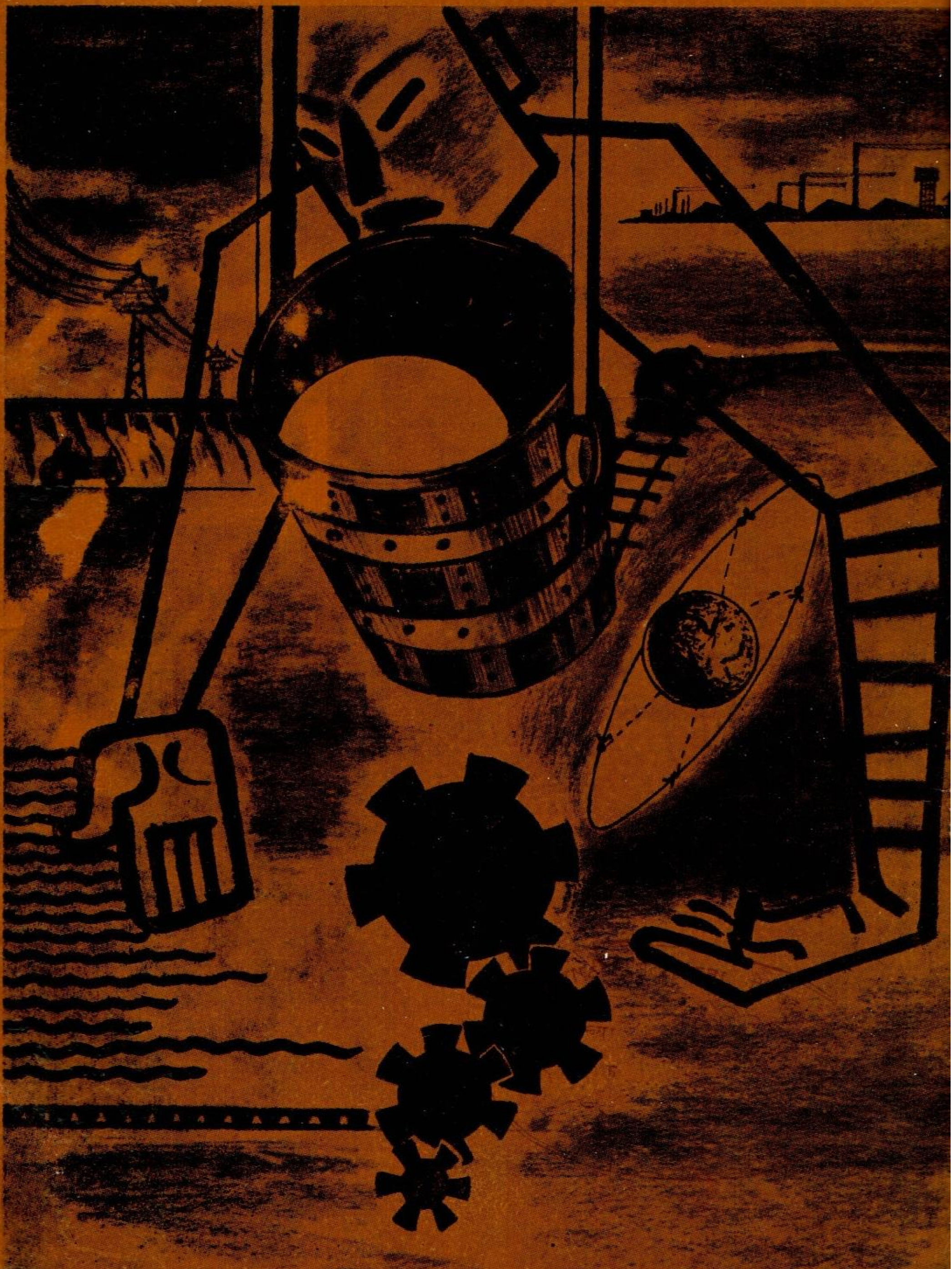
V No. 1
March 1964

national productivity council journal

PRODUCTIVITY



NATIONAL PRODUCTIVITY COUNCIL

The National Productivity Council is an autonomous organisation registered as a Society. Representatives of Government, employers, workers and various other interests participate in its working. Established in 1958, the Council conducts its activities in collaboration with institutions and organisations interested in the Productivity Drive. 46 Local Productivity Councils have been established practically all over the country and work as the spearhead of the productivity movement.

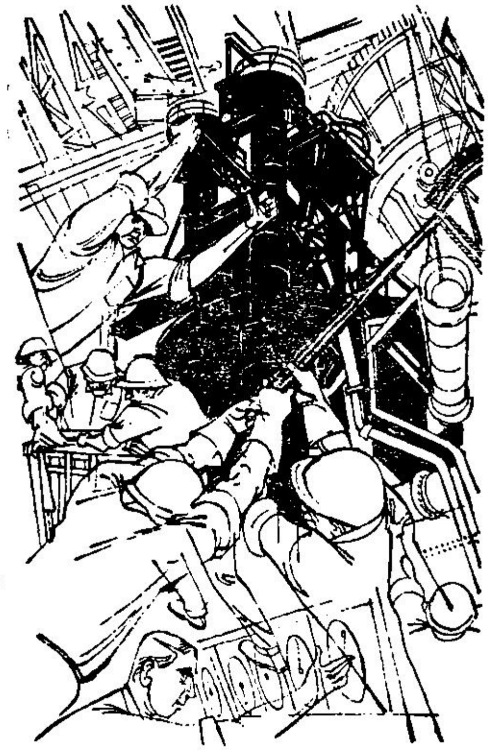
The purpose of NPC is to stimulate productivity consciousness in the country and to provide services with a view to maximising the utilisation of available resources of men, machines, materials and power; to wage war against waste; to help secure for the people of the country a better and higher standard of living. To this end, NPC collects and disseminates information about techniques and procedures of productivity. In collaboration with Local Productivity Councils and various institutions and organisations it organises and conducts training programmes for various levels of management in the subjects of productivity. It has also organised an Advisory Service for industries to facilitate the introduction of productivity techniques.

Recognising that for a more intensive productivity effort, the training and other activities of NPC designed to acquaint management with productivity techniques, should be supported by demonstration of their validity and value in application, NPC has decided to offer a PRODUCTIVITY SURVEY & IMPLEMENTATION SERVICE to industry. This Service is intended to assist industry adopt techniques of higher management and operational efficiency consistent with the economic and social aspirations of the community. PSIS is concerned with the investigation of management and operational practices and problems, measures of improvement and their implementation. NPC has also established at Bombay a special Fuel Efficiency Service.

NPC publications include pamphlets, leaflets and Reports of Productivity Teams. NPC utilises audio-visual media of films, radio and exhibitions for propagating the concept and techniques of productivity. Through these media NPC seeks to carry the message of productivity and to create the appropriate climate for increasing national productivity. This Journal is an effort in the same direction.

The Journal bears a nominal price of Rs. 3.00 per issue and is available at all NPC offices. Annual subscription (Rs. 12.00 to be sent by cheque in favour of National Productivity Council, New Delhi) is inclusive of postage. Subscription for three years, however, can be paid at the concessional rate of Rs. 32.00.

Opinions expressed in signed articles are those of the authors and do not necessarily reflect the views of NPC.



a challenge well met

ON THE 3RD JANUARY, this year, the 'E' blast furnace at the Jamshedpur steel works was blown out for relining and enlarging. It was a big job involving 2,100 tonnes of refractories, 1,700 metres of piping, 7,600 metres of electric cables and 1,100 tonnes of steelwork and castings.

When the original schedule was halved from 180 days to 90, many thought it to be impossible. But a team of Tata Steel engineers, technicians and workers took up the challenge and completed the operation in 84 days, 6 days ahead of the drastically revised schedule.

The 'E' blast furnace, with an original capacity of 315 tons a day, was bought second-hand from the U.S.A. 45 years ago. Its rated capacity has now been stepped up to 660 tonnes of pig iron a day without sinter burden, or to 725 tonnes with sinter and sized iron ore.

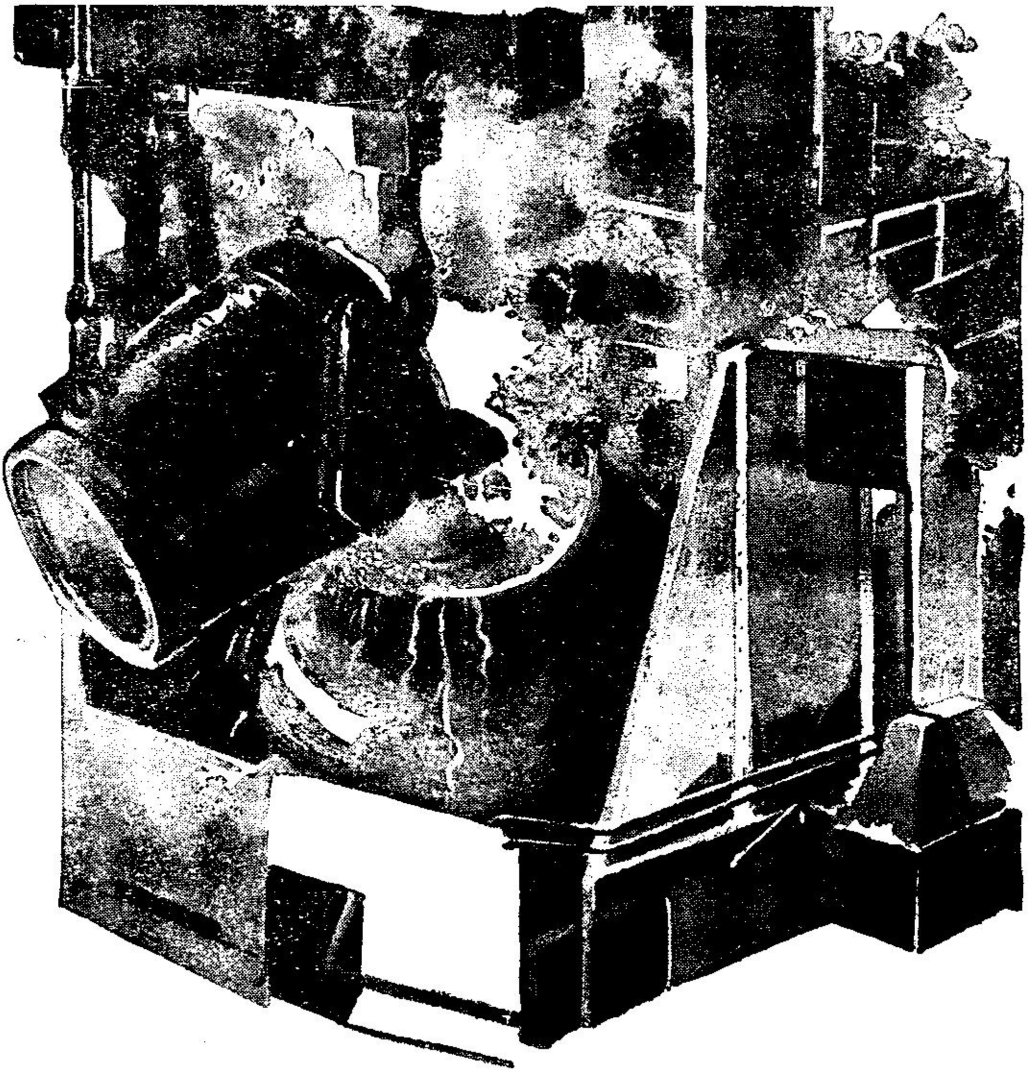
The record-breaking achievement is another demonstration of efficient team-work, technical know-how and sustained efforts to attain greater productivity with the minimum outlay that characterize a city like Jamshedpur, where industry is not merely a source of livelihood but a way of life.

JAMSHEDPUR

THE STEEL CITY

GIVE FREELY TO THE NATIONAL DEFENCE FUND

Tata Iron and Steel Company Limited JWTTN 19



NPC QUARTERLY JOURNAL

PRODUCTIVITY

A few recent opinions

"...Glad to tell you that ~~the July-September 1963 issue of~~ Productivity came up to my long expectations. I was especially fascinated by the idea of getting people to write playlets on Productivity. This is something that we are perhaps a little too hide-bound to do, and I wonder whether, even if we did produce any, we would find anybody to perform them. Did your authors have this pleasure I wonder? . . . Seriously, the magazine does preserve a very high standard..."—**RUSSELL M CURRIE** ~~*ICI, London*~~

"...Received with great interest in Denmark..."

—B Krum-Moller The Danish Trade Fund, Copenhagen

"I should like to tell you that the articles you are carrying are thought-provoking and certainly informative. That it is one of the best publications in the field of management, and particularly in the field of rationalisation, goes without saying."

—Dr Louis J Rago Professor of Management School of Business Administration Pittsburgh

College of Commerce & Business Administration, University of Illinois

"...We have found your Journal extremely interesting and informative..."

—AW Curtis Board of Trade, Industries & Manufactures Dept London

"...very informative and interesting..." *Pakistan Industrial Technical Assistance Centre*

"...contains valuable material..." *RD Kulkarni, Ahmednagar*

"...most interesting..." *John F McComb, US-AID, New Delhi*

"...a very informative Journal..." *Lt Col S Ram Ministry of Defence*

"...We appreciate this contribution very much..." *Asian Productivity Organisation*

"...excellent publication...the articles contain many valuable observations and reflections based on a wide cross-section of experience..."

—George V Haythorne ~~Deputy~~ Minister of Labour Canada

"...your Council's publications are much treasured by our Centre for their rich mine of information...."

Centre De Development Industriel, Saigon

"A typical authoritative opinion about 'PRODUCTIVITY' the National Productivity Council quarterly journal, is that it is 'absolutely' first-class!

True to its name, the issue for the fourth quarter of last year contains some excellent articles and is, as may be expected of the journal, both informative and thought-provoking.

The issue contains a special section on inventory control, an important aspect of the science of productivity. The articles here are as comprehensive as they are authentic.

Articles on work study in the general section contain one by Lord Mountbatten on his experience of the subject. There are some good articles on the theory and practice of case study."

Financial Express~~, 26th Jan 1964~~

Productivity in The News

productivity + socialism

"......*We shall proceed in the task we have undertaken : the task of building up a new* **India**, *with agriculture and industry based on modern science and technique and raising the level of all our people. We hope to march to a Socialist State.*" **From Prime Minister Nehru's message to the Indian Republic Day Issue of Soviet Land.**

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even the judiciary has to be productive

"......*In a message recorded by All India Radio soon after he was sworn-in as Chief Justice, Mr Justice Gajendragadkar said judges of the Supreme Court were aware of the 'historical role' they had to play in the context of the socio-economic revolution, which law was attempting to bring about by means of a rational, reasonable and harmonious synthesis between individual liberty and social good......*"

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productivity in agriculture

Delivering the Convocation Address to the Udaipur University, Dr VKRV Rao, member of the Planning Commission called for steps to bring about a transformation of agriculture from 'a mere way of living to an economic and business enterprise'......'To do this we have not only to increase inputs, guarantee prices and afford incentives, but also modernize the methods of cultivation and ensure the application to agriculture of science and technology most appropriate to its varying conditions in different parts of the country!... quite apart from the fact that the majority of the people were directly dependent on agriculture for their existence, the productivity of agriculture was esssential both for capital formation and for industrial development... It was also important to instil in cultivators the basic elements of business accounting so that they could look at inputs and outputs from a commercial point of view and exercise their judgment in choosing methods most appropriate to maximize both productivity and profit..."

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the Japanese miracle

"*The effective shifting of labour from low productivity areas like agriculture to high productivity areas like heavy industry was the secret of Japan's national income growth being the highest in the world today*". Prof Shigeto Tsuru's address to the Delhi School of Economics

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rising costs and taxes do not affect the productivity of whisky

"*As the old year ended, the Scots of course raised their glasses—and a good many of them must have drunk, in whisky, a toast to whisky. Last year was a bumper one for Scotch. This looks like being even better, despite the producers' natural grumbles about rising costs and increasing sales competition, American import duty restrictions, and the British Treasury's 'penal' taxation. Despite all these handicaps, the whisky industry's output goes on soaring up*". The Economist (London)

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productivity of gold

"*Gifts of gold, frankincense and myrrh from the Queen were made at an Epiphany service at St James's Palace. The gold—25 sovereigns—was redeemed after the service and returned to the Bank of England*".—Guardian.

*

productivity of research

"*Lew Grade, managing director of Associated Tele-Vision said today: 'We are not going to ask the researchers to tell us what programmes to do, but once we have made up our minds about a programme we want to know if we are putting on stuff that is inane or nonsense'.*"—Evening Standard

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rural productivity

"*The rural council at Mildenhall, in Suffolk, has decided that in future its tenants can each keep a pig if they want. 'This is an agricultural area and our people like to keep a pig as one of the family*".—Guardian

tional productivity council journal

Vol V No. I
Jan—March '64

RODUCTIVITY

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HE ENGINEER

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योग: कर्मसु कौशलम्
True Yoga is Efficiency in Action

GENERAL SECTION

PRODUCTIVITY AND THE ENGINEER*

An Unfinished Story

THE CONTRIBUTION OF ENGINEERING TO PRODUCTIVITY IS yet an *Unfinished Story*, for the revolution in the productive powers of mankind[1] brought about through the instrumentality of the self-made engineers of the Industrial Revolution, is not only a continuing but a multiplying one. The real rate of growth in Productivity can be broadly gauged by dividing Einstein's nuclear power function by the quantum of energy in Watt's steam engine, with which this Business of Industrial Productivity really began.

Seymour Melman in his famous thesis on the *Dynamic Factors in Industrial Productivity* has also emphasised the same conclusion: "*The dramatic rise of industrial productivity over the last half century is traceable primarily to transformations in the technique of production*... They are the source of the large and lasting productivity gains, for the character of production equipment and allied methods governs the potential output towards which other factors such as organisation indeed contribute..."

We in this country are yet to experience a like transformation in the techniques of production. The subject of Productivity and the Engineer is specially important at this stage of economic development, as most of the jobs that we have now to do, have to be freshly engineered. The engineer is therefore going to play the most important part in planning, designing, layout, the whole process of construction and manufacture: in fact the whole structure of production has to be engineered into productivity.

