

Machine Readable Text	Organisation
Journal of Chemical Documentation	American Chemical Society
Beowulf	IBM Research Labs
The Bible	University of Fittsburgh
Dictionaries (Various)	Lockheed Missile & Spare Co.
Golden Book Encyclopedia	System Development Corporation
Encyclopedia of Science & Technology	McGraw-Hill
Webster's Medical Dictionary	RCA

TABLE 6

Programme Name	Author and Date	Source
"ORACLE"	Phillips 1960	
"IDL"	Sable 1962	Communications of the Association for Computing Machinery
"Automatic Language Analyzer"	Householder 1962	
"Synthex"	Simmons 1963	American Documentation
"BASEBALL"	Green, Clonsky 1963	
"Protosynthex"	Simmons 1963	
"Sadsam"	Lindsay 1963	
"Fact Retrieval"	Copper 1964	Journal of the Association for Computing Machinery
"SMART"	Salton 1964	
"STUDENT"	Bobrow 1964	American Documentation
"SIR"	Raphael 1964	
"DEACON"	Thompson 1964	
"PLM"	Kirsch, et al 1964	
"SQA"	Black 1964	

list of significant words from a text, showing the context within which each appears. This technique has been used in reference systems to produce indexes for articles from key-words appearing in titles, and for books from their content. Computation of the statistics of text-word frequencies, lengths, distributions, associations, etc.— has linguistic interest, to aid the analysis of written language. It also has application in reference systems. H.P. Luhn suggested that the relative frequency of occurrence of words in a text was a criterion by which the computer could select subject terms to be assigned to the text.

Deeper analysis of text requires an ability to handle syntax and semantics. Several approaches have been tried by which the computer might be progarammed to derive the syntactic structure of a sentence from the syntactic classes of the words in it (as specified in a dictionary). For example, one approach, called **immediate constituent analysis**, considers simply the sequence of the words in the sentence. From them possible sequences of syntactic classes can then be derived, and one of them hopefully will be the only acceptable sequence. Another approach is **phrase structure analysis** which, like traditional parsing, treats sentences as combinations of basic phrases (the "noun phrase" and the "verb phrase" for example). The most complex approach is **transformation theory** which treats sentences as variations of certain basic sentence structures. (For example, "The ball was hit by John" and "Did John hit the ball?" are both clearly describable as fairly simple variations of "John hit the ball.")

These kinds of text processing techniques have particular value in humanistic scholarship. Analyses of word frequency and of sentence structure have been used for analysis of style, since they reflect patterns of word usage. Concordances and mechanical "collations" of text have been used to aid textual criticism.

One of the major frontiers in information retrieval research is the use of text processing and logical analysis to find answers to questions by analysis of the implications derivable from statements made in the text. A number of experimental **question-answering** systems, listed in Table 6, have been used to demonstrate such capabilities and to explore the technical problems involved.

Characteristic Problems in Information Retrieval

In the development of each of these systems for application to information retrieval, several problems arise which are significantly different

and more complicated than those in the more traditional computational and business data processing tasks. Roughly, these can be categorized into four classes of problems : utility, communication, pattern matching, and file organization.

The first, and most difficult to handle, are those problems relating to the utility of these systems. Their function is to collect and save data, which has been produced for some defined purpose, to serve later uses for other, usually unpredictable purposes. Thus, business data arising from accounting functions is saved for subsequent management decision making ; scientific articles printed for a particular audience of readers are stored and referenced for the use of other audiences, etc. But, whereas the original recording of the data may have had clearly defined value, related to the purpose of its generation, the utility for other, unknown uses is not at all clear. Furthermore, the costs of acquiring data in the first place usually represent the major cost consideration. Since this is a "capital investment", it must be amortized, in some sense, over these future, unknown uses made of it. As a result, the costs of an information retrieval system are difficult to justify. Furthermore, inherent in its operation is a high degree of **uncertainty,** not only with respect to the uses to which the data will be put even to the reliability of the data itself. In fact, a primary problem lies in determining what data will be acquired by an information retrieval system.