*The title has been specially designed by Mr Alec Miller, Chairman of the Indian Council of the Institution of Production Engineers

[1] **"In English society the day of labour had acquired in 70 years a surplus of 1,700 percent of productivity, that is to say that in 1840 it produced 27 times as much as in 1770."**—The Poverty of Philosophy (Karl Marx) quoted by Dr KS Sangha in his article on ***Productivity**: Its Concept and Measurement*, NPC PRODUCTIVITY Journal, Volume 1, No. 5, p-343

In order, however, to be a really productive functionary in the complex society of modern times, the engineer who for long periods of time has been *only an engineer*[2], will now have to associate himself with a number of other disciplines and with a number of other functionaries. So far the engineer was concerned purely with technical planning and his empire consisted mainly of machines and materials.

An Absolutist Philosophy

Since machines and materials have measurable magnitudes, there developed in the mind of the engineer a certain absolutist philosophy, which worked largely because machines and materials have no feelings and the men involved counted for little during the birth pangs of the Industrial Revolution. The distance between the engineer even at the operational level, and the men he worked with, was enormous. Now this distance has shortened. The engineer is one functionary in a large set-up where there are other functionaries who are equally important. The industrial structure has necessarily become more democratic. No longer is it possible as in the early days of the Industrial Revolution in England or in the building of the Railways in India in the 19th century, for an engineer to ride rough shod over men. *The mind of the engineer has therefore to acquire a certain flexibility* and he has to accept that machines and materials and layouts and all such engineering details have to be adjusted to the psychology of the people who work on them.[3]

The contribution of the engineer to the productivity of the Indian Economy —including Agriculture[4]—will increase substantially if the Indian Engineer's training in modern techniques is integrated into the general pattern of Indian society and philosophy and the socialist policies of the State.

There is another reason why engineering has a large scope in India's industrial economy. This is due to our peculiar cost structure. So far the engineers as productivity experts have concentrated on the reduction of labour costs and have naturally experienced considerable resistance. The result has been a sort of conflict between the engineer and the labour union which makes a large part of the engineering effort infructuous. Actually the labour cost in Indian products

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[2] In this context, it is interesting to find that the American Institute of Industrial Engineers (AIIE) claims to be in its own right a Peace Corps, on the model of the late President Kennedy's world-wide organisation:

"AIIE is a Peace Corps today—its members are giving generously of their time to work on Indian reservations, in hospitals, with the blind and the handicapped. What is needed is a greater effort—each of the 10,000 members of AIIE must accept this challenge to better serve mankind not only in the United States but throughout the world. In this way AIIE'S membership together with members of other professional societies could help to fill this much needed role of Peace Corps in the United States of America."

[3] For a scientific analysis of the issues involved, readers would be advised to read Sri SS Khera's article on Men and Machines (The Science of Ergonomics) NPC PRODUCTIVITY Journal, Volume III, No. 2, p-164.

[4] It appears to be a reasonable hypothesis that the basic cause of the continued backwardness of Indian agriculture, despite enormous investments in irrigation and fertilizers, may be really due to the fact that the job of cultivation has itself not been engineered. It appears probable against the background of this hypothesis that the advance of Indian agriculture to a position of real productivity may be brought about by the injection of a substantial volume of engineering talent in the business of agriculture.

is relatively small, very much smaller than it is in the West whose productivity techniques we are attempting to emulate. 50 to 80 percent of the cost of manufacture represents the cost of materials. It is this large area which gives the widest possible scope for cost reduction through more economic designing. If for example the quantity of materials going into a telephone receiver is halved, as in some designs which are now available in the market, it will mean a substantial reduction in the cost of production. If we could so re-design our products with the material content materially reduced while not affecting quality or usability, our engineers will have played a good part in the productivity drive.

The Clouds of Anti-Productivity

This, however, is only the beginning of the end : as we have said, the Engineers' Contribution to Productivity is an unfinished story : it will never be finished, unless the Engineers of India (and of friendly countries) engineer the 450 million people of India into productive entities : then the Game of Productivity will be a self-perpetuating one. The Take Off will have taken place and we shall be flying above the clouds of Anti-Productivity, that now blanket the Indian Economy.

NPC—ICIPE Collaboration

This Special Issue on PRODUCTIVITY AND THE ENGINEER is an unfinished story, also from the institutional standpoint. During the last 6 years that the NPC has been at the apex of the Productivity Movement in the country, it has freely collaborated with sister institutions which are *devoted to the cause of making this country powerful through productivity.*

In this collaboration, the NPC PRODUCTIVITY Journal which is an integral part of the functioning of NPC, has shared fully and intimately. The first effort in this direction was our association with the Indian Statistical Institute which furnished the entire material for the Special Issue on Quality Control.* Our next adventure in collaboration was with the Indian Institute of Cost & Works Accountants of India whose President and entire membership of many hundreds of experts made their experience of several years available to us for processing a Special Issue on Cost & Budgetary Control.

This is our third adventure in the line and it is a matter of extreme pleasure and privilege to record that the collaboration† with the Indian Council of the Institution of Production Engineers has been an extremely rewarding one. The papers published here—all of which have come from the

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* And they richly appreciated our labour: "All the members were highly appreciative of the effort that had gone into the preparation and publication of the NPC Journal, special number on SQC...very well brought out. The National Productivity Council and the Indian Statistical Institute and in particular, the persons directly associated with the preparation of the number, deserve congratulations." *SQC Policy Advisory Committee*

† Mr Alec Miller, Chairman of the Indian Council of the Institution of Production Engineers was, because of his association with this Special Issue, requested to write a Guest Editorial regarding the collaboration between NPC and ICIPE. It is being printed here as a Foot Note, partly because it came too late for inclusion in the text but mainly because it contains a rather exaggerated account of the part played by the Editor. In this apparently successful

Institute apart from contributions by NPC personnel—represent only a part of the total volume made available to the NPC. It is a matter of personal regret to the Editor that we have not been able to accommodate a large part of the material, entirely for reasons of space. The papers published in this Section, as readers will see for themselves, are not only of high quality but they also show the wide range and perspective of the Indian Engineer as he has evolved out of the rough experience that it must have been at a time when the entire national life is being reconstructed and '*sort of engineered into productivity*.'

The intimacy of collaboration with the Indian Council of the Institution of Production Engineers can be judged from the fact that its Chairman,

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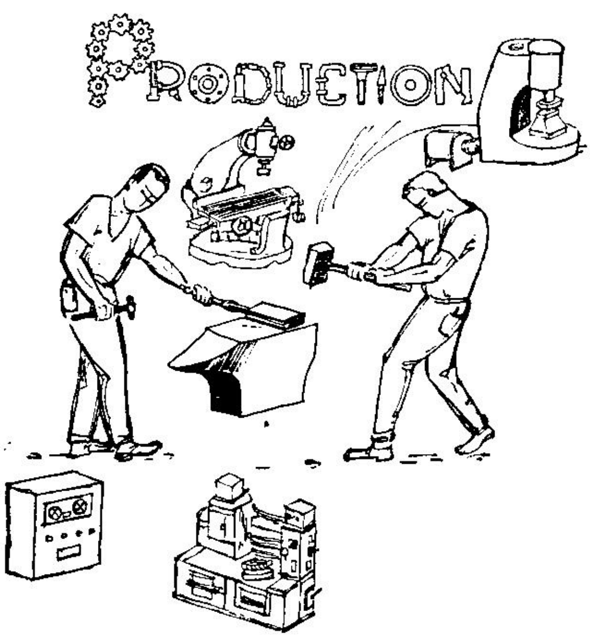
collaboration, the major part and the really creditable part has been played by the experts of the ICIPE, particularly its Chairman. The Editor has played the part only of an honest broker between the intellectuals who have written the papers and the intellectuals who are going to read them. The text of the Guest Editorial of Mr Miller runs as follows :

"It had been a long dark night and Ramu sitting in front of his hut awaited the dawn. The soft light of the pre-dawn shone over the hills in the east and quickly the rays of light from the hidden sun streamed into the sky pushing over towards the west the mantle of night, and the clouds took on a golden glow. The first rays shone upon Ramu and gave him new life, for another day was born. It seemed to his tired eyes that this was specially for him and an inspiration was born .... *Always we look for the light and our light is productivity.* The Institution of Production Engineers striving with difficulties and often in the dark found an inspiration in a ray of light when the Editor of Publications of NPC had a discussion with Mr Haldar the Secretary of the Institution of Production Engineers, Indian Council. It was suggested that a collaboration be made and the combined experience of the Institution mellowed in words and understanding by the Editor would spread its influence over Indian production established and to be established... Mr Butani came to the Institution of Production Engineers' Council meeting in Bangalore and explained the value of the NPC's magazine, its method of selecting a theme, short and pithy articles to maintain interest, *the value of obtaining knowledge from highly skilled and experiened men* and blend the whole into a book of interest anyone would be pleased and proud to pick up and read. The seed had been sown. The Committee met to decide on the method of approach and the theme suggested was a mythical factory from the buying of the land, machinery, the building and servicing, the establishing of controls, industrial engineering, planning, tool rooms, jigs and fixtures. This was enthusiastically received and from that moment the campaign started in earnest to obtain from its members articles which the Editor of this Journal would blend into an interesting volume, which you can now read......"

Mr. Alec Miller, has personally drawn practically all the cartoons printed in this Journal including the one shown below and the Fairy Cartoon printed on page 13. The able and energetic Secretary of the Council, Sri RN Haldar, who desires not to be mentioned, has played a vital role in this collaboration between the NPC and his Council. It was he who suggested to the Editor to attend meetings of the Council to see if we could work out something fruitful for the Productivity Movement; and when the Editor actually attended the Bangalore session, the entire resources of the Council were placed at his disposal and Mr. Miller saw to it that his colleagues kept their word and made the material available for publication in this Issue of the Journal. As every one knows, this is quite a feat in our country.

It is only therefore proper that the NPC puts on record its high appreciation of the value of assistance received from the Indian Council of the Institution of Production Engineers, its Chairman, Secretary and members, in the hope that this collaboration will also remain an unfinished story.



The Past And The Future

PJ O'Leary*

This is an extremely interesting piece, addressed to young engineers: rather rambling† and impressionistic, but deep enough to be called philosophical. Born‡ during the First World War, the author received his Technical Training in the Royal Air Force, where he was commissioned as an officer. He was seconded to the Ministry of Aircraft Production towards the later stages of the Second World War. Now from the hill-top of his experience, he speaks to young engineers of what life was and what it could possibly be: "By so looking back and taking stock we can perhaps set a better standard for adoption by our successors...In looking back myself I see mirrored many spotted surfaces which could so well have been immaculate, and many darkened rays which could well have been resplendent."

I WELL REMEMBER IN THE 1920s and early thirties examples of gross social injustices, when human rights were rarely considered important by management, when the dignity of labour was so often lowered into the abysmal cesspool of unemployment, soup kitchens and dole queues. Those who had fought between the years of 1914 and 1918 had left the battlefields of war for the battlefields of peace, and were sadly and bitterly disappointed.

In the building up of the great society of workers, in the slow but sure introduction of social justice and social security, we have, in

*The author joined Guest, Keen, Williams in August 1946 and is now its Deputy General Works Manager. He was the First Secretary of the Indian Council of the Institution of Production Engineers and represented the Council on the NPC for two years. He was member of the Guiding Body set up to form the Calcutta Productivity Council. He is associated with many technical and charitable institutions (Chairman of the Cheshire Homes; Managing Trustee of the Cheshire Foundation), Member of the Board of Governors of the West Bengal State Technical School; Representative of the Indian Engineering Association on the Metric Cell, etc.

†Though this is being published for the first time, it was originally delivered as an Address to Young Engineers (inaugural meeting of the Calcutta graduate section of the Institution of Production Engineers) As probably the readers would not like to miss anything that Mr O'Leary said during the course of his speech, we may reproduce here the prologue:

"It has often been said, Gentlemen, that man's greatest achievements are birth and death. In the first instance because he sees, for the very first time, the light of day and in the second, dependent upon the findings of his creator, he enters eternal darkness or eternal peace. During the gap between these two achievements—the span of life—which in true fact is the human race, man witnesses great scales of joy, gigantic scales of human suffering, and we Gentlemen who participate in this race, contribute to both......During this span of life we have three loyalties—loyalties which I put to you in the following order—the first to our Creator, the second to our family and the third to the society within which we live. It is of the latter, our loyalties and responsibilities to the society within which we live and the part you can play in that society, I wish to speak this evening......We older members are slowly but very definitely approaching man's second greatest achievement. Perhaps it is not a bad moment therefore to look back, take stock, and ask ourselves—could we, your elders, not have contributed more fairly? Could we not have contributed more? Have we really contributed sufficiently to our society? Have we used the right measure?......"

‡After the Prologue, Mr O'Leary thus introduced himself: "As for myself, I was born during the 1914-18 war, a war, Gentlemen, that in the delirium of subsequent peace was referred to as the war to end wars. I recall—perhaps a little dimly—being embroiled in a cruel and bitter fight for independence in my country—Ireland—which was followed by an equally cruel and bitter civil war—a civil war in which those who had once loved and stood united, now hated, fought and killed. I recall more clearly being engaged in the 1939-46 war and *somewhere amidst all this I have memories of being educated.*"

some instances, arrived at a point where the conscience of the worker no longer belongs to him. We have reached a stage where trade unions are as illogical and intolerant as the one-time management, and it is not uncommon for unions to battle for political strength rather than for the worthy aims upon which they were originally founded.

We have in this land—India—a condition which is bordering on the ridiculous: a country which is so grossly over-legislated by labour rules as to make the very concept of the application of good management techniques seem farcical.

Again as my memories race back to the early twenties and thirties, I well recall those untold hardships and sufferings brought about by slumps and resultant unemployment. I can recall the time when bread and dripping would often be a family's main meal, and I well remember when the miners of South Wales walked 180 miles in silent protest to the Houses of Parliament in London—a wonderful and dignified appeal for better conditions, not so much for their own sakes as for the sake of their families.

Insecurity was the order of the day for the worker and his dependents, but this insecurity, this social injustice, cruel and bitter though they were, did act as a human adhesive for the family. It brought about a bond of sympathy and understanding, and so very often, a united prayer for better conditions.

Today, I see in certain countries a swing to the opposite extreme. I see a deterioration of the family life, a deterioration brought about by soft living and a labour shortage, conditions which result in both husband and wife working (they have simply a place to sleep in) and the children are often neglected and deprived the very essential basis of parental love and family life.

I well remember, as a child, sitting around the warmth of a coal fire and listening to stories told by my parents: stories of hardships, excitement and fun. And then the wonderful realization that I could read and my gluttony for books. The art of storytelling, and the art of reading are indeed fast disappearing, as a form of an evening's entertainment.

From such a background we arrive at Today. We have been the witnesses of gigantic forward strides in the field of medicine and scientific technology, and we have entered the space age through a combination of both. We see nations expending fabulous sums of money to achieve leadership in this space race—a race to get away from this planet to another, a race that apart from its technological achievements, has brought mistrust and fear into the hearts of nations.

I would like the tempo of this race slowed. I would like to see less money expended on it and more spent on this planet so as to make it less desirable to leave, and more pleasant and peaceful to stay.

I and my generation have seen a considerable increase in the tempo of life. Distances are no longer vast, and the peace and tranquility, so well appreciated in the past, are today raped by the ease of communications. The pony and trap, the cycle, the motor car, the aeroplane, the modern jet and tomorrow, the space craft. The landscapes of the beauty spots of countries have been transformed into eyesores by the hideosities of factories and power stations. The life of the slumberous village is being transformed into the humdrum of city existence.

Machines operate faster and more accurately; handskill has been almost completely replaced by machine skill. The load and pace of management have increased to such an extent, that often, its worries and responsibilities, result in the curse of coronary thrombosis, ulcers and nervous breakdowns. It was at one time a pleasure to read the front page of a daily paper. Today it is invariably horrifying, and the press seems to devote as much time to protons, neutrons and isotrons as they do to morons.

With today's complications, with its international politics pregnant with intrigue, with its continuous mistrust and threats of war, you may well say, that we, your elders, have done badly. In saying so however, you must also be prepared to learn from our mistakes and not be hesitant in taking part actively in your own future, and the future of your society. All centuries are dangerous; *it is the business of the future to be dangerous.* It must be admitted that there is a degree of instability which is inconsistent with civilization. But, on the whole, the unstable ages have been the great ages.

The students and graduates of today are the heirs-apparent to the throne which we will shortly vacate. At present you are potential engineers on the threshold of your careers. Most of you will become corporate members of the Institution of Production Engineers, many will reach the top levels of specialization. Some will enter the field of scholastics and some will reach the very peaks of industrial management.

Mr NN Sen Gupta, the well-known and able Principal of the Calcutta Technical School, when asked, what he produced, as a member of the Institution of Production Engineers—replied, "*I produce good engineers*". India requires thousands of good engineers if the developments being brought about by industrialisation are to operate efficiently and economically. Good engineers can only be produced by imparting good technical education in the colleges and technical schools, and also, and this is equally important, by giving a good sound basic education in the primary schools. In order to achieve this, the teaching profession in this country must be placed on a basis worthy of its vocation, and until this is done, good teachers will not be available, good education of the required standard not given, and good engineers not produced in the numbers required.

The late Sir Fredrick Handley Page was perfectly clear in his mind when he said "I am not one of those who believe that you can divide education and training into vocational and non-vocational......in my view we must look to two things—the life of man as a responsible human being and as a member of society, and we must look to his competence in some chosen field. A full personality is based equally upon a man's cultural, intellectual and spiritual life as upon his competence in his actual occupation, be it craft, technology or management. His inner life and his outward life together make up the whole man and neither can be sacrificed without detriment to the other".

One of my greatest disappointments in a period of twenty years' total residence in this country, has been the language controversy and the recent decline—the enforced decline—of the English language. If this decline is permitted to continue at the present rate, it must have far reaching repercussions on the quality of the country's engineers. I submit that every nation should retain its heritage and it is the duty of every nation to ensure that the background of its heritage is not lost. The experience of Ireland on the issue of languages could well be taken as a lesson, and I would like to quote an extract from a recent issue of *Time* magazine regarding Ireland's language problem with reference to its present day rapid industrialisation and growing prosperity:

"Among those who stayed on there was a paralysing sense of frustration and fatalisation. Life was not only hard—it was dull. To many Irishmen the perverse, the pervasive mediocrity of their culture was typified by the Gaelic worship. The dying Gaelic tongue had become the badge of Irish nationalism during the revolution. Even before 1949 when the Republic was established, the Government had made the Gaelic language study compulsory in the schools and even encouraged students to take other subjects entirely in Gaelic."

Ireland has, at the very high cost of crippling emigration, learnt a lesson, and the tendency today is to veer away from extreme idealism and ultra-nationalistic policies. I am not, for one minute, suggesting that India's languages should not be taught and spoken freely. What I am predicting is, that *the decline in the English language can only result in a decline in the sciences and technologies, and in the quality of engineers.*

The term "Production Engineer" came about at the time when Henry Ford's production methods were developed, and its acceptance was accelerated during the first world war when the production techniques in the factories of the United Kingdom had to be completely re-organised. The Institution defines a Production Engineer as one who by reason of his education, training and experience in technology and management, is competent to determine the factors involved in the manufacture of commodities and to direct the processes so as to achieve the most efficient co-ordination of effort with due consideration for quality, quantity and cost.

When Sir Walter Puckey, a past President of the Institution, was invited to attend the 47th Indian Science Congress in 1960, he took advantage of the visit to give several lectures throughout the country. Some of you may recall his address in Calcutta to a joint session of the Institution of Engineers and the Institution of Production Engineers, when his subject was "On Top or On Tap". In other words, why are not more engineers leading the engineering industries instead of serving them? I would commend to you the article by Mr HP Barker in the Institution's Journal of May this year, and I suggest that this problem must remain constantly in your mind.

It is true to say that *the engineers of the past contributed as much, if not more than any other profession, to the techniques of management.* A large number of these engineers created and managed their own industries and attained exceptional heights in management and in leadership. Statistics show that in Britain and the United States only 17 percent of top management are engineers and it is obviously evident that both countries have depressed the participation of engineers in this sphere. The reverse is the case in Russia. There is obviously a reason why the most advanced capitalist countries have reduced the participation of engineers in top management to a level ill befitting their profession.

Let us examine the engineers' claims to top management: Management has been defined as "The art of getting things done through people". Engineering has been defined as "The art of combining science, men and money for practical purposes". There is therefore, in the interpretation of both, a great affinity.

A trained engineer, by virtue of his training, which necessitates him to work with all classes of men, will have had opportunities to exercise management command. The experience that he gains on the shop floor will impart the necessary discipline at an early stage. He is most decidedly directly concerned with money, because the economies of production call for this concern. Above all the engineer is the creator of the products and of the processes of industries.

In the last century, the purchaser of engineering products invariably went direct to the manufacturer and the engineer was the top man. This period was paradise for the manufacturer. With the passing of time, the problems of production became subjected to those of marketing and to the new problems of administration and financial control. In the bad days—the days of slump or near slump—the sales marketing specialist and the accountant blossomed forth and ascended new heights. The emphasis was on selling at a minimum price. Shortly afterwards came the introduction of refined and sophisticated administration, when masses of paper were introduced from which only a few of the most enlightened organisations have managed to liberate themselves. As engineers we must admit that we are *intolerant of documentation*, and are often quicker than others in pin-pointing nonsense disguised as figures. Engineers have also made themselves indispensable to such an extent that they cannot be spared for administrative posts. We have as a profession, accepted this, because the fascination of engineering has been self-rewarding. Nevertheless the top management has parted from the creator of the processes and products and joined the marketeers and financial administrators.

Another important contribution to the present day state of affairs is that in the past the top man dominated in the works whereas today he dominates from Head Office. I would like to quote from Mr Barker's paper:

"Finally there is yet another and more subtle reason. Machiavelli in his book The Prince said, if I may coursen his elegant phrases, that *if you want to be a prince, the first thing is to get into the palace. Now in industrial terms the palace is the Head Office*, and men who work there enjoy the political advantage of propinquity to the seat of power; whereas the engineer is seldom seen in the carpeted vistas of executive suites. Accountants in particular enjoy the special advantage of presenting the news to the boss which they properly accompany with their own comments and criticisms. When things go badly it is not unnatural for the boss to say to the accountant "you had better take over this mess yourself". Perhaps it is not too fanciful to compare the adventitious promotion of accountants with the American tradition of the millionaire who started life selling newspapers. It was not that selling newspapers was profitable, but it gave the young man a quick and easy access to influential patrons. All these things taken together go a far way to explain why so many engineers of great management potential have been buried in the corporate fog."

Industries have been paying a heavy price because of the lack of technologists and technological understanding at the top, and because of the relegation of the engineer to the back room, but fortunately the position is slowly changing, and I hope that young engineers will contribute to increasing the pace of this change. One of the paragraphs in the book "How to run a Bassoon Factory" describes a Managing Director as a person who should know where his factory is located and endeavour to pay a visit once a year!

What do our critics say of us? Well, they say that we adopt superior attitudes and are sometimes arrogant to non-technical colleagues; that we tend to consider selling and profits as beneath us and fail to recognise all the managerial dimensions. They accuse us of being narrow men and sometimes bores, unable to accept anything but pure engineering matters. But, although these accusations may be true, they are also true of men of the other professions.

A few words about the future and in particular the future of young engineers. In order to more clearly assess the future it is perhaps as well to examine certain events of the past.

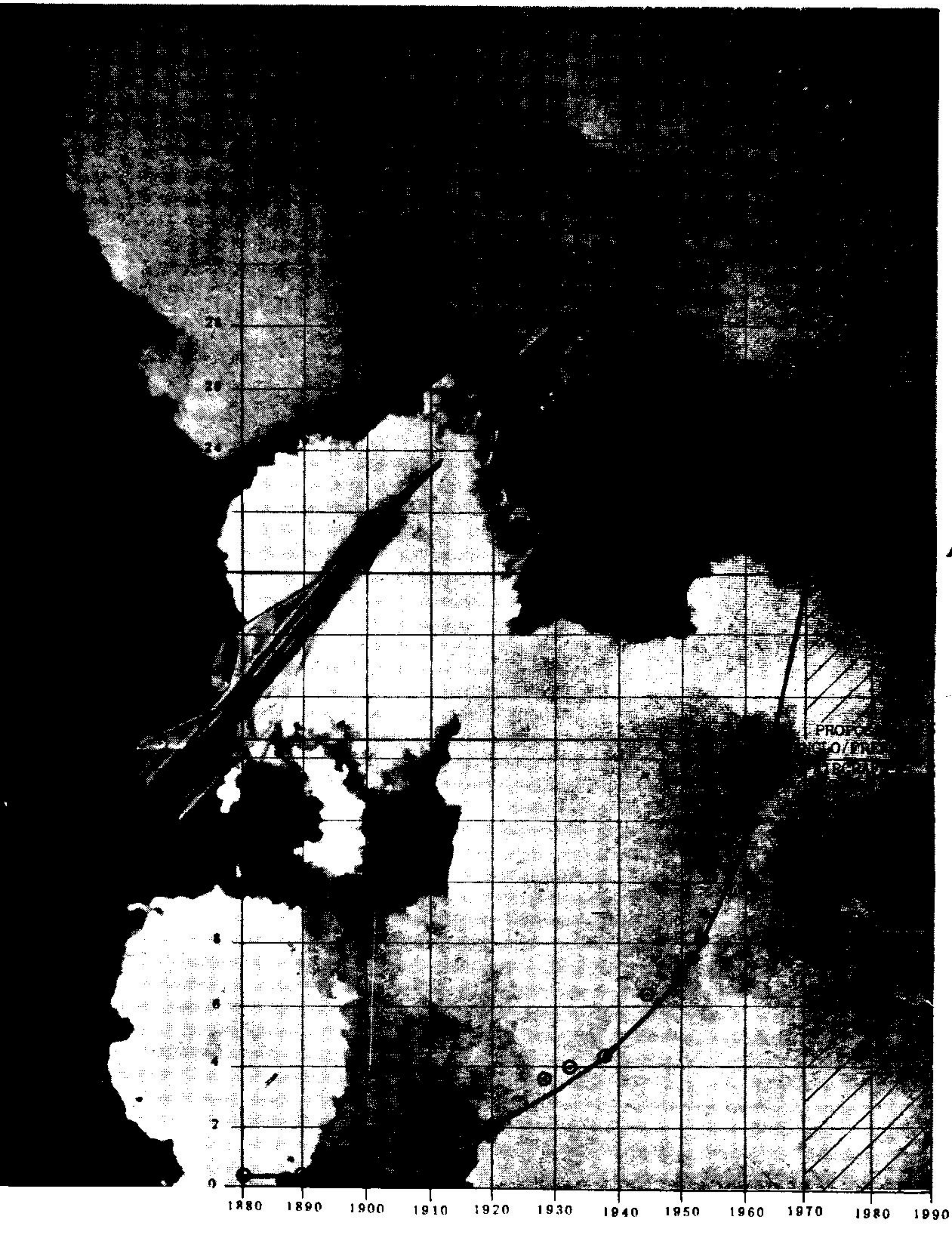
Your generation has been born at a time when the conditions affecting your lives are constantly changing. You are therefore subject to the belief that such changes have always been the case in the past and that such rapid changes will continue possibly at an increasing tempo gathering momentum all the time for an indefinite period. I submit that this belief is erroneous, that in the past and up to the commencement of the 19th century the rate of change was slow, and that in the future there will also be a slowing up.

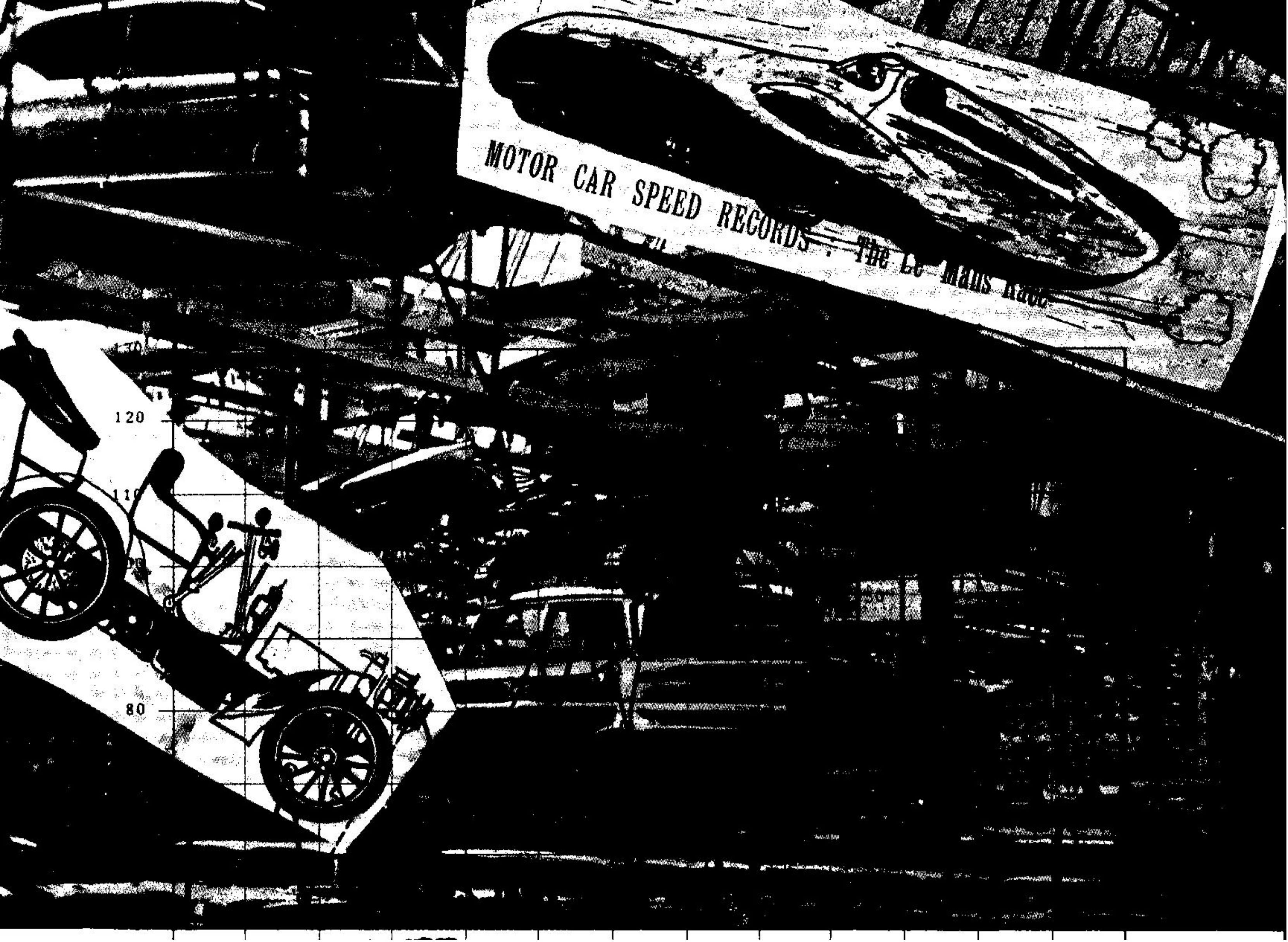
As I have spent some considerable time in the field of aeronautical engineering I will take the opportunity of quoting some facts clearly presented by Professor J Loxham, Head of the Department of Aeronautics, Cranfield. Professor Loxham refers to statistics relevant to man's scientific and technical achievements in travelling at speed over the earth's surface and utilizing aircraft, space craft and automobiles.

You may for instance find it difficult to accept the fact that up to the commencement of the 19th century from as far back as 100,000 BC the speed at which man travelled over the earth's surface remained relatively constant. The changes in this century, particularly during the last four decades, have been so incredibly violent that, we may well wonder, how man accepted it.

The chart (printed opposite) indicates the rate at which man has travelled in manned surface vehicles and aircraft from the year 1880 to 1962. From this Chart it will be seen that in 1880 the speed approximated to 40 mph and remained relatively the same for the next twenty years. From 1900 onwards we see an increasing change until 1950 when speeds of approximately 760 mph were achieved. There is then a sharp rise in 1955 to a speed of over 1100 mph, and then we

AIRCRAFT SPEED RECORDS (MPH×10²)




MOTOR CAR SPEED RECORDS
120
80

have the Anglo/French supersonic venture which will travel at 1400 mph and the proposed American aircraft with suggested speeds of 2000 mph. If the graph therefore is projected at the present rate of change, there is every reason to believe that manned aircraft will travel at 3000 mph in the 1970s and 4000 mph in 1980s. This is very very unlikely, not so much because such achievements will not be possible, but chiefly that it would be very costly and that we really are not prepared for such speeds. The Anglo/French project consists of a long and short range supersonic aircraft. The former being built in Britain, will fly from London to New York in three hours. Unless there are some miraculous changes in our traffic flow, our highways, our airport and customs facilities, it will take as many hours to get aboard that aircraft as to fly across the Atlantic to New York. Nevertheless this joint venture will cost the taxpayers £700,000,000.

The American *X15* experimental aircraft will undoubtedly exceed 4000 mph by 1970, but although this aircraft is manned, it is, and will remain, purely experimental. It is launched from the mother craft at heights of 50,000 ft and climbs to 250,000 ft and above, burning up all its fuel and attaining speed of 3,500 mph. It glides to earth and utilizes a landing strip approximately seven miles in length.

As far as passenger aircraft speeds are concerned, we can readily accept the fact that the rate of change experienced during the last twenty years will not continue during the next twenty.

Satellites orbit the earth at 18,000 mph and those in outer space are planned to attain speeds of 25,000 mph. It is not anticipated that these speeds will vary much during the next twenty years, although undoubtedly the craft will carry heavier loads at of course a very much heavier cost. The United States are at present expending £34,000,000 per day in an attempt to be the first to land a man on the moon.

Let us return to earth and study the automobile as presented in the Picture (printed opposite). At the Le Mans race started in 1906, a speed of about 64 mph was attained. Just before the first world war a speed of approximately 73 mph was reached and then came a drop to 68 mph in 1926. In 1930 a speed of about 90 mph was attained and in 1939 approximately 105 mph. Since 1951 we have seen averages of 110 mph. It is evident from the picture that the rate of increase between 1950 and 1962 slowed down considerably in comparison to that between 1922 and 1939. Another interesting fact is that the variation year by year was very much greater between 1922 and 1939 than between 1950 and 1962. In spite of the fact that we have attained averages of 110 mph at the Le Mans race it is most improbable that we will attain this average on our roads and highways over the next twenty years. We may attain them and even exceed them for short spells on motorways but the average speed for getting from A to B will be very much lower. The world speed record of 394 mph set up by John Cobb in 1947 still remains unbroken after nearly twenty years.**

So far the 20th century has been the most exciting century as far as scientific and technological achievements are concerned but we have ahead of us a period of consolidation and a period of perfecting.

Professor Loxham gives three examples which clearly denote the need of perfection and which also magnifies the gap existing today between performance, quality and reliability.

(1) *From the Sunday Times 29th December* 1962.

"BMC's Morris 1100, I nominate without reservation as the car of the year in popular motoring. In devising it Alec Issigonis has shown great ingenuity and imagination. In building it BMC has shown a willingness to

** This 18-year old record was broken by Craig BREED LOVE driving a jet powered tricycle car at 407.45 mph on 5th August 1963, only 13 mph faster than the 1947 record.

accept new ideas while others seem content to hide behind the skirts of convention.

Unfortunately evidence is already accumulating that the car's reputation is suffering from poor assembly and inferior finish. If this continues in important markets where assembly faults are less acceptable than they appear in Britain, the virtues of the 1100 may be lost before they are even discerned."

(2) *From The Daily Telegraph 4th January 1963*

"The probable cause of the Comet crash at Ankara airport Turkey, in which 27 people died in December 1961 was a loose screw in a horizon director instrument. It gave the Captain an inaccurate reading causing him to make an abnormally steep climb and the aircraft to stall at about 450 ft and crash only 8 to 10 seconds after take off."

(3) *From The Daily Telegraph 5th January 1963*

"We *can talk to men orbiting the earth* at a height of 150 miles and travelling at 18,000 mph. *But we do not provide the means for a train driver to communicate from his cabin to the man in the signal box.* If the train driver had been able to talk from his cabin to the signalman he would not have concluded that the red signal was a mistake and taken his train further along the line and caused the collision in which 18 people were killed and 50 injured."

It will be seen from these examples that we have a lot to do in perfecting and ensuring safe application.

Young engineers are being treated with generosity and with kindness and this will continue. For instance, there is little possibility that you have been employed at the age of 15 and dismissed at 21, a practice common in the past. You commence your careers having no justifiable quarrel with society. One of your aims therefore must be to attempt in a most honourable and sincere manner to give more than you receive. No group is better qualified nor more indebted to society than you.