The second set of problems — communication — arises because the stored data must be selected so as to describe things external to the system in a form adequate for those later, uncertain uses. The description of people, signals, or ideas is not simple, since it is never clear what data will be needed nor is it clear how the data should be represented. The same issue arises in the translation of requests into a form in which they can be handled. In data base systems, this may mean simply the use of code books ; in reference systems, it usually requires the creation of dictionaries and thesuari which, as described earlier, show the relationship among terms; in text processing systems, the internal logic for communication becomes extremely complex, to the point that some investigators have claimed it exceeds present day knowledge of language structure and the capacity of existing computers.

The third set of problems — pattern matching — arises because the purpose of retrieval is the selection of "relevant" data from the file, but the meaning of relevancy is so ill-defined that it is usually not clear how it should be measured. Furthermore, the uncertainty, or even actual error, in the description of both stored data and requests is so great that it is not clear that precise measures of relevancy are really meaningful. Usually, it is necessary to provide a succession of measures of match, the ultimate one being the judgment of the user. Each serves as a screen to limit the number of records to be examined, in more detail, by later screens. These increase the likelihood of missing desired items which may be rejected by one screen even though they would be accepted by a later, more sophisticated screen. Again, the difficulties created by the quality of the original descriptions becomes important, since not all descriptive data can or will be included and significant relationships among descriptive terms may be missed. The combination of communication problems with pattern matching problems has led most of the people developing information retrieval systems to the belief that man-machine interaction is a necessity. As a result, much attention has been paid to the use of "on-line" computing techniques.

The fourth set of problems — file organization — arises because in each of the important applications the size of the file becomes so great that it is impossible, or at least uneconomic, to scan every item in it. For example, whereas a large matrix, such as would arise in solution of a partial differential equation, might require at most 10^7 or 10^8 characters of storage or a very large inventory control file might require 10^8 to 10^9 characters of storage, the catalogue of even an average university library requires 10^9 to 10^{10} characters. For large information retrieval problems the size of the file can be as large as 10^{11} to 10^{12} characters.

With such large files, it is necessary to structure them, to store them in different levels of memory, to provide indexing mechanisms, to use the succession of screens as means for reducing the number of records which need be examined in detail. It is this fourth set of problems which really constitutes the ultimate technical issue, since it is here that the size of file, the required response time, the available equipment, the degree of selectivity, and the accuracy of response all interact.

Summary

In summary, information retrieval has become an area of widespread interest and application for the computer. Although a variety of types of systems can be identified, they all partake, to one degree or another, of certain fundamental problems — uncertain use of uncertain data, immense files, complex data structures, and marginal economic utility. But, in application after application, the problems have been solved and useful operating systems have been created.●●●

Computerised Flight to the Moon

Amazing and decisive has been the role of computers in the Apollo 8 flight. They did their work by digesting enormous amounts of information sent out from tracking stations, at Goldstone, California, Madrid in Spain, and Canberra, Australia. The computers are located at the Goddard Spaceflight Centre at Maryland, and at Houston Space Control Centre. The Goddard machines, mainstay of the Apollo tracking and communications system, are linked by landline to Houston.

The incredible part of this aspect of Apollo flight is the following: Information fed from three world-wide tracking stations at the rate of 5,400 "bits" per second was turned into position and velocity information almost instantaneously and relayed to Houston. And throughout the flight, updated information was fed periodically to the Apollo-8, constantly changing the time and length of burns required for the next firing, the most crucial operations in the entire moon adventure.

The Apollo-8 flight is estimated to have cost Rs 260 crores (subject to correction). The entire Apollo programme—Apollo-9 and Apollo-10 schedules are already nearly fixed—is estimated to cost Rs 18,000 crores.

(Extract from *Socialist Congressman:* '1968 to 1969 and U.S.A. in Human History'.)

Computing in the 1970's

R L Patrick

BY 1969 THE SHOCK OF IBM's SYSTEM/360 had largely subsided. It had been an expensive experience for manufacturer and user alike. Multi-programming generally worked fairly well, but the software overhead was greater than expected. System generation was no longer the chore it once was, and software changes no longer came with disconcerting frequency. The users, while not quite euphoric, had licked their wounds, completed their conversions, and were generally happy with the product and the results they were getting. Some big shops had finally embraced PL/I totally and were working the bugs out of using a single "universal" language. Programmers were genuinely interchangeable, since they all enjoyed the same language and operating system. This, however, did not make them all equal since differences in technical background, experience, and ability were still very apparent.

In late '68 and early '69 the users discovered the benefits of modularity. The manufacturers have been making systems more or less modular for years. When S/360 and its counterparts hit, the manufacturers reaped many benefits immediately from the building block approach. In 1968 the user discovered that this could help him too. As a company's contracts fluctuated, the computing manager adjusted his configuration to match his load. The manufacturers responded by building popular equipment units for regional inventories to allow reconfiguring with ease. With the advent of multi-programming, the trimming could satisfactorily take place by adjusting the number of I/O channels and devices to allow fewer tasks to operate simultaneously. Thus, throughput and cost could be moderately changed without changing the cycle time of the CPU or affecting the unit cost for a specific application.

The shake-out of primary manufacturers continued and we lost several. Those that remain are stronger and better able to compete. Two of the also-rans have firmly established themselves as suppliers of consoles and I/O devices. They discovered that IBM's standard hardware interface allowed them to design to one electrical specification and penetrate the IBM community with sufficient volume to get the price down within reason.

The federal government's standards activity continued to wallow along until 1969. By that time the GSA had the world's prime repository of unwanted used computer equipment. Some dated back to the early '60s. The book value of the junk kept them from disposing of it, and the cost of storage soared. The original manufacturers kept raising their maintenance rates until some third party maintenance companies were formed. When this happened, the whole used market opened up. Trading became spirited and competition healthy. This was sparked, in part, by a thorough housecleaning at the BEMA shop in 1968. This resulted in industry assuming the initiative in standards and leading rather than holding back.

While all of this was going on, the users were not idle. One of the big aerospace companies developed a programme which would translate from source language to source language, based on tabular descriptions of the two languages. When this was done three things quickly happened : the long sought programme interchange suddenly became a reality, the table format required by this programme became the language definition

standard overnight, and a rash of application-specific languages sprang up. With easy translation, the user could use a convenient language for stating a problem solution and then turn the job over to the central programme maintenance group who worked in a consistent single language.

By 1970 several large file-oriented systems had appeared which qualified for the title "data bank". These were large, integrated file systems serving multi-users in both on-line and batch fashions. The groundwork for these efforts had been laid earlier, but until the third-generation hardware and software had settled down, progress was slow, frustrating, and expensive. In 1967, applications analysts realised that basic files had to be built as part of some on-going process. Soon, fully documented "save" tapes started regularly appearing in the archives. Finally, when the tools were available, the files had been stored, and the data bank could be established. The whole thing threatened to flounder until a bright, young programmer teamed with a smart hardware designer to solve the restart problem without extended downtime or unnecessarily expensive backup provisions.

About the same time wisdom and light settled on BEMA, the professional society ice jam melted also. Enough of the founders had retired so that the societies were repopulated by members who considered computing and information processing to be their sole interest and not just a happenstance career. The societies restructured along lines devoted to hardware, software, and applications. Numeric techniques was **one** of the pillars of the applications group. The software society absorbed both SHARE and GUIDE, which had merged in 1968, reorganized along software lines, and discarded their machine orientation, made obsolete by the 360. Each manufacturer still supported a small users group as a sounding board for his products, but the advent of true language standards allowed software to be handled at a level more professional than parochial . . . .

(Our observer arrives at the 1973 FJCC exhibits).

BOB : "Hi, Robert : Moving sidewalks seem to bring old friends back together. How are things in the outerspace industry?"

ROBERT : "Our business volume is holding well. We just got a new trillion dollar contract for another space station. Say, if you're going down to tour the exhibits, let's do the show together."

BOB : "It's good to get out of that crowd. Let's go look at those midget computers mounted in the typewriter stands."

ROBERT : "I'm glad that panel decided these could be considered as a computer, a desk calculator, or as ac onsole depending on how they're used.

"Now, isn't that nice. A computer with 16K memory, add time of 10 microseconds, and modified typer . . . all for $ 5000."