Keep your priorities in the right order. History has proved beyond doubt that *although selfish and wrong behaviour may gain success for a season it has always and will always be doomed to failure.* When you get to the top, try and place less emphasis on profits than we have done and are doing. Do this by keeping in mind that *people are more important than profits.* Try and reduce the ever-increasing gap between top management, management and men, and always remember that *irrespective of how expensive your machinery is, if man has not the heart to operate it, the results will be disastrous.*

Your challenge is to enter the future inspired, dedicated and keen to be of service. My generation has laid the foundations of many of the facilities you are to utilise. Use them and refine them so that your achievements will create a sense of pride and gratitude.

Read and keep up to date on current and past affairs. Read the history of the last two hundred years—it was in 1765 that James Watt invented the first steam engine with a separate condenser—the development we see today started when man discovered the way to obtain motive power from steam.

Leadership is one of the most important qualities of good management and it cannot be developed by book reading or passing examinations. If you wish to capture the position of top leadership you must be men of worlds other than your own. Remember the pen is more powerful than the slide rule; you may wish to be a manager but it is your superiors who finally decide whether or not you possess the requisite qualities.

Bear in mind too that it is not always the incompetent who destroy an organisation. The incompetent rarely get into a position to destroy it. It is those who have achieved something and want to rest upon their achievements who are the greatest deterrents to society's progress.

In conclusion I would like you to consider an extract of an advertisement in an American paper by the firm WARNER & SWASEY of Cleveland :

"Voting money for schools does not make this an educated nation—it is not billions for more veteran hospitals that will make America healthy—*it is honest production, not shorter hours that protect jobs*—it takes more than costly playgrounds to cure juvenile delinquency. Pouring our billions all over the world does not buy security or peace.

Nothing worth having or worth being is ever reached except by honest hard work, but it is becoming the tragic fashion to think we can short cut work, and have everything we want if we only spend enough 'Federal' dollars. And then we mistakenly feel 'The Government has taken care of it', so we can sit back and relax.

Another once great nation withered and died when its people were drugged with the same fatal poison—perhaps the 'Decline and Fall of the Roman Empire' should be required reading in many places today.

Everything Government offers 'free' is obviously and always paid for by all of us in higher taxes or worsening deficits, not only deficits in dollars, but even more tragically deficits in national character and self respect. What would ever be worth that?"

Acknowledgements

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FINAL INSPECTION !

What Every Industrial Engineer Should Know

RF Bruckart*

When I was a boy, not too many years ago, a certain publishing house in the US made a fortune in publishing what were called "the little blue books", which appeared in hundreds of titles, covering nearly every imaginable subject. Two of the most popular books of this list were the titles "What every little girl should know", and "What every little boy should know". As might be imagined, these dealt with a subject frequently forbidden in the homes of the little boys and girls concerned—namely sex, and these little books served an important purpose of communicating in an articulate sense important information needed by these young people. My title for this piece: "What every industrial engineer should know" might be thought of also as articulating information useful to industrial engineers—although it is not related to sex, for *industrial engineering is obviously sexless.* In fact, some shop workers and Union representatives will go further and say that industrial engineering is not only sexless, but is *also heartless*—and sometimes they suggest, perhaps facetiously, *also brainless.*

WHATEVER THE FACTS IN THIS MATTER MAY be and possibly because of them, it is well that one should occasionally recite the behaviour characteristics the industrial engineer should display, even if they sometimes seem obvious. For some of the tasks the industrial engineer undertakes are dependent on these characteristics, so he should be able to see his position clearly, and preferably from a lofty point of view.

Probably the nearest approach to an ideal for the industrial engineer is to combine humble and conquering feelings into what might be called healthy self-confidence, and to strike a happy medium between in-growing and out-growing characteristics, what the psychologists call ambivalence. To reach this desirable state, he needs to build a personality made up of seasoned youth, knowledge, personal maturity, emotional stability and mental and physical alertness.

*Prof. Bruckart, as the readers of this Journal know, is no longer with NPC. He is now working for the US-AID Ankara (Turkey). This is one of his rambling, unfinished pieces he left with the Editor, who has taken the liberty of polishing it up for publication. Apologies are due to Prof. Bruckart for publishing this piece in his name.

This means continuing to learn. *One great foe to efficiency in an industrial engineer is the thought that he knows it all.* Experts in various activities may do jobs, but the direction and counsel and the organizing of big affairs are done by men who are always learning.

The industrial engineer should have a part both of an active and a contemplative life. He should spend time thinking. His character can be nothing else but the sum total of his habits of thought. *An enriched life demands an enriched mind,* and to speak on a very practical level, ten years of effort directed to one's work may not be so effective as ten minutes of concentration backed up by an informed thinking in a disciplined manner.

An industrial engineer should know that he is not fighting in a static field. He needs be increasingly conscious of the territories yet unconquered. *His story is one of endless re-commencements,* of the dispersal and reforming of doubts, and of the need, every once in a while, to examine whether he is measuring up to his own standards and those set for him by society.

No matter how far an industrial engineer travels on his upward path, his ability is put to serious tests. So long as his physical and mental health holds out he revels in these challenges. He would rather accomplish something in spite of circumstances than because of them. He likes an atmosphere of collision and disturbance. As an honest workman, he even welcomes failure, because it teaches him something and gives him a new starting place.

The opportunity to do worthwhile things crowds upon a man who is sensitive to it. *Only weak men cry for "opportunity"*. Sometimes in his life—many times in some men's lives—opportunity knocks imperiously at the door. It offers itself in proportion to a man's ability, his will for action, his power of vision, his knowledge, and his readiness. All of these are virtues within the reach of every industrial engineer in this country.

What counts in a man's life is the number of opportunities he grasps. Some men waste their time looking for big opportunities without preparing effectively to capture them when they come within reach. The big man uses his time, taking advantage of the little ones as they come.

Complacency and self-satisfaction are dangerous traits. They cannot possibly lead to that sharp vision of higher and better things which is the mark and symbol of leaders. They mean, when we see them in a man, that he is *content to flounder along on last year's or last century's knowledge*, looking over his glasses severely and *saying "no" automatically to everything new*. He is a negative person, in whose way of life there is nothing to hope for, but only deterioration and destruction.

Both the aspiring young industrial engineer, and the one who has experience, get more satisfaction from doing a job than from contemplating the finished product. Far more real than completion and ease and prestige is the stimulation that arises from the sense of accomplishment. It is not a "game" as some may call it, but a way of behaving and thinking that the industrial engineer finds rewarding, and one in which he believes.

As to the industrial engineer's long view of life, and the purpose of it, he must have *a certain idealism, a vision of what might be*. He *needs an honest purpose*, founded on a just estimate of himself, and steady obedience to the rule of life he has decided is right for him. He will, of course, have a sense of the perpetually unattainable. He must always be trying. But so long as he succeeds in being every day just what he wants people to think he is on that day, he is perpetually attaining.

The industrial engineer must think not only of his positon in the company which is employing him, but of himself as a responsible member of the society in which he lives. The industrial engineer is not merely a robot who functions within and for the company which pays his wages. His is also *a role which is part of the social drama*. Meeting the demands of both the function and the social norms may create strains, and a feeling of dissociation with the industrial society of which he is an integral part.

Too often I have observed industrial engineers in India speaking of "...the management, *they*...", rather than "...the management, *we*...". The industrial engineer may find it expedient to remain silent in the face of views of top management which differ from those he holds, because overt difference of opinion may hurt his chance for promotion. He must protect himself, however, against the tensions produced by the conflict between the different roles he plays if he is to survive and function effectively.

What are these roles? Every industrial engineer recognizes two major aspects of his position: The technical one, by which mechanical changes, objective analyses and impersonal applications of the principles of good management are applied to tasks under his jurisdiction. The second role is a more subjective one, in which his actions affect the welfare of the shop workers. For better or for worse, and through no choice of his own, the industrial engineer becomes a middle man between the management who claim his loyalty, and the workers around him who share his friendship. Thus is created a potential conflict. And as an industrial engineer he may find himself compelled to take actions which are contrary to the demands of the social role he holds in the community.

One solution to avoid conflict is to keep the roles and their behaviour norms in airtight compartments so that the conflict which is a necessary condition for conflict never occurs.

This approach to the problem is difficult to maintain, however. In the book "Folklore of Capitalism", Thurman Arnold provides a newspaper report telling of a well-known American industrialist testifying in 1937 at Congressional hearings on a certain wages and hours bill then pending. The industrialist had told how in the depression days he had "allowed" grandmothers to work for $ 6 a week "as a human thing". This shocked the members of the committee and they examined his attitude more closely. He then burst out : "Why I've never thought of paying men on the basis of what they need. I don't inquire into what they want. I pay men for efficiency." He observed : "Personally I attend to all those other things, social welfare stuff, in my Church work"—whereupon the entire audience burst into laughter. He sneered as he glanced at the audience: "Of course, some people don't know about that sort of thing, church work and so on...but that's the *feeling* side of life, church contributions and church work—*that's not business*[1]."

Probably, not many industrial engineers hold as fragmented a view of the responsibilities they carry out as this, and those who do would not be likely to admit it. But they have the same psychological need as this industrial executive had, and also need to avoid conflict between values.

Such conflict arises in many respects in the industrial engineer's daily activity. The introduction of labour-saving devices in a mill in a community where widespread unemployment already exists is an obvious example. Whose responsibilities are paramount—those of the company employing him, or those of the ordinary citizens whose wage already is at a subsistence level? Does the industrial engineer unfailingly proceed to separate his fellow man from his source of income for the sake of unrelentingly secure objective, impersonal, unfeeling efficiency—or does he sabotage the desire of his employer to improve shop efficiency, and thereby permit conditions to remain unimpaired?

In India one of the most actively discussed concomitants of the national productivity drive is a stated need for what is termed "sharing the gains of productivity". A recently published "working paper" issued by the National Productivity Council suggests on this matter : "The distribution of productivity gains can be effected in various ways :

......wage and salary increases
......productivity bonuses
......profit sharing bonuses
......decreasing the hours of work
......lowering prices"[2]

A short time ago a political leader commenting in a meeting sponsored by the National Productivity Council said :

> **"This (raising the quality of people) is our basic objective. All other objectives are subsidiary to it: even the objective of productivity......How do we achieve it? The whole nation will not make the necessary massive effort for productivity only to make some individuals richer. Of course, individuals need incentive, but individual incentives are not sufficient for national effort. Hence we have to** *look at the productivity movement from the point of view of the people as a whole.* **The objective is national prosperity and the people as a whole reaching higher standards of living...one has to aim at widespread benefits accruing to the whole community....[3]"**

We should not be deceived into thinking that this concern is limited to India, or to the so-called under-developed countries in general. Just a few weeks ago in the US, William McChesney Martin, the Governor of the Federal Reserve Board, commented in a talk : "Throughout our country we must not only increase productivity, but also pass some of the gains on to the consumer in the form of low prices, rather than having it all go exclusively to labour in higher wages or to management in higher profits."[4]

At this point, therefore, it becomes easy for the industrial engineer, as for others less well informed, to find themselves nodding their heads in agreement. On available evidence they conclude that the industrialist should be more open-hearted and share his profits with others. It is commonly agreed that everyone is in favour of doing something for the under-dog —for the less fortunate—especially if it can be done with money and other resources supplied by someone else. And they conclude if such an impersonal source as an industrial organization may provide the wherewithal—all are in favour of doing what must be done to the utmost.

To the industrial engineer, this is more than of passing interest; for it is with his active participation that additional profits are created to finance such welfare goals; or, on the other hand, from his unenthusiastic lack of action, may arise a continuation of the *status quo* for whatever good or evil that provides.

Accordingly, another of the things he should know is that the concept that business must be actively and energetically devoted to social endeavour also has its opposition wing. These opposing points of view are articulate and logical, and vigorously advanced.

One writer has observed recently : "...... the business of business is profits....... In the end, business has only two responsibilities ——to obey the every-day face-to-face civility (honesty, good faith and so on) and to seek material gain". He sees dangers otherwise of "the corporation investing itself with all-embracing duties, obligations and finally powers—and eventually moulding men and society into the image of the corporation's ambitions and its essentially unsocial needs,"[5]

Others fear that too much concern for social welfare will interfere with the corporation's getting on with the job. A concise objection to extensive social welfare in industry is stated as follows : "For the management of a corporate enterprise to dispose of what rightfully belongs to the stockholders without their free, affirmatively expressed consent is despotism, and it remains despotism no matter how benevolent or wise management is in acting for what it thinks is the best interests of its stockholders."[6]

Although in India this dichotomy has not yet crystallised, the design of the future is already evident, and the industrial engineer is squarely in the middle of the situation. If the thinking industrial engineer is baffled as to how he can justify the performance of his task in the light of possible losses to individuals or isolated groups of individuals, no one will condemn him. However, he will find no easy solution in sight. Traditionally he is advised to set his sights high so as to keep in view the gross good rendered for the many, rather than the difficulties created for the few. The task of the industrial engineer is to improve the efficiency of the industrial operations in his organisation. This advice casts him entirely in association with management's objective point of view, whose philosophy is that by so doing are created the only conditions under which the standard of living of the workers in the shop may be improved. He creates the conditions by which workers may be made productive. If doing so for the good of the greater group means that unnecessary inefficiencies are removed, this is a natural process which cannot and must not be impeded. Only under these conditions can social welfare prevail.

As techniques for improving industrial efficiency have been developed, the industrial engineer has been in the forefront, advancing and applying these techniques. The troubles of the early days of industry are not completely forgotten, but are secondary in the present day. The industrial engineer now talks about Operations Research, Mathematical Programming, Data Processing, and other techniques which did not exist at the time of the Gilbreths and Taylor.

Even today, however, it is not so much what he says as what he does that distinguishes the outstanding industrial engineer. The most modern ideas merely talked about, solve no problems; while the most fundamental principles in application create a wealth of benefits, tangible and intangible.

Thus we turn again to the original question : what *is* it the industrial engineer should know? If there is one thing which every industrial engineer should know it is that his efforts will be judged by what he does, rather than by what he *says.*

In a recent American management journal , a question and answer column contained a complaint from an executive reporting that in meetings with his staff, nobody volunteered fresh ideas; the discussions were vague, until he came up with an idea, then everybody "hops on the bandwagon". He observed, "I'm not right all the time, and I'm sure my ideas aren't the best, but nobody seems to disagree with me or wants to carry the ball on his own. What should I do about this?"[7]

The expert supplying the answer commented in his answer :

> "It takes a very special kind of boss to tolerate true independence among those who report to him. Most executives, whether they are aware of it or not, deeply resent or even fear anyone who expressed views that are contrary or critical". Furthermore : "As far as the attitude of subordinates is concerned, proponents of 'democracy in business' overlook the fact that most subordinates really do not *want* to participate. Far from bubbling over with new ideas they can hardly wait to impart, they are actually quite uncreative and uninterested. They enjoy being told what to do and it is genuinely upsetting to them to be asked to think through high-level problems and suggest risk-taking decisions.
>
> The mere fact that your subordinates reacted with silence to your overtures suggests that it was so out-of keeping with both your personality and theirs as to seem ludicrous to them. Evidently they were right........."

Have you ever heard of or known an industrial engineer with such characteristics? If the industrial engineer is of this calibre, waiting for the boss to show the way, his ability to resolve his conflicts is negligible; and his assistance as a staff member is greatly limited. Only those who display self confidence, a willingness to take a calculated risk, and *constructive non-conformity* are adequately prepared to deal with the problems they face daily.

Mental conflict is unnecessary and unbecoming to progressive young managers—especially industrial engineers. By his words and his works the industrial engineer must surmount his own unstated fears and those of others whose livelihood depends on his actions. *The industrial engineer in India must be an educator*—he must teach others how to overcome fears of the tools and techniques by which he does his job—fears of time study, incentives and of such things as redundancy, rationalization, and like concepts frightening to the workers—and sometimes frightening to the industrial engineer himself.

So to mummarise: what again may we say every industrial engineer should know?

First, that certain personal characteristics are required of him if his task is to be undertaken with confidence of success;

Second; even with the finest of personal qualifications, the most challenging problems will arise in which personal conflict may prove a most troublesome component;

Third: it is his acts by which salvation may be achieved, and through which personal relief may be secured—not by words, but by actions, and only the most progressive and enlightened actions are sufficient.

It has been observed that *every cause is great if greatly pursued*. What greater cause could we aspire to pursue than that of the industrial engineer?

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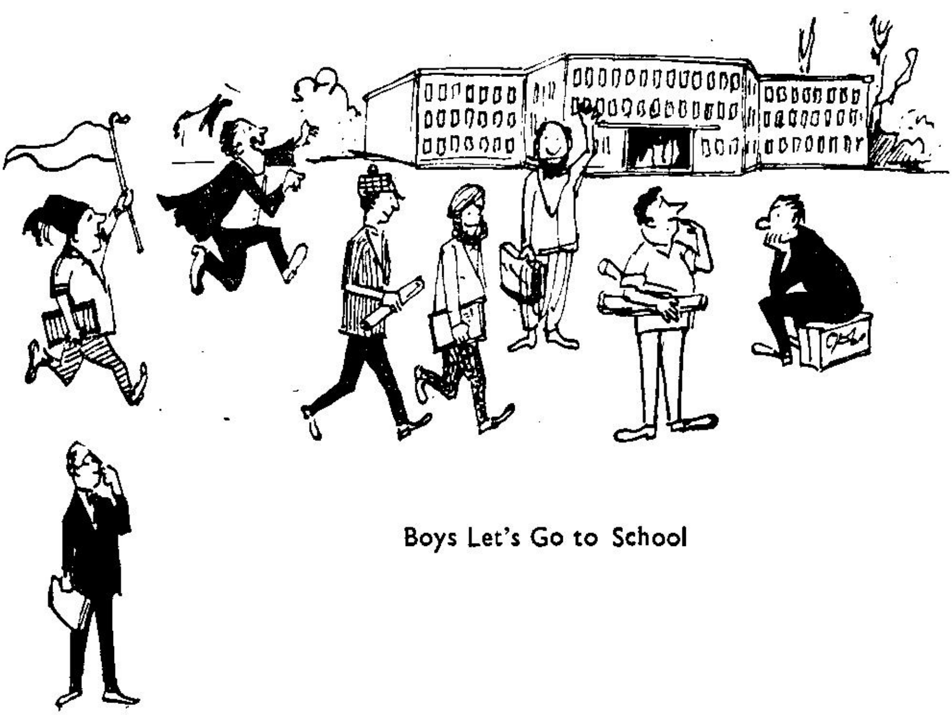
7. *Management Method*, "Manager Asks Expert' January 1961, p. 57

School of Productivity in Management



Boys Let's Go to School

STARTING A NEW FACTORY

EA Brackley*

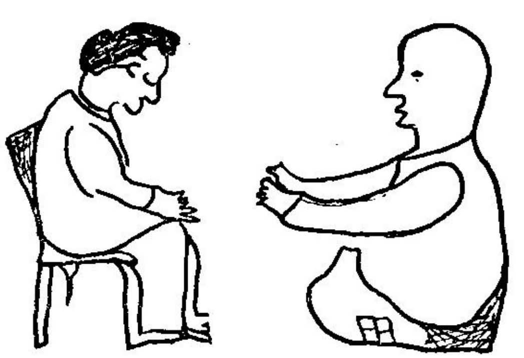
Before building a new factory, there are many points to be considered. Assuming that finance is there, the other factors to be considered are: location, land, type of building, services (water, gas, electricity etc.), availability of labour, material supply, transport both for raw materials and for finished goods, machinery, expansion plans, welfare services, handling equipment etc., which are all inter-related and must be planned.