BOB : "What I like best is the flexibility. The memory bus is brought out to these connectors so we can just plug in this software loader box and preset the software in the Hold-Tite store. That's one way to get the price down : leave all the unnecessary stuff out. Of course, I suppose the price of circuits and core has come down by a factor of 25 in the last 7 years.

"If you get a loader box for each machine it's only $ 1500 more, but then it can have several software packages and a basic operating system. This will really solve some of our problems back home."

ROBERT : "We have two uses for it right now. That little design group over in the test Hangar needs a limited amount of computational gear with a customised application language on it. We could set them up for $ 5K and write the compiler for the big machine. Once we wrote and checked out the compiler at Central we could put it in Hold-Tite and let the Hangar crew work by themselves. It gets rid of that requirement for a secure communications crew to maintain the comm-link from the Hangar to Central.

"The other need I know of is for shipping. We could hook two of them up in tandem to

handle the rating and routing function. One typer would have those special forms that have to go with every shipment. The other would be the I/O keyboard for the pair. The clerk can input the load description, measurements, and scale readings. The computer will compute cube, tons, best way, and charges. It can also edit the input and format the output on the slave. If we get stuck and run out of memory we can either buy a loader box for holding rate tables in read-only form or use that acoustic coupler to make the tandem a satellite to the Central".

BOB : "I'd forgotten about that acoustic coupler attachment to the Touch-Tone Fone. With that jack on the side of the new phones, the coupler and the auto-dial can signal over the normal audio phone circuit to Central. You can get it for $ 100 with no installation charge.

"Let's go find those Immense-Files Next."

ROBERT : "Wow! Lok at the crowd. I wonder if we'll be able to get close enough to see them work? The advertising brochure claims the Immense-File is to the bulk file what the bulk file was to the drum. I guess that's about right. The Model I Immense-File holds 15 billion bytes in one module and the mechanical part only takes 4 square feet of floor space."

BOB : "I guess the part I like best is the price. It rents for $ 1,500 per month, and the control unit only costs $ 1000." Let's see. Back in 1966, we could get 800 million bytes on-line for about $ 6K per month. Now, if we install two Model I's on a single control unit we have 30 billion bytes on-line for only $4000 per month. Say, that's enough capacity at a small enough price to put that engineering technical library on-line, isn't it?"

ROBERT : "Yes , that will easily fit. Those reports average only 50 pages per document, and there aren't but 10,000 of them. If it were all text, that would use up about a fifth of the capacity of two modules, but since we've got to digitise all those graphs and pictures, it probably would take about a half of the twin modules. That would even leave us 15 billion bytes to hold some of that test data they keep crying about because it takes us too long to find the tapes in the archives and get them hung. The test enigneer gets tired of sitting at his console before we get the data displayed for him.

"With our new publications system, we can build those technical document files as a by-product of the publication process. In about three years we'll have the most interesting documents stored in the single Immense. We'll probably have to go back and pick up about 10 per cent. of those old reports to complete the file ; some of that stuff never seems to get too old to be of interest."

BOB : "I wish we could get close enough to see the removable cartridge. I'd like to see what handling problems they've built for us to solve this time. Since this crowd doesn't seem to be getting any smaller, let's move on and come back later. Maybe we can get a private showing since we think we've got a legitimate application."

ROBERT : "Hay — there's a booth over there with absolutely no customers. The contrast is amazing."

BOB : "Oh yes, that's the Bell Tel booth. I think that's made every show for the last ten years in the same form. That big map of the United States with the lightning flashes shooting between those telephone handsets leaves me cold."

ROBERT : "The only thing that's changed since we first saw them back in the '60s is the lads giving the sales pitch. If you change them often enough, they can maintain their sincerity since they don't know they're falling behind two years every year."

BOB : "Yo'd have thought after that fierce fight over the touch-tone modification that the Bell System would have loosened up a little bit and recognized that the computer was here to stay. It's amazing how the chief engineer fought against modifying the touch-tone handset so that an inexpensive acoustic coupler could just be plugged into a jack."

ROBERT: "Yes, that made a big difference, so I guess all the fight was worth it. I'd like to see the charters for public monopolies changed somehow so the design laboratories of the

major manufacturers could cooperate with the big utilities to get a balanced design.

"Do we need to go look at those new graphic terminals over there, or can we see enough from here?"