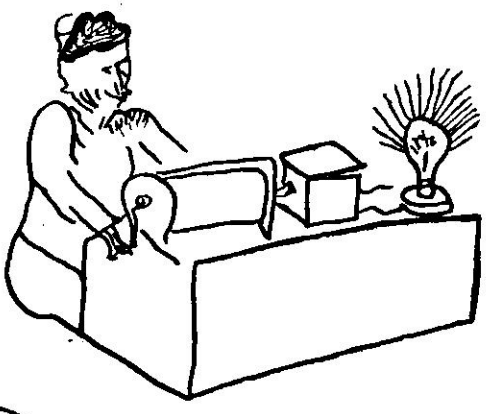
THIS RAISES MANY PROBLEMS, all of which have to be carefully studied before choosing a site. Ideally you may find a place that is near raw material supply and near the markets, but then you may find the cost of land prohibitive and areawise, little room for expansion. Similarly if you go further afield, land costs may be lower but services may not be there; transport costs may rise for raw material and finished goods. Skilled labour may not be available which may mean, housing facilities to be provided. Care must be taken to ensure that the site chosen is not liable to flooding. Remember that once a site has been chosen and purchased, you are committed. It will be too late to withdraw if you find that the building is up and the local river floods the area. Another point to watch is sewage disposal.

The Town and Country Planning Acts, and the industrial policies laid down by the local Municipal authorities as well as by the State Government, need to be examined

* Metal Box Calcutta

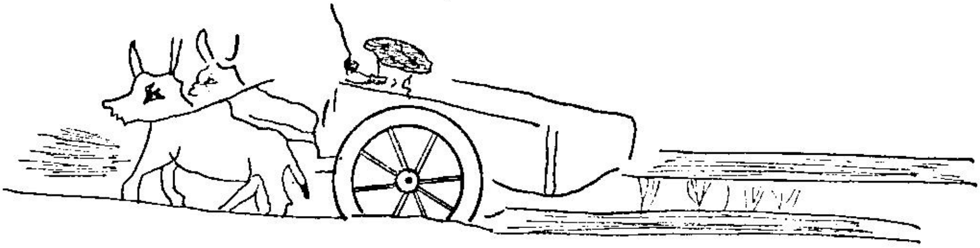
I've the best possible land for your new factory—Cheap





Electricity on Site

Almost Level



Good Approach Road

as also the postal, police, firebrigade and telephone services.

Another important point to bear in mind is that it is better to purchase sufficient land for future expansion and recreation facilities, as land values nearly always tend to increase rather than decrease.

building & services

How pleasing it is to visit a factory with an attractive building and well laid out garden and sports field, so different from *the old days when factories were constructed more like prisons;* pleasing as it may be for the visitor, it is far more pleasing for the employees to have pleasant surroundings in which to work and where they can relax in between working hours. Type of building varies with the nature of the industry which it houses.

multi-storeyed building

This type of building may use up less land, but it would require very solid foundations and re-inforced flooring if heavy machinery is to be installed; thought must also be given as to how the heavy machinery can be installed on upper floors. Yet for lighter industries a multi-storeyed building might be ideal, as gravity can be used for transferring operations from one floor to another. Provision must be made, however, for lifting the raw material in the first instance, to the top floor.

single-storeyed building

This type has a number of advantages. The foundations and flooring are less expensive to build, you can have natural north lighting, easier ventilation, less vibration, easier supervision and less risk of fire.

You have the choice of making the structure from steel, concrete, brick or stone. Steel frame buildings are more advantageous as they can be quickly and easily constructed. Services can easily be installed on the steel framework.

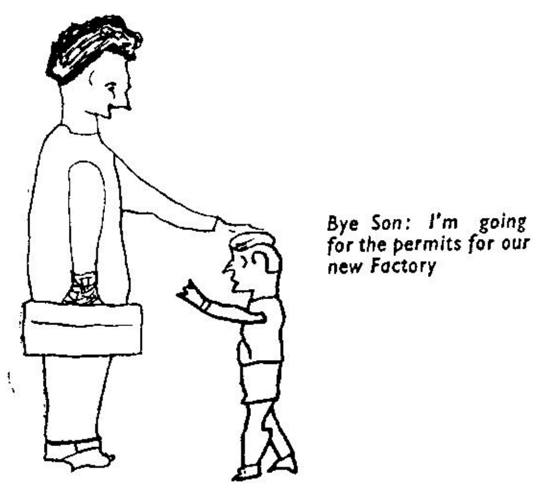
Types of walls and roofings may vary according to the climatic conditions—glass walls for instance are not suitable for a hot climate like India. Adequate light must be provided but glare should be avoided; similarly roofing should be chosen to suit climatic conditions. Smoke, fumes or unpleasant odours should be extracted from the factory area, and care must be taken to see that when doing so, neighbours are not subjected to the nuisance; watch the local bye-laws carefully when dealing with this problem.

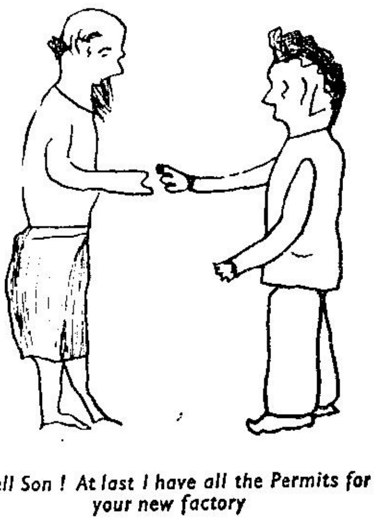
The surroundings of the building, where possible, should have wide roads leading to the doors. Space should be allowed so that vehicles can turn round. Ample room should be left for future expansion and facilities provided for a sports field, durwans' quarters, cycle sheds and garages. Many factories incorporate a lean to or a canopy of structure at the sides of the factory building to accommodate cars and cycles. A good plan is to have a multi-storeyed administration block, as a separate building to the factory; the ground floor to accommodate the Time Office, dispensary, cloak rooms and pay counter; second and third floors for office administration and top floor for Canteen.

After all the above factors have been considered individually and collectively, a layout plan should be drafted. The departments should be drawn up on a large scale drawing and each unit or equipment represented by a tinplate or scale model, pipes services must also be shown; at this stage it is advisable to form a committee to study the layout. The Committee should consist of the Chief Engineer, the Works Manager, the Work Study man, the Production Engineer and the Building Supervisor. The Personnel Manager and Head of Stores can be co-opted when required. This committee should examine the plan and make adjustments wherever advisable.

points to be considered

1. **The best layout is one in which the operations and movements of material will flow with the greatest ease and economy.**
2. **The type of product produced will have to be considered in planning the layout.**
3. **The sequence of operations and the process flow must be taken into account.**
4. **Flexibility of equipment and services to take advantage of future improvements of methods of production; i.e., services, gas, electricity, water, should be laid out in such a manner that little difficulty is experienced, should alterations become necessary at a later date.**
5. **Machines, where possible, should be individually motorised and overhead shafting avoided. A bus bar system allows for flexibility of future movement of machinery.**
6. **Avoid dividing walls and partitions inside the factory; they restrict movement, ventilation and mar its appearance.**
7. **Ensure gangways are wide enough for fork lift truck handling and that they provide easy access to all work places.**
8. **Ensure flooring strength is adequate where heavy loads are stored.**
9. **Avoid overcrowding of machinery which increases maintenance problems and accidents.**
10. **Provide ample storage space for stores, materials and finished goods stocks, make use of the maximum height of the building by palletization and use of mechanical handling equipment. Similarly, leave sufficient room for raw materials and semi-finished items at various work stations.** ***Ideally try to maintain a straight line flow*** **from goods inwards to finished products and despatch.**





An Inter-Disciplinary Approach To Industrial Engineering

DH Butani

WHEN the Editor of Industrial Engineering asked me to write*, I resisted it for a long time due to the feeling that a man with a social science background should withhold judgment on a field so professionally technical, as industrial engineering. It occurred to me, however, that I have noticed the same shyness among my engineer friends with regard to the economic and social implications of their technical projects. This set my mind backward over the whole history of economic thought of which I was a professional student a long time back. The paramount impression it has left on my mind is that this dichotomy between industrial engineering and social sciences has been a pretty costly one in terms of human suffering; how much, for example, of the immense social cost of the industrial revolution could have been avoided if the engineer and the economist had thought and worked together. As it happened, both worked in separate streams. The result was a confusion of thought, represented in the baffling fantasies of Carlyle, Ruskin, Shelley, Browning and the whole host of romantics who dominated the thought and literature of the time in Great Britain, then the world's workshop. This type of literature, however, only served to confuse the governing classes and became the real obstacle to the rationalisation of industrial policies.

A classic case comes to my mind which I am just quoting from memory. Ruskin was at one time lecturing on what had to be provided for the mass of workers: adequate quantities of nutritious food, housing and education on the most modern scale and the whole host of things which we now associate with the Affluent Society. At the same time, Ruskin was for some sort of a pre-industrial revolution type of society in which men smoked and women spun. Simultaneously, he wanted cosy working conditions, shorter working hours and all that. Not realising the contradictions involved in his own *naivette*, he waxed eloquent over what needed to be immediately done, when probably an engineer among his audience intervened to say: "Sir, do you realise how many hours per day a worker will have to work if he is to enjoy what you want him to. May I tell you, Sir, he will have to work for 272 hours a day!" Quoting from memory I may not have correctly reproduced what exactly happened but the above is broadly the substance of what transpired.

This has a bearing on what I have to say with regard to the future of industrial engineering. It is very obvious that *the industrial engineer is going to be the major instrument of change*, which is being brought about through the programme of economic development. It is very obvious to those who can see a long way ahead that *even agriculture has to be industrialised* if the country is to produce all the food that it requires for a population of nearly 450 million increasing at

*This was originally written for the Engineering Industries Annual Number. It is published here by the courtesy of its Editor the rate of 2 percent per annum ; if it is to produce all the raw materials that are going to be required in such immense quantities for the industries that are developing all round us. *Even small industries will have to be thoroughly 'engineered'* if they are to survive and prosper as sound business propositions. Industrial engineering will thus come to occupy a key role in the economic system.

If so, how is the system to be organised? Is the industrial engineer to work alone, as the industrial engineers did in the early phases of the industrial revolution? Are industrial engineers going to be the administrators and managers of the millions of projects that have to be executed through them? These are vital questions in administration and in economic and social policies. Do we associate the engineer with men from a large variety of disciplines: economics, sociology, psychology, management and the like, or do we make these disciplines an intimate part of his training in industrial engineering?

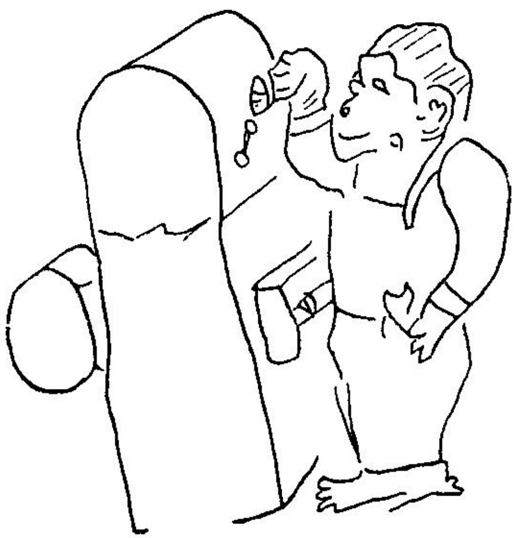
It appears to me that we shall have to follow both these lines of action. *The industrial engineer will have, of course, to be the fulcrum of the whole team of brain trust* that has to be constituted as the thinking mechanism for any large scale organisation. We have to think increasingly in terms of Team Direction. It is neither wise nor practical to put either an engineer or an administrator in sole charge of an organisation. Even in the army, quite a number of other disciplines have come in. It was a sociologist who prevented the shooting down of the Japanese in the war time camp in Arizona. The US Army Commander Incharge of the Japanese Camp had decided to shoot down unarmed Japanese concentrated in the camp at Arizona because they were found to be particularly troublesome. It so happened that there was a sociologist on the Board of Governors who intervened to say: "These Japanese are unarmed. We can shoot them at any time but should we not in the first instance ask them what they want? If their demands are impossible and there is no other means by which we can keep them in check, we can shoot them." In the American system of team work, these reasonable propositions cannot be challenged; and it had historic consequences. It was found that the demands of the Japanese were strictly according to the US law on the subject and the demands were by all standards reasonable and relatively easy of satisfaction. In fact the Government of the US had provided the necessary resources. What happened has been beautifully recorded in one of the master-pieces of the post-war period: The Governing of Men by Alexander Leighton, who was the sociologist on the Board.

This has a bearing on what I have to say with regard to the position of the industrial engineer in the society that we are building up, for the absolutism of the industrial engineer has been, as we have said, a very costly process. To the credit of the engineer it must be said that the whole industrial civilization of the last 200 years or so with its immense productivity and its infinite possibilities owes a debt to his talent and perseverance. As a result, however, of the very magnitude of the engineering achievement in the field of technology, there has developed in the engineer's mind a sort of absolutism, which in the social and economic sphere is self-defeating. There are people old enough to recall the mighty resistances evoked by the Time and Motion Study of Fredric Winslow Taylor who thought of mechanical contrivances to the exclusion of everything else, including himself! Even in the American industrial economy, so tempered now by the great advances in human relations, quite a few of the old tribe of Taylor yet persist and believe in the formula, to use a phrase which I actually heard in the US: "*Engineer the whole job*". Such persons are, of course, very exceptional in the industrial economy of the US. In fact one can draw a sort of curve of productivity which went up phenomenally with Taylor's earlier experiments in Scientific Management. An apogee was, however, soon reached and *with the very intensification of Taylor's techniques, productivity began to decline under the stress of industrial tension.* It again increased with the application of human relations techniques. At the present moment, in the USA, productivity is low in those concerns which still follow the path of Taylor. It is high in concerns which follow the path of Elton Mayo, Prof Whyte and men of that tribe. It is true that both extremes laugh at each other, but it is clear, who has the last laugh. An engineer still insists that standards are not negotiable but the management team of which the engineer is a part actually daily negotiates standards.

A new historic development is really taking place. Industrial engineering is emerging as an integral part of a new inter-disciplinary technique or rather two inter-disciplinary techniques, known as Operations Research and Ergonomics. These are attempts to *make the new technology an acceptable and workable part of current social experience.* Here it will take quite some time to develop these comprehensive techniques, for it can be done only when we have developed both industrial engineering and social sciences to a fairly high degree of concrete achievement.

In the meanwhile what do we do? In the first instance, as in the teaching of medical sciences, we should introduce practically the whole range of social sciences. It is possible with the new techniques of communication to see that the engineering syllabus is not unduly overloaded. In the second instance, in the public sector enterprises, we should be able to establish management teams in controlling direction of the organisation. Many of the new organisations have not attained their maximum productivity because either an administrator or an engineer has been put in sole charge. Where an engineer has been put under an administrator, there has resulted a degree of frustration that has for the most part cancelled the advantages of expert direction. In concerns where an engineer has been placed at the top, a degree of working class resistance has emerged which negatives the policies of the State. These are easily remediable arrangements. Most of these projects with an extremely high capital intensity can afford as part of their normal cost, a team of persons: an administrator, an economist, a sociologist, a psychologist and an engineer who may be treated as the *primus inter pares*. That will give balance to the system and will ensure an optimum mixture of idealism and realism: we have had so little of the latter!

Monkeying or Engineering?



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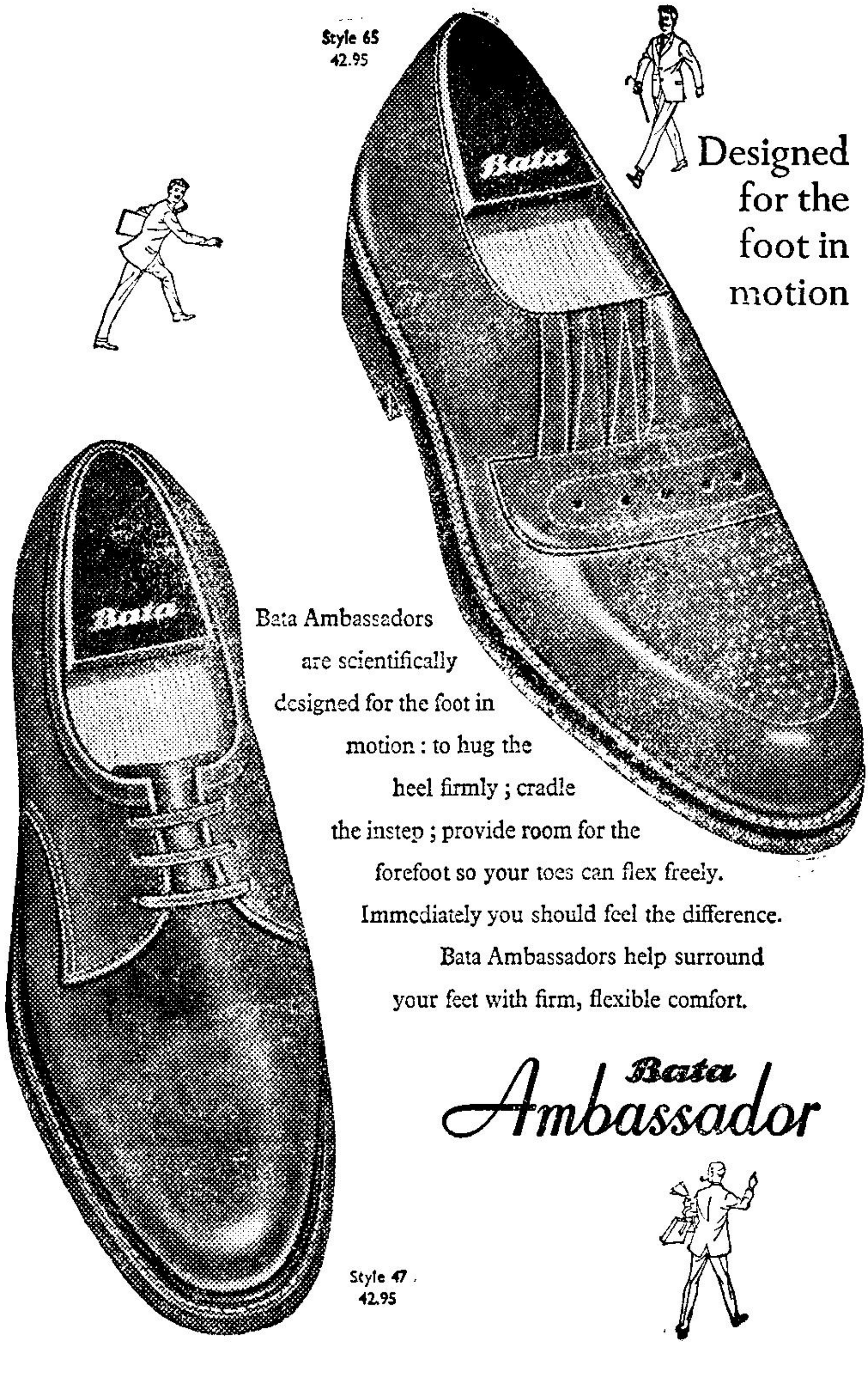
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Research in Production Control By Analogue Computer

WG Ainslie*

General Principles

Discrete and continuous problems

MOST engineering problems can be classified into two types: (a) those dealing with a fixed set of conditions of a static nature, and (b) those dealing with varying quantities of a dynamic nature. For example, in Fig. 1 a spring, initially free, is loaded with a mass. When the spring finally comes to rest in its new position, the displacement is given by the ratio

$$x = \frac{\text{Mass}}{\text{Spring Stiffness}} = \frac{M}{E}$$

that is, it is a discrete or single value.

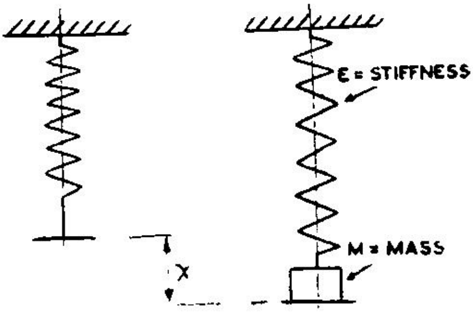


Fig. 1. Static extension

In Fig. 2, however, an example of damped forced oscillation, where the spring-mass-damper system is attached to a vibrating frame whose movement may be expressed by $P \cos pt$, the displacement from the neutral or static position is not so easily determined. It is obtained by writing down the force equation and solving, as follows:

Inertia Force = Mass × Acceleration = $M\ddot{x}$
Damping Force = Resistance × Velocity = $R\dot{x}$
Elastic Force = Stiffness × Displacement = Ex
Inertia Force + Damping Force + Elastic Force = Applied Force.

i.e. $M\ddot{x} + R\dot{x} + Ex = P \cos pt$...Equation 1†

This is a second order differential equation from which it can be shown that the displacement at any instant t is of the form

$$x = A \cos(pt - a)$$

That is, x is a periodic function, one continuously varying with time[1].

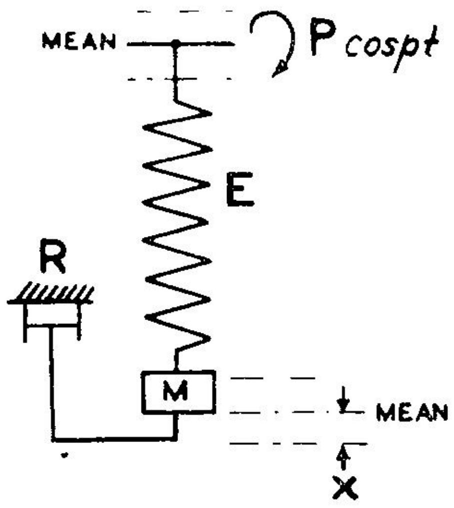


Fig. 2. Dynamic Oscillation (forced and damped)

* The late WG Ainslie was Senior Lecturer in the Department of Production Engineering, University of Birmingham.

† Dashes above x indicate differentiation with respect to time.

The *discrete* method of solution gives single results for each chosen set of static conditions. For a large number of conditions a correspondingly large number of discrete calculations are necessary, but they are all identical in procedure. For example, if the problem in Fig. 1 is to be solved for a series of loads, and for varying stiffnesses, then the number of separate calculations is the product of the number of each variable, and can be quite substantial. Of course helps are introduced to speed up the manipulation, such as sets of tables of previously prepared results, the aid of desk calculators, or even the service of digital computers *which simply carry out the calculation of each step at very high speed.* In Fig. 2, the displacement of the mass at any point of time can be calculated *discretely*, say at any time interval t from 0 to 10 seconds in steps of 0.01 seconds, requiring 1,000 calculations. If the effect of varying any of the constants E, R and M are to be explored, the number of calculations is multiplied proportionately. If 10 different values are given to each of E, R and M, then 10^6 calculations are required. The *digital* computer comes into its own and produces 10^6 answers in print, but these are difficult to visualise as a whole, unless they are plotted, but this is *analogue* output.

Fundamental operation of the digital computer The digital computer has three fundamental units of operation, '*and*', '*not*', '*store*'. It can multiply only because it can do so by continuous addition. When claims are made, then, that a digital computer can integrate, differentiate, generate series, solve equations and so on, what is really meant is that some mathematician has reduced the problem by mathematical numerical analysis to a series of simple arithmetical steps. Integration, for instance, is done by numerical summation of a sufficiently large number of discrete numbers. This is why a mathematician is often needed to run a digital computer economically. His role is the numerical analysis of the steps of the problem, and then the programmer is able to ensure that the sequence of operations in the digital computer conforms to such an analysis by coding it in numbers. Only numbers, usually binary, actuatethe counting devices, and only numbers are produced by them.

Principle of Analogy The continuous method of solution is to set up some model or analogue which will simulate the problem and will present a continuous record of results graphically or by indicator.

One of the first analogues was the slide rule, where lengths are proportional to the logarithms of numbers. The sum of two lengths is analogous to the sum of the logarithms of two numbers, hence the overall length simulates the product of the numbers.

The planimeter is another example of analogy. The angular rotation of the disc is proportional to the area traced out by the mapping point, and hence the graduations on the disc scale are analogous to areas.

The mechanical integrator shown in Fig. 3 is another analogue which was the key element in the mechanical differential analyser originally used for solving differential equations. If the disc is rotated through a small angle $d\theta$, then, assuming no slip, the cylinder is rotated through an angle proportional to $d\theta$, and x, say $A.x.\ d\theta$. If the constant

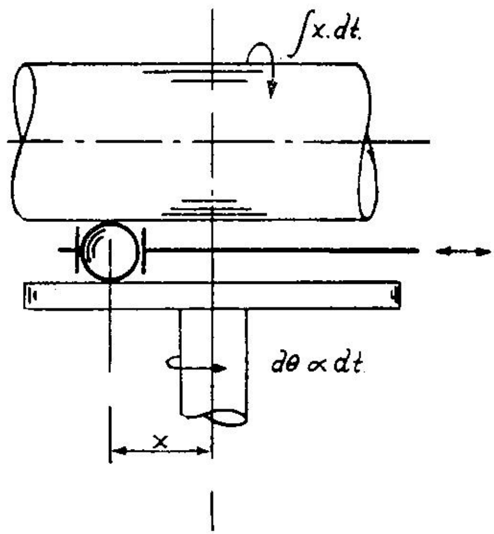


Fig. 3. Mechanical Integration

rotation of the disc simulates time, then the total rotation of the cylinder is $A \int x.\ d\theta = B \int x.\ dt$.

Mechanical devices have drawbacks, such as slip, friction, inertia, speed limits, and hence they are being superseded by electrical devices. Electrical analogies have advantages of ease of simulation by circuit design; they can amplify, give an immediate and continuous indication by calibrated metres, and can provide continuous graphical records. They also have some disadvantages analogous to the mechanical drawbacks, but these are more easily rectified or compensated.

Fundamental operation of the analogue computer Typical operations performed by an electronic computer are addition, subtraction, multiplication, division, integration, differentiation, function generation, coordinate conversion, switching, plotting; these are performed directly and almost instantly without long numerical analysis.

Using the previous example of Fig. 2, that mechanical vibration can be simulated by an electrical vibration in the circuit shown in Fig. 4, the voltage equation is obtained as follows:

Voltage across $R = Ri$

Voltage across $C = \frac{1}{C} q$

Voltage across $L = L \frac{di}{dt}$

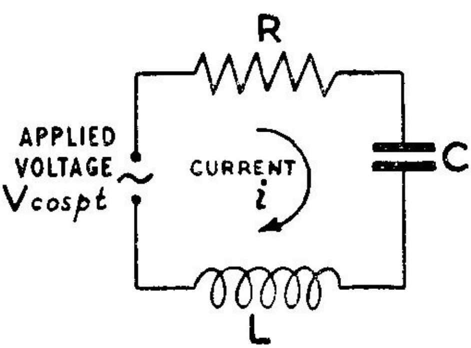


Fig. 4. Electrical Oscillation Circle

Where $R =$ Resistance
$C =$ Capacitance
$L =$ Inductance
$i =$ Current
$q =$ Charge

For instantaneous equilibrium,

$$L \frac{di}{dt} + Ri + \frac{1}{C} q = V \cos pt.$$

Substituting $i = \frac{dq}{dt} = \dot{q}$

$$L\ddot{q} + R\dot{q} + q/c = V \cos pt \quad \text{... Equation 2}$$

$$\text{cf. } M\ddot{x} + R\dot{x} + Ex = P \cos pt \quad \text{... Equation 1}$$

Thus, by appropriate scaling of the constants, the mechanical system can be studied by the fluctuating voltage in the electrical system either by an indicating meter suitably calibrated, or by a recorder giving a graphical record, or a CRO giving a curve trace as in Fig. 5.

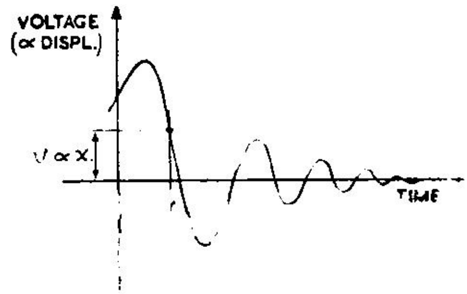
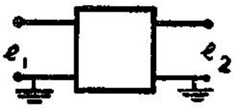
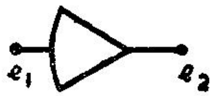
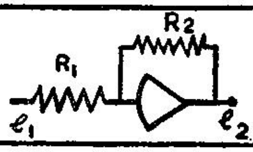
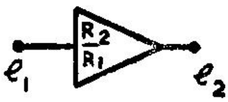
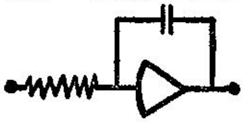
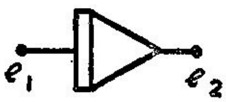
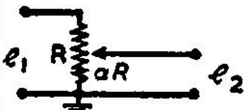
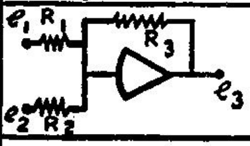
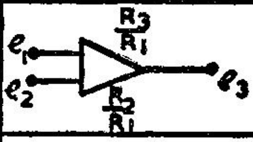
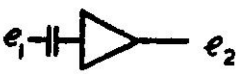


Fig. 5. CRO Solution

In the analogue computer, a set of *R-C-L* components gives an almost instant answer and a pictorial representation of the whole vibration. The values of *R*, *C* and *L* can be altered easily by switching and by using variable components. The general analogue computer usually has a wide range of values for *R*, *C* and *L* with separate tappings connected to a main switchboard, called a patchboard. By plugging or interconnecting, it is possible to set up a wide variety of problems quite unrelated but for their mathematical similarity.

Some of the basic computing elements are shown in Table 1, with the operating equations, and with the symbols sometimes used in system design, although these are not yet generally standard. There is preference in Britain to the use of the multiplier symbol and then to show the other elements as circuits, or blocks.

TABLE 1 BASIC COMPUTING ELEMENTS

ELEMENT	BLOCK	SYMBOL	EQUATION
① AMPLIFIER			$e_2 = -Ae_1$
② MULTIPLIER			$e_2 = -\left(\frac{R_2}{R_1}\right) e_1$
③ INTEGRATOR			$e_2 = -\frac{1}{RC}\int_0^t e(t)dt + k$
④ DIVIDER			$e_2 = ae_1$
⑤ SUMMING AMPLIFIER			$e_3 = -\left(\frac{R_2}{R_1}\right) e_1 - \left(\frac{R_3}{R_2}\right) e_2$
⑥ FUNCTION MULIPLIER			$e_3 = -ae_1 e_2$
⑦ DIFFERENTIATOR (LITTLE USED)			$e_2 = -RC\frac{d(e_1)}{dt}$

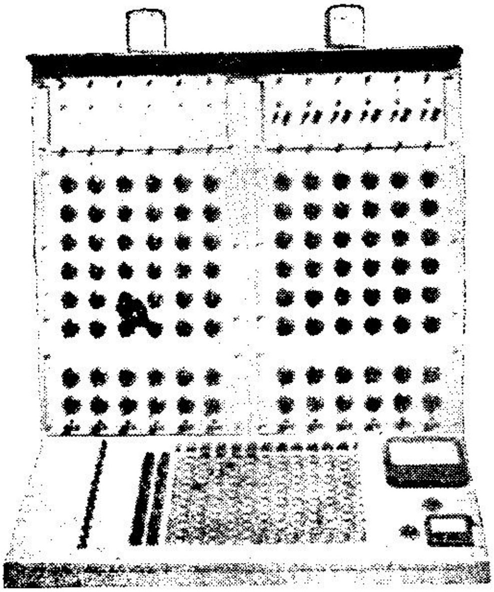


Fig. 6. General Purpose Analogue Computer (Birmingham University)

Fig. 6 is a photograph of a general purpose analogue computer built by the Department of Electrical Engineering at Birmingham University, and used in the researches described later.

Appraisal of analogue computation

Limitations The most common criticism is against precision. The components can rarely be made to function closer than ±0.01%, whereas the digital computer can be as accurate as is desired by extended registers. Too much is made of this point, however, since by careful circuitry, iteration and switching, results can be obtained to the degree of accuracy normally required. Most production control personnel would be contented with even only 1% variation from the production plan!

Speed of input is limited to about the same as a desk calculator or typewriter unless special provisions are made, such as motor-driven rotating switches.

Output is usually in the form of a curve, which may require further interpretation as far as numerical values are concerned, although analogue-to-digital converters have been developed to overcome this difficulty, and are now commercially available.

Advantages Generally, the analogue computer occupies very much less space, and costs much less than a digital computer of the same capacity. Unit construction is well advanced so that one can develop any special-purpose computer and assemble it from standard components, amplifiers, potentiometers, resistors, etc. Once an analogue circuit has been assembled, it is a simple matter for the engineer himself to set up his actual values and adjust them at will, within the range of the apparatus. For example, in the vibration problem, if the initial values of stiffness and damping factor are giving unsatisfactory responses (which are directly observable on the recorder or CRO) he can immediately change them by switching to a lower or higher range. A digital computer would have to be partly or wholly reprogrammed to accommodate such alterations, and would require the services of the mathematician to develop, modify and interpret the numerical analysis.

Application to Industry Computers for production planning and control in industry have been limited almost exclusively to the digital type. That is, the situation at any given instant is 'frozen' into a static or discrete problem, and the digital computer carries out the arithmetical operations to produce the relevant figures. If an analysis of the factory situation is required each day for the past year, then 300 to 350 discrete sets of calculations are required. If the situation is required for each hour, then this process is multiplied by a factor of 8, 16 or 24, depending upon the number of shifts worked.

The *interpretation* of the results is a fatiguing task of considerable magnitude and hence the analysis is sometimes uneconomic on that score alone. It is often advanced that a digital computer provides working schedules and sets of punched cards which can be used as actual control documents by supervision, but even in the simple case quoted above it can be seen that information in this form can become quite cumbersome to digest. To ease this burden, attempts are made to reduce the number of changes of input data, but this approach can result in the adverse effect of stagnation, or resistance to new ideas, new designs, new processes and new materials.

If an *analogue* computer can be designed to simulate the factory, then it would provide an easy means of studying the situation *as it is continually changing*. That is, it *assumes* that the factory is a *dynamic* system, with rates of change which affect the final working efficiency. In effect, this leads to the analogy of a complex vibration system with a multitude of factors affecting amplitude and frequency. Feed-forward and feed-back elements also are present, and these must be incorporated into the analogue, thus yielding a servo-mechanism of considerable complexity.

It should be noted that there is no advantage here to the few—if any—steady, continuous, unvarying flow production lines. The analogue computer is best used to determine what happens when something is *changed* ; it measures rates of change and their effects, and hence the underlying theory is one of differential equations.

fields of production control

The meaning of Production Planning and Control must now be considered, for there are four distinct fields in a large organisation, which may well merge in the smaller firm.

Overall production programme This has to be settled by the owners or directors who decide the monthly, quarterly, or annually rate of production of the separate products, orders, or service. Here is the input information used by planning department from which to produce the next document.

Factory Production Schedule which gives the rate of production of individual components or units per week, day or hour.

Departmental Production Schedule is usually compiled from the factory schedule where many departments are involved, in order to eliminate the circulation of unnecessary information. Both schedules are usually best produced in a central planning department.

Process Load This is the individual machine or process schedule, and is usually best done at departmental level, using the schedules 3.2 or 3.3 as the input information.

production control models

The analogue must start with the right input, hence the little research which has been done has been concentrated in the field of overall production programmes.

Tustin's Theory Professor Tustin drew attention to the likeness between some diagrams of economists and engineering servo-mechanisms, and he suggested an approach based upon servo controls to analyse the economists' models, showing that there existed a good analogy[2].