BOB: "I think I know as much about how they work as I need to know. They haven't changed that keyboard/CRT/hard-copy-printer unit for several years now. I guess the main change in the last year is getting the price down to $5K purchase."

ROBERT: "We installed one of those earlier terminals, and by the time we got through adding the light pen, the scope, the plotter, and all of the special electronics it took we had almost $6,000 a month going out for a single station. That was a little steep just to give a few engineers the opportunity to fool with graphic displays.

"We ended up scheduling it so tight that the engineer could hardly afford to think at the machine. Fortunately, these new ones will rent for about $120 a month installed and all they need is a pair of twisted copper wires That makes installation a lot less than it used to be when we had to put in multiconductor coaxial

"I think the price on these things is finally coming down to a point where the normal engineer can get access to one whenever he wants to without too much trouble, and can keep it as long as he needs it. With these prices, we can get graphical ability out to the design areas where it's needed, and still support them centrally with our multi-CPU. I'm really looking forward to getting some of those Immense-Files on-line so we can hold enough drawings in detail to make up a complete assembly. That should make a big difference in the way we handle engineering changes."

BOB: "Did you see those new optical page readers that can scan a variety of documents and fonts and transmit the data to Central over a twisted pair?" They have a programmable digital computer in them just about like the one we saw in those reactive consoles a while ago. The font recognition and document format are all completely programmable—based on tables stored in core. The output is that same accoustic coupler to the touch-tone that made the satellite consoles so popular.

"With the monthly rental getting down to about $200 we may finally be able to collect our primary input data directly from the fundamental documents and eliminate the keyboarding step that's always cost so much. If we put three of them in shipping and receiving, a pair in purchasing, and back that set with one of those new Quik-Disc files, we'll be able to get purchased item status reflected in the new project control system and the financial liabilities report in a way that means something. The price and flexibility of these new devices has made it very worthwhile to consider picking up some of these applications we've talked about for 10 years, but haven't been able to deliver economically."

ROBERT: "That paper on the new master operating system this morning was interesting I was glad to hear a user instead of the usual manufacturer. Users are always more candid than salesmen. Evidently he's finally getting good operator information so he can figure out what's going on while the machine is processing several jobs simultaneously. As a by-product of this he's getting decent accounting inputs for billing purposes. He said he had trouble getting the system installed initially, but that the thorough set of audit trials they built into the system allowed the troubles to be isolated and corrected easily."

BOB: "I was glad to hear that the fail-soft system qualities were really delivered as promised. We've been living on borrowed time for several years: with our file storage getting bigger and bigger, and those multi-user data banks growing by 10% per year. I wince every time I think of what a catastrophic failure costs us. I still remember that time when we had 200 consoles operating and lost the master index table to the work files. One thing led to another, and it took us 63 hours to get back on line.

"With this new system working as well as he said it did, I think we could go ahead and order those Immense-files...I think the days of the catastrophic failure are now behind us."

ROBERT: "The multi-CPU shared-storage hardware allowed us to have systems which

could reconfigure themselves dynamically in the event of a malfunction. Technically, we owe a lot to the early work done on BUIC and the old FAA system. They finally showed us how to build hardware-software systems which would really fail in stages and not in one big heap.

BOB : "Yes. Those same examples helped us design commercial hardware that reconfigures very nicely in case of a component outage. If we can believe that speaker, the problem can now be solved by changing a few tables and selecting the right pre-stored module. Maybe we're ready to think about going on line with that second batch of 500 consoles now.

"I liked that other paper this morning surveying hardware architecture features. It seems that every major manufacturer now carries some form of compatibility as a fundamental design objective: the 32-bit, register-oriented, variable instruction length machines, based on the 8-bit byte.

"If I understood him, some of them have true hardware compatibility but others have found it sufficient to build a machine which is logically similar so that programmes devoid of I/O can be automatically translated from one to the other. The panel discussion left me kind of cold though. I don't really see that the definitions of 'compatible' and 'logical subset' were worth all that time and effort."