The following are selected from his many examples :

Keynes's Economic Model (Fig. 7) is a typical balance of the overall economy, in which Y is total income, divided into C (purchases) and S (savings); C is the customers' demand for P (production), which results in income. I is the rate of investment which adds to income, Tustin inserts the 1 (one) and k to convert it to a servo block diagram.

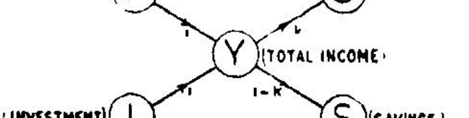


Fig. 7. Keynes's Economic Model

Kalecki's economic model (Fig. 8) is more elaborate, and again Tustin shows the analogous servo-loops with their transfer functions.

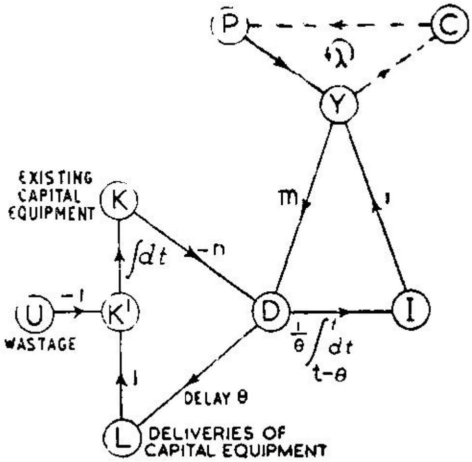


Fig 8. Kalecki's economic model

Tustin's final example shows how complex the diagram becomes as one considers the whole economy, but if the *national* economy can be discussed in this way surely it is feasible to consider a *factory* in similar fashion.

Morehouse, Strotz and Horwitz These three research workers designed a model and constructed an electrical analogue circuit to enable them to study the fluctuating quantities in a producing factory[3].

Certain assumptions of operation were made, enabling logical deductions to be drawn, which were then expressed in mathematical form. The latter enabled an electrical circuit to be designed whose operating equations were analogous to the production system. A very brief summary of the steps is as follows:

Assumption 1. Demand price P_d is directly proportional to the quantity of goods exchanged (Q_e).

i.e. $P_d = a + bQ_e$ ....(P1)

Assumption 2 Minimum supply price (P_s) is directly proportional to the quantity produced (Q_p).

i.e. $P_s = c + dQ_p$ ....(P2)

Assumption 3 Excess of demand price over supply price is an incentive to increase production, i.e. incentive $= P_d - P_s$.

Resisting this increase are two factors,

3.1 Sales inertia in drawing upon stocks, which is proportional to the rate of change of the quantity of goods exchanged, that is fQ_e.

3.2 Production inertia in stepping up output, proportional to the rate of change of the quantity produced, that is gQ_p.

Hence $P_d - P_s = fQ_e + gQ_e$ ....(P3)

Assumption 4 Excess of demand price over an equilibrium price (P_0) is the incentive for increasing the quantity exchanged.

i.e. incentive $= P_d - P_0$

Resisting this change are two factors,

4.1 as above in 3.1.......fQ_e.

4.2 Stock Control Inertia.

Stock can be expressed as the sum of the units accumulated between any given two intervals of time, i.e.

$$\text{Stock} = \int_{T_0}^{T} (\Delta Q)dT.$$

This reflects the policy of reluctance to stock change, and if the inflexibility of this policy is expressed by a factor $1/h$ then

$$\text{Stock Control Inertia} = \frac{1}{h}\int_{T_0}^{T} (\Delta Q)dT.$$

In order to control the new equilibrium level, an additional factor P_i is added, and, omitting details of derivation,

$$P_i = (P_1 - P_0)[l - \exp(-\mu\, \overline{T - T_0})] \quad \text{(P4.1)}$$

$$\text{Then } P_d - P_0 = fQ_e + \frac{1}{h}\int_{T_0}^{T} (\Delta Q)dT + P_i \quad \text{(P4.2)}$$

Assumption 5 The relation of supply price to inventory is given by : $P4.2 - P3$, i.e.

$$P_s - P_0 = -gQ_e + \frac{1}{h}\int_{T_0}^{T} (\Delta Q)dT + P \qquad \text{(P5)}$$

(a, b, c, d, f, g, and h are arbitrary constants).

To transform these five equations into electrical relationships the analogies assumed were :

Price	=	E.M.F.	=	E
a, c	=	Battery voltages	=	V_1, V_2
b, d	=	Resistances	=	R_1, R_2
Quantity	=	Current	=	I_1, I_2
f, g	=	Inductance	=	L_1, L_2

Then the corresponding electrical equations are :

$$E_1 = V_1 - R_1 I_1 \quad \ldots\ldots\ldots\ldots\ldots \quad (E1)$$

$$E_2 = V_2 + R_2 I_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (E2)$$

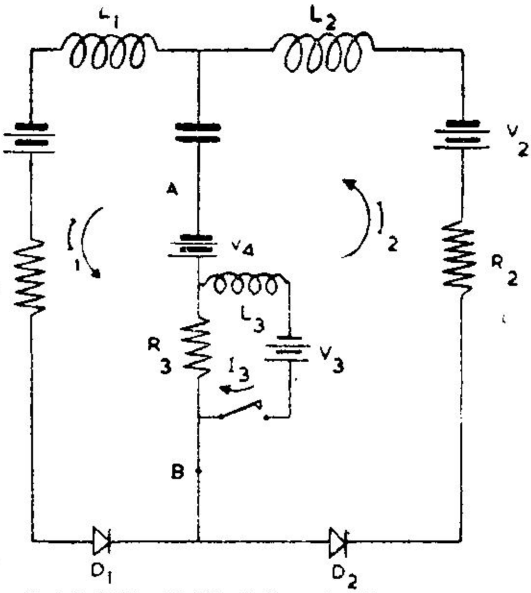
$$E_1 - E_2 = L_1 I_1 + L_2 I_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (E3)$$

$$E_i = (E_1 - E_0)\left[1 - \exp\left(\frac{-R_3}{L_3}\cdot\overline{t - t_0}\right)\right] \quad (E4.1)$$

$$E_1 - E_0 = L_1 I_1 + \frac{1}{C}\int_{t_0}^{t}(I_1 - I_2)\,dt + E \quad (E4.2)$$

$$E_2 - E_0 = -L_2 I_2 + \frac{1}{C}\int_{t_0}^{t}(I_1 - I_2)\,dt + E_i \quad (E5)$$

The actual circuit employed is shown in Fig. 9, and this was plugged into a general purpose analogue computer to provide a convenient way of varying inputs and measuring outputs. Many studies were made, such as increasing the demand, removing marketing inertia, modifying production inertia, changing stock levels and so on, full details of which are given in the reference.



D1 & D2 PRECLUDE NEGATIVE SALES & PRODUCTION

Fig 9. MS and H Circuit

HA Simon[4] gives an interesting theoretical development using Laplace transformation techniques, which is worthy of close study by the research worker, and an excellent survey of the field of published work is presented by OJM Smith[5].

production control analysis

The work in the Department of Engineering Production at Birmingham University in this field, alluded to by Professor NA Dudley in his article[6] is taking three forms.

'Black Box' approach Here the whole factory is considered as a black box with only input and output information examinable. The input is the demand, or orders, the output is the supply of finished goods, or deliveries. For any one factory, at one time, the total capital equipment is fixed, and the total number of personnel is also fairly constant, hence the factory has a maximum possible output, with an average output and a certain fluctuation about that level, corresponding to a fluctuation similar to that of an analogous servo system. Thus, by selecting typical factories and examining their inputs and outputs, it should be possible to establish their 'transfer' functions and hence to simulate the operation. Several studies of factories are now in hand, and one report by Chagnon on Input-Output Correlation of Batch Production has examined one factory in detail using the technique of Correlation Analysis to determine the dynamic characteristics[7].

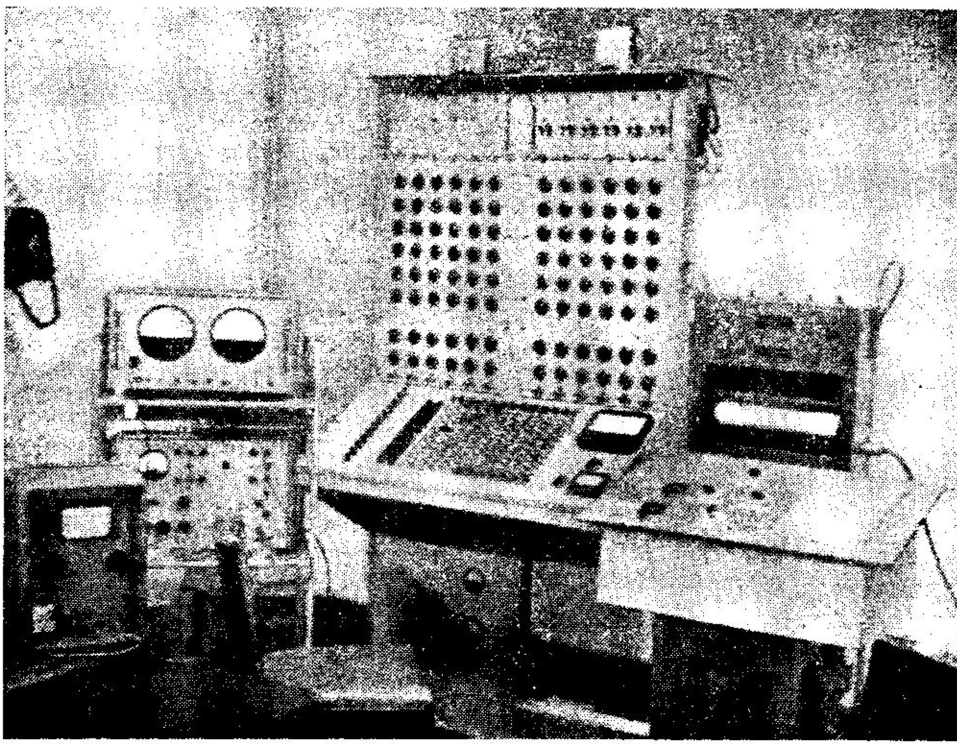
'Servo approach' The second method is the attempt to pick up the important control factors in a system and simulate them using graphical, mechanical, and electrical devices. Again the field studies are providing much data which will be analysed as the work proceeds but, in the meantime, the relevant theories are being developed, and here one very real danger has been to avoid over-simplification. If a servo is being adopted as the analogy, then since this is 'error-actuated', it is futile removing errors from the original system to simplify the analysis. Again, reduction of complexity of the problem may well lead to the elimination of oscillation, with the analogue giving the true but useless answer that there is nothing to control since there is no

error to effect the controlling!

A Production Simulator has been built by Sunde[8] which consists of a small analogue unit to be used in conjunction with a general analogue computer. Fig. 10 shows the arrangement of the set-up. The general analogue computer of the Electrical Engineering Department is in the centre, only four of its 12 units being used in this application. The simulator is in a separate cabinet on the right, together with the recorder. Fig. 11 gives an inside view of the unit and Fig. 12 is a symbol/block diagram.

The Production Simulator has been designed to enable a study to be made of stock levels and production rates. Risk functions (a new contribution) have been introduced into the system to represent economic deterrents, and the idea of units of production has also been introduced to provide a common reduction factor for various products, in practice corresponding to unit work content. Rates of production and demand are simulated by grid bias battery voltages, and these are integrated in amplifiers 1 and 2. The sign of the demand voltage is reversed in 3 and the demand thus subtracted from production by 4. The nett demand passes through the detector which switches it to the 'delay start' or the 'delay stop' circuit depending upon its value. The ensuing signal passes to the controller which is a function generator operating a motor rotating a potentiometer. This potentiometer represents the factory machinery; as it turns one way, it is simulating the switching on of more machines, and the other way simulates gradual switching off. The output is also fed back into the circuit, to

Fig. 10. Production Control Simulation set-up



complete the servo control loop.

Experience with this simulator has shown up some inherent defects and weaknesses, which are being rectified in a modified design.

The third approach is the study of the planning and control system at central planning level. Here a block diagram has been prepared similar to Fig. 13 (at page 43) and attempts are being made to reduce this to a servo symbolic diagram with circuitry.

The following analogies are being developed:

Current represents volume of work flowing.

Resistance represents the factory resistance such as material and labour shortages, avoidable delays, breakdowns, scrap, and other hold-ups.

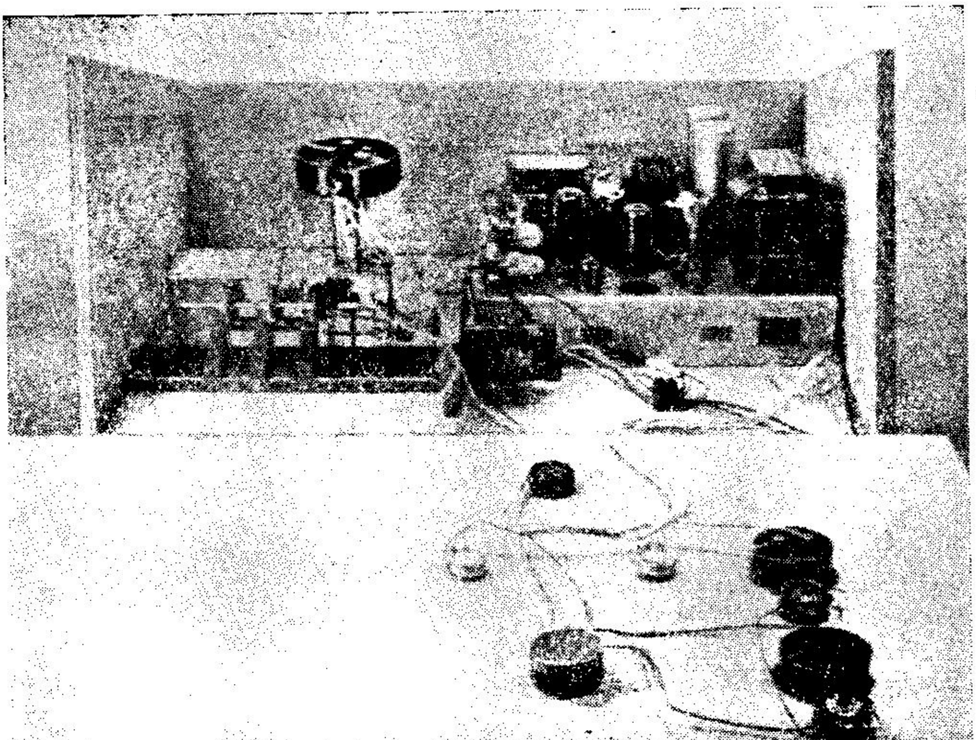
Voltage represents the pressure of work, or the incentive of profit, or some other policy which drives the organisation.

Inductance is an inertia, and industrial inertia is in three forms:

(a) *preparation inertia*, including programme decision, process planning, tooling, setting-up.
(b) *production inertia*, including changnig the rate of production of processes and operators (starting, speeding up slowing down, stopping).
(c) *distribution inertia*, i.e., stock acceptance rate, stock delivery rate, materials handling rate.

Capacitance Corresponds to capacity or storage, and factory storage is found in several forms, such as raw materials, goods

Fig. 11. Production Control Simulator—internal rear view



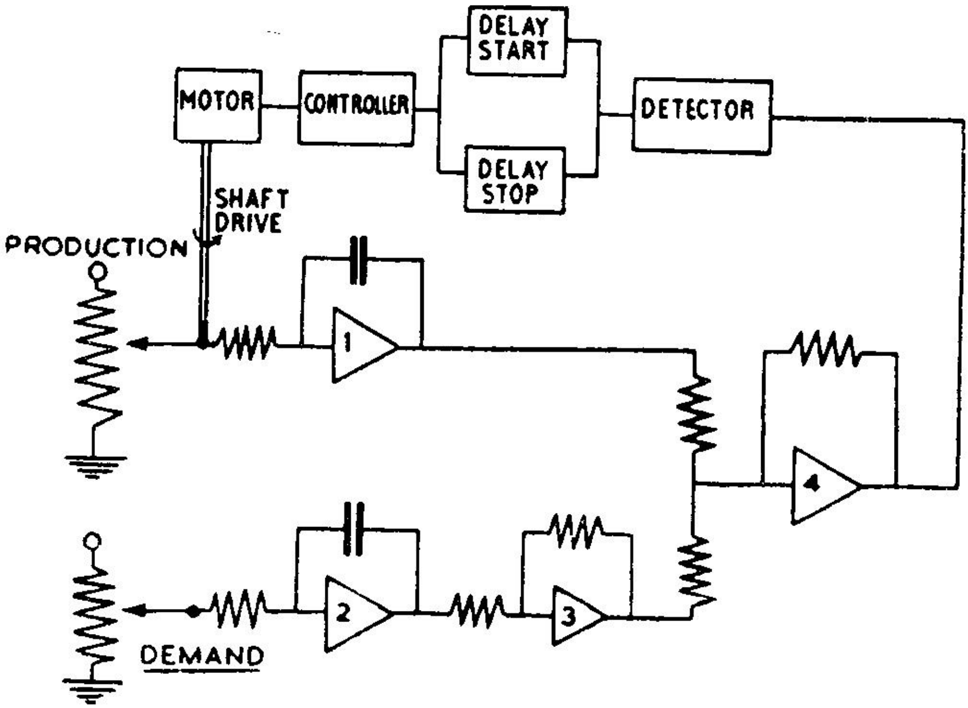
in progress, finished goods, spare or new machines, spare or new operators. (Some of these are often negative !)

There are major problems yet to be solved, which, in servo control language, could be summed up as the establishment of the range of transfer functions for each loop of the servo, particularly the feed-back loops representing capacity utilisation of men, machines and materials.

Conclusions It is hoped that eventually it will be possible to simulate production control in such a way that studies can be readily made of the effects of varying production load, rates of output, quantities of raw material, inter-operation and finished stocks, and plant capacity. Such a tool would give a quick, visual representation of the efficiency of the factory, or of the planning and control system, or of the decisions of the board of directors. It may be possible to build a simulator to act as a direct controller in the more mechanised plants. There are limitations and difficulties to be overcome, both theoretical and practical, but the newer techniques of mathematical statistics, econometrics, linear programming, queueing theory, and control systems analysis are powerful tools which should lead to interesting developments.