ROBERT : "Well, even though they couldn't agree, I know what it means to me. If I have to put any more than 10% of the initial effort into moving from machine to machine, don't bother to send the salesman by to tell me about it. And even if the instructions are completely identical in format and function, if it won't take my file organisation or if they fool with the sort order again, just forget it.

"We're already up to the point where most of the cost is in the I/O devices and files. If they gave me a CPU, they couldn't cut my rental more than 5%. I'd just as soon as they concentrated their efforts elsewhere."

BOB : "Well, it looks like they've done quite a bit with this new 'triple-vote' modular design. They'll guarantee 95% up-time on all that electronics even if you have only one module. With the new design you can put in the redundant unit and cut the mean time to repair down to 8 minutes. But if you really need the reliability, you can go for that three-processor option with the special control and they'll give you that 'Lloyds of London' policy that will reimburse you for the indirect losses you take based on less than 100% reliability. Boy, that must be reliable stuff.

"We might want to consider putting in one triple-vote system to handle communications, switching, and the message queuing if we decide to get those Immense-Files and put that second 500 consoles on line. With a thousand people on line, we can show a hard saving of $10,000 an hour just in people-time waiting for us to get the system back on line. And this doesn't include anything for the graphics, processing, and data we might have to re-enter or regenerate in case we collapse completely."

ROBERT : "If we go to that second 500 consoles, we'll surely have to pick up the on-line engineering change system, and that carries with it the responsibility of running the manufacturing plant. Management would probably be delighted to have the triple-vote system just to get that Lloyd's insurance covering us against possible business loss.

"The new modules have simplified building control systems out of these general purpose modules. Depending on the box it's in, one of these memory-logic modules can be a part of that souped up console, reduce the cost of those intelligent graphic terminals, or control the scan in that optical page reader. The same unit would also support those on-line medical experiments we're doing in the lab because it interfaces so nicely with analog sensors and digital control devices. They really did well when they got 16K core and 10 microsec add time in a hermetically sealed super flat pack the size of a 3-ring notebook. The power required is so low we can run it off those little thermo-electric sources or the rechargeable cells that have that optional solar face on them."

BOB : "Should we go to that session tomorrow on the user's report describing his expe-

rience with the new software? It sounds very interesting."

ROBERT: "I read the preprint and I'd like to attend. He thinks they've finally figured out how to build modular software which is subsettable based on your needs and machine size, but has almost the performance of custom written code. The paper didn't describe exactly how they do it. I hope they explain it in the talk."

BOB: "Didn' the announcement say that part of the modularity lets you routinely change the orientation of the system from real-time to teleprocessing to batch in any combination and with any emphasis?"

ROBERT: "Yes, that's what they tried to tell us. This user maintains they did it and both kept the performance up and the programme size down. Furthermore, they have a new language definition for action languages.

"Remember back in the mid-'60s — some of the more theoretically inclined managed to state and describe procedural languages in terms of grammar and syntax? Well, some similar work has just been completed on action languages. They've put some of that same theory to work and come up with a definition of action languages to handle control of the computing system, communications with the operator, all the I/O device actions and scheduling, and the sequencing of processing we used to call job control. It now has some harmony to it, which we've lacked for several years. Matter of fact, I hear it's even easy to understand and has only a few exceptions."

BOB: "Well, if they've managed to do that and also include all those data base handling facilities we've heard so much about, it really ought to be a fine new system. I'm looking forward to the panel discussion after the user talk because I want to ask some questions about these new contract terms.

"Sam Dollar of the Executive Finance Committee heard we were thinking of switching to the fourth generation and sent for me the other day. He pulled out the file with the financial audit of our conversion to third-generation. He had those conversion costs recorded to the penny. The true costs of the conversion were posted to one account and he had two other accounts showing the costs due to late hardware and the costs due to late, sloppy software. He made it very clear to me that he wasn't about to approve any expenditure for fourth-generation equipment which didn't include contractual guarantees on the part of the manufacturer. He told me I could order whenever I wanted, but when he signed the contract it better have firm dates for hardware and software with enumerations of required functions and stipulations covering minimum acceptable performance.

"Somewhere he heard we'd been simulating how our proposed workload would pan out in fourth-generation equipment. He advised me if I couldn't think of a better way—to include that simulated performance as part of the contract.

"I'm going to lay that contracting question in front of tomorrow morning's panel if I have a chance."

ROBERT: "Let's go, get a drink. What do you think we should have done in the late 60's to have been better prepared for what we saw today?"

BOB: "Well-let's see. We should have wired that new plant so we could put in a private digital communications network independent of the phone company; placed some restrictions on applications programmers so they wouldn't aggravate the conversion problem by using all of the features of the programming languages just because they were there, kept the descriptions for all those old files we stored so we could figure out the tapes if we ever had to re-read them. I wish I had attended that seminar on assigning functions in multi-computer systems. We should have hired that young guy who knew so much about file organisation and integrity. There are several more, aren't there ?"

ROBERT: "Yes, I have a few more: but first, where was that DATAMATION cocktail party?". ●●●

The Computer Plays The Checker Game

Donald G Fink

The machine played a perfect ending without one misstep. In the matter of the end game, I have not had such competition from any human being since 1954, when I lost my last game.
—Robert W Nealey

IN THE SUMMER OF 1962 AT YORKTOWN Heights, New York, a former checkers champion of Connecticut, Rober W Nealey, lost a game of checkers for the first time in eight years. His opponent, a comparative newcomer to the game, had first learned to play in 1955 and had picked up the fine points of the game rapidly. Mr. Nealey was concerned, understandably, to be defeated by a tyro — and it was not consoling that his conqueror should be a machine, an IBM Model 7094 electronic computer. The automaton won fairly and squarely, without coaching from the sidelines. Moreover, it had learned to play as a human being learns from experience and observation, recognising mistakes and remembering not to repeat them.

An expert at checkers watching the game would have been confident that the machine displayed highly developed intelligence. The play showed that the machine was "looking ahead" as many as twenty moves and was employing strategy worthy of a champion, as its victory clearly demonstrated. Most remarkable was the fact that the man who devised the checker-playing routine for the computer, Dr. Arthur L Samuel, was not himself a noted player. He did not, and indeed could not, plan the particular strategy that defeated champion Nealey. So far as outward appearances were concerned, the machine seemed to have "a mind of its own." Of course, the machine was not intelligent in the human sense. But in the special world of championship checkers, it behaved as if it possessed a highly trained mind.

Actually, the computer was doing only what it was designed to do — arithmetic, and a particularly simple-minded arithmetic at that. It added, subtracted, shifted, compared, and remembered numbers composed of just two digits, 0 and 1. It manipulated these numbers in accordance with a master plan based on the rules of checkers. It is interesting to see how a computer can make judgments in a game and decide its next move, how it learns from experience. For the present, we need only note that the machine did beat a champion at his own game, by following a computation devised to imitate the behaviour of the human mind.

Learning from Experience

Why should a machine play checkers at all? Using a large and expensive computer to play

checkers might be dismissed as a "stunt," of no lasting significance to science or technology. But Dr. Samuel's purpose was more profound than merely to put IBM 7094 against Mr. Nealey. He adopted checkers as an example of an intellectual pursuit, with well-defined and not too complicated rules that could be reduced to computer science. His objective was to demonstrate methods by which a machine can be made to learn from experience.

When the 7094 computer was first set up to play checkers, it was arranged to make only the elementary moves. The machine was a raw beginner, and even a child could beat it. But the machine was programmed to store away on magnetic tape, the sequences of play resulting in capture of the opponent's men and invasion of the opponent's king row. Since a single roll of computer tape can store many millions of digits, the machine was able to remember a prodigious number of patterns of play. In deciding on its next move the computer compared the existing pattern of play with many patterns it had stored away, and it chose a move that its experience had showed would lead, most probably, to the discomfiture of the opponent.

As the machine continued to play, its store of experience grew. It became able to produce and store more general patterns of play, the tactics of keeping control of the board, and of protecting the king row. The day came, in fact, after several thousand games, when the IBM 7094 machine could consistently defeat Dr. Samuel, who rates himself a "fair amateur" at the game. At that stage the machine's store of checker lore, for particular moves as well as for general strategy, had outgrown the mental capacity of the man who taught it!●●●

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—"Is your Auditor Really Necessary?" by J.P. Landau, *The Accountant* February 24, 1968.

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