——:o:——

Fig. 12. Production Control Simulator



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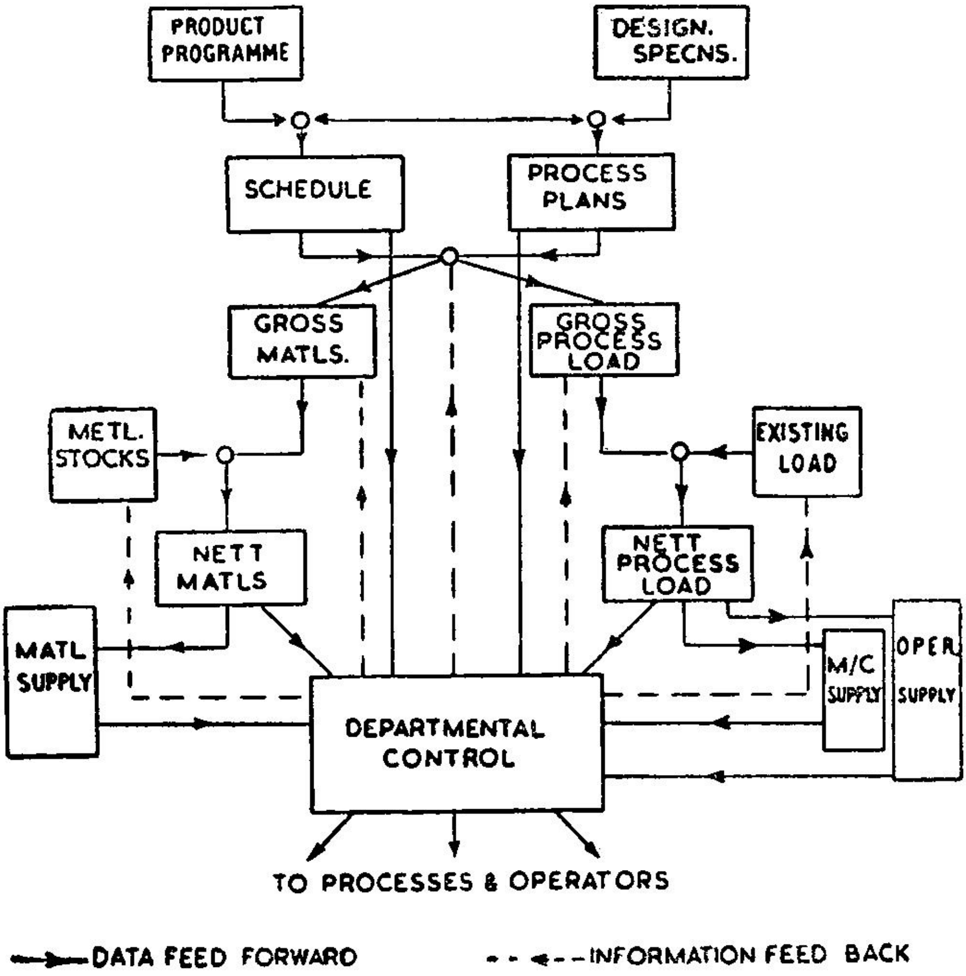


Fig. 13. Production Control Model

HOW EFFECTIVE IS YOUR PRODUCTION CONTROL?

Hugo E Remke*

Major benefits may be expected from a well-organized production planning and control department. Among other gains, it should aid in *reducing manufacturing costs, provide prompter deliveries to customers, facilitate employment stabilization, and improve relationships between the purchasing department and vendors*—**your material suppliers.**

A RECENT SURVEY WAS MADE in the United States, of production planning and control programmes of a number of progressive manufacturers. Based on the findings of this study is the following checklist of sound practices, against which you may check your own methods:

1. Does top management, in consultation with sales executives, issue a Sales Forecast for a year ahead that Production Control can use as its authority to plan production?
2. Is this Sales Forecast maintained current (i) by revisions of the requirements for the quarter immediately ahead according to finished goods inventory and market conditions, and (ii) by additions of requirements figures for the last quarter?
3. If the product is manufactured as ordered by the customer or according to the customer's specifications and a Sales Forecast is not practical, does top management provide a comprehensive policy that Production Control can use effectively to plan and schedule production?
4. Does Production Control break down the Sales Forecast into requirement quotas for all component parts, combining all common parts into single shop orders to cut down on number of set-ups or make-readies and to increase the length of runs in the shop?
5. Is Production Control provided with up-to-date bills of materials that specify product model and name; part numbers and descriptions; their arrangement into sub-assemblies and assemblies; material specifications and requirements for all parts; number of parts required for each model; and whether the parts are to be manufactured or purchased finished?
6. Are current blueprints that clearly indicate dimensional tolerances, finish, heat treatment, and assembly fits provided by the engineering department?
7. Does Production Control prepare a master schedule of material requirements that are based on the Sales Forecast and bills of material as to quantity and type and on the delivery dates as to time when the material is wanted?
8. Is the purchasing department informed of the materials required by material requisitions from the Production Control Department, where the quantities to be requisitioned have been determined by comparing materials needed on the master schedule against the materials on hand as shown on the inventory records of raw materials, work in process, and finished parts and complete assemblies?
9. Are the inventory records completely trustworthy because they are kept strictly current and because the mate-

***Member George Fry Team attached to NPC**

rials on hand are stored "under lock and key" and issued only by authorized persons according to a system of requisitions?

10. When ordered materials are received from vendors, are they inspected and tested as the specifications require before they are charged into inventories so that they are immediately usable when issued to the shop without rework or extra process?

11. Does Production Control have access to shop routings—operation sequence sheets; operation lists, or whatever they are called in your plant—that give operation sequence; operation description (in sufficient detail to insure that all the work, no more and no less, is performed at the operation) machine or work centre by symbol or description; manpower requirements; job classification to be assigned; rate of production; and perishable tools, jigs and fixtures to be used?

12. Does Production Control prepare a master machine load schedule through which top management can appraise plant capacity in terms of the product required by the Sales Forecast and break any bottlenecks before they snare production?

13. Are shop orders issued only when materials of proper size, type, quality, and quantity can be allocated to them? If substitutions are necessary in present-day shortages, are the substitutions controlled?

14. Are these shop orders released to the shop through despatch booths, or other definite points of control, so that the Production Control Manager can be held responsible for work flowing through the shop?

15. Are specific operational orders, based on the shop routing, issued to the workers according to the master machine load schedule and not according to the foreman's choice?

16. Do these operational orders identify the machine upon which the operation is to be performed, specify the production quota for the operation, and indicate the time that the operation must be finished?

17. When the operation is completed, does the workman turn the operational order into the despatch booth so that Production Control maintains control of the work in process?

18. Is quality control in your plant sufficiently stringent to ensure that parts sent from operation to operation meet specifications and do not require schedule—disrupting re-work?

19. Does a clear channel of communication exist between Production Control and purchasing so that late deliveries are spotted as far ahead as possible and the affected runs re-scheduled?

20. Are tools, standard and special, controlled through strategically located tool cribs so that the needed ones are available when the jobs are scheduled in the shop?

21. Are the perishable tool inventories controlled so that they reflect the need for them according to the work flowing through the shop?

22. Are Production Control and plant layout or plant engineering aware of each other's activities so that any re-arrangements of equipment that are necessary are dovetailed into production schedules without disruption?

23. Is Production Control kept informed of the activity of the maintenance crews so that work done on equipment is properly scheduled with regard to production runs?

24. Are finished goods inventory records kept current and the finished goods physically controlled?

25. Does top management realize that Production Control is merely a score-keeping or statistical department of the manufacturing division and that is as effective as the data supplied to it from other departments allows it to be? ●

Does Production Planning Require a Plan?

HC Ramanna*

THE PLANT CONSISTED OF OVER 1,500 EMPLOYEES. About 450 of these worked in the Machine Shop, about 150 in the Assembly and the rest in various other shops and office. The Production Planning Department consisted of about 33 employees in addition to the material handling gang. Inventory control and Industrial Engineering did not come under the purview of production planning.

An examination of the books and of the operations showed that the plant was working anywhere between 30 to 40 percent of its capacity. Machine and equipment utilisation was low, materials handling poor. There was considerable in-process lying here and there and yet the assembly shops were short of parts. A brief analysis showed that the chief culprit for the entire situation was the Production Planning and Control Department.

The second line executive was approached and apprised of the situation. He was told that even a little more analytical understanding on his part would produce considerable results. Thereafter a conversation ensued :

SECOND LINE EXECUTIVE (SLE) You know we are job-lot manufacturers mainly. We have no idea as to what order we get next ; and many a time we do not know how long the present order would run.

INVESTIGATOR That is the very situation I am discussing a remedy for. Don't you think that attempts must be made at stabilising operations?

SLE We would have done it long back if we could. What can you stabilise when your orders are in others' hands? Customers' whims and fancies that want design changes 20 times before the order is finished. In addition we have the vagaries of governmental policy causing frequent shortages of steel, coal, etc.

INVESTIGATOR Don't you think that these are the very circumstances which need investigation into ways of achieving stabilisation? If one can feed material at one end and draw out the product at the other, and straight send it to a market where the product is readily absorbed, is there a need for an investigation into the conditions that would favour stabilisation? Strangely, Mr Executive, the greatest need for stabilisation is felt where the maximum amount of unpredictable factors exist and this is where planning techniques help us.

SLE This is just the difference between theory and practice. I am quite aware that last month we had 30 percent overtime, but looking into the records three months ago, you will find 50 percent of our strength had barely any work. We had to lay off some men. This is the one reason you find so many temporaries and casuals.

fluctuations in activity

The above is a sample but to a greater or lesser degree we find the situation somewhat like the above practically in every factory.

In every organisation it is possible to detect fluctuations in production of the type mentioned above, but to a varying degree and assignable to various causes, such as raw material, labour, sales, etc. Of these, perhaps, the most important for the production plant considered is fluctuation in sales.

The forecasting, to the extent possible, of sales is closely integrated with stabilisation of operations and employment.

*Director, Management & Industrial Consultants Bangalore

Under a situation like the one mentioned above, an analysis is to be made in order to determine

1 the extent of variation in sale from the previous period ;
2 the extent of variation in sale from time to time during the period under consideration ;
3 the extent of attenuation possible to reduce the peaks and valleys in the sales pattern ;
4 conversion of the so modified pattern into a pattern of production operations ;
5 reviewing the modified pattern of operations on the basis of variation that may be caused due to factors other than sales. The following analysis sets out, in brief, how such a pattern could be arrived at and how stabilisation could be effected.

forecasting

Variations in the sales pattern exist in practically all types of industry—in some to a wide degree, and in some others to a lesser extent. These variations may be due to the following causes :

1 *Trends* These are long range movements of businesses towards increase or decrease.
2 *Irregular factors* like strikes, political disturbances, drought, floods etc.
3 *Political Factors* arising from changes in Government policy.
4 *Business cycles* overshadowing the above four : these are the well-known fluctuations in economic activity.

From the above paragraph we see that forecasting is needed in all organisations but the importance of forecasting depends upon

a. whether production is to order or to stock
b. Time involved in making the product
c Complexity of the product mix.

The steps involved in forecasting are

1 Correlation between a national measure of economic activity and company sales
2 Establishment of relations between the company's sales and the industry's sales
3 Analysis of the firm's sales by products and by territories including (a) field surveys of important consumer markets (b) surveys of concentrated markets for industrial and producer goods.

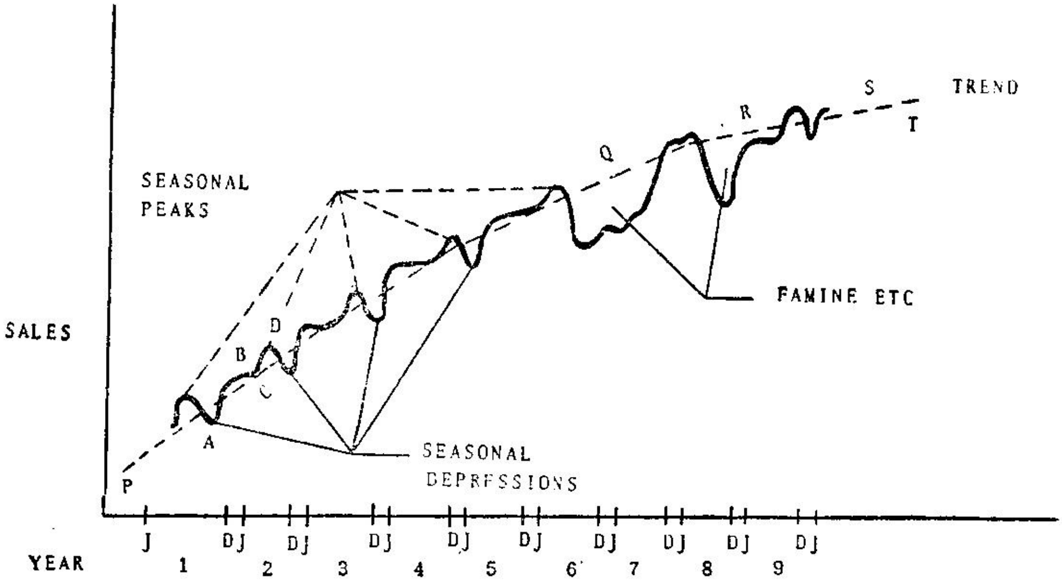
The information in respect of data needed for forecasting can be culled out from various sources such as (a) professional forecasters, share market reviewers (b) reviews of periodicals (c) analysis of governmental activity and attitudes (d) market information from field sales reports (e) past sales records and (f) temporal characteristics.

the ultimate pattern of sales requirement

The curved line ABCD (drawn for a year) represents a pattern that forecasting follows. The line PQRST is the trend line in respect of long range forecast. To raise or lower the operations on the basis of the long range forecast raises no serious problems but the question of meeting the peaks and valleys indicated in the curve is a somewhat different matter as it requires an attenuation of fluctuations.

In order to attenuate fluctuations several alternatives or steps can be taken as follows :

a To produce before the peak period and to sell as much as possible;
b To produce before the peak period and to stock so as to meet the peak demand when it actually occurs;
c To produce after the peak period when possible;
d To expand the capacity during peak period where possible temporarily;
e To make major alterations in capacity where it is warranted.



Of the above, the safest course is to produce and sell before the actual requirements occurs. But this would mean giving necessary incentives to the customer to purchase and stock. When this has been tried out and achieved to the maximum possible extent, the producer has to carry surplus stock so as to meet the customer demands when they actually occur. But this would mean locked up capital. Whether this is a safe enough policy, particularly under the vagaries of present financial and economic conditions, is a matter that has to be decided on the basis of calculated optimisation. Having achieved the first two steps to the extent possible, the remainder of the fluctuation has to be absorbed by producing after the period of peak demand. This is a rather risky step and unless customer relations are ensured and customer needs are elastic, the producer may have to give its up altogether; but there is a certain small amount of the shock that this technique can absorb.

Then comes the question of economic adjustment in capacity during the peak period. Such adjustments would call forth variation in overtime, in working hours, extra shifts, minor alterations in assignments, sub-contracting and such other techniques. The success of such a step lies essentially in organisation, flexibility and temporal factors. Occasionally it may be possible to resort to a permanent adjustment in capacity. This would be warranted only if subsequent activity of the company, or utilisation by sales of the expanded capacity, is planned well before hand.

product-mix

The above represents methods of attenuation of variation in respect of a simple, single integrated product. Generally the situation is made more complex by overlapping patterns of variation for each different product as also due to the pattern of variation arising from an uneven flow on account of internal factors.

A multiple mix of products is often generally an advantage to the extent that the variation in activity presented by one product attenuates the effect of variation in another product. Not all products are needed in the same quantities at the same time. This has a great advantage in that a small amount of stability is

APPENDIX

Converting a Sales Forecast into a Schedule of Operations

Month	April 1964				May 1964				June 1964			
Product	A	B	C	D	A	B	C	D	A	B	C	D
1. Sales Forecast (in units)	12,000	Nil	2,000	5,000	8,000	Nil	1,000	3,000	6,000	1,000	Nil	2,000
2. Sales Forecast modified by preproduction and presale	11,000	500	2,000	4,000	8,500	500	1,500	3,000	9,000	1,000	2,000	2,500
3. Sales forecast further modified by preproduction for carrying stocks	10,000	500	2,000	3,500	9,000	500	2,000	3,500	9,000	1,000	1,500	4,000
4. Sales forecast further modified by getting buyer agree to postponement of delivery	10,000	500	1,500	3,000	9,000	500	2,000	3,500	9,000	1,500	2,000	4,000
5. Desired shipping schedule		same as	above			same as	above			same as	above	
6. Man-hours per 100 units for Assembly	60	210	120	80								
∴ Man-hours for Assembly required by Shipping schedule	6,000	1,050	1,800	2,400	5,400	1,050	2,400	2,800	5,400	3,150	2,400	3,200
7. Man-hours per 100 units for Fabricating parts	240	840	480	320								
∴ Man-hours for Fabrication of next month's requirement of Assembly	21,600	4,200	9,600	11,200	21,600	12,600	9,600	12,800	21,600	16,800	9,600	14,400
8. Total Man-hours required each month		57,850			68,250				76,550			
9. Total Man-hours after allowing 20% for extras		69,420			81,900				91,860			
10. No. of days available		25			26				25			
11. Number of hours available		200			208				200			
12. Men required		347			394				459			
13. Men Required if Absenteeism allowance is 10%		382			433				505			
14. Recommended Employment		375			375				375			
15. Overtime & Extra shift (Also temporaries)		1,400 hours			11,600 hours				26,000 hours			

——:o:——

Note: 1. The above schedule does not have modifications as basis of purchase forecast and forecast of personnel. These have to be built-in in the final picture.

Note: 2. Column 7 has to be more complex, in general, than is represented here. As parts move in, the process of Assembly begins. The manufacturing cycle time, and the percentage of parts that are expected to move in from the previous month's fabrication, and the fabrication of its earlier month that flows in, have all got to be built in for actual operation.

attained without recourse to any of the techniques mentioned above in the previous section. But to be able to take advantage of this factor, it is necessary to clearly visualise the pattern of variation of each product (of each group of products in the case of minor products). A clear analysis must be made to visualise the ultimate pattern on account of the fact that the shipping schedule, the assembly schedule, and the fabrication schedule are all staggered over different periods; in other words, to meet the demand of a certain level of work in the assembly operations during this month, it is not correct to plan out the same level of operations for the fabrication shops also this month; in general, the activity called forth in the assembly during this month will be due to the parts produced probably during last month, or so depending on the manufacturing cycle. An illustration of the way that these figures are worked out for such a situation in an engineering factory manufacturing more than one product is given in the Table printed as Appendix.

To summarise what has been said in the above paragraphs, it must be remembered that stabilisation is called forth particularly at a place where it is rather difficult to stabilise; and where management fails in its attempts to achieve stability, one must work out all the details of stablisation. There is no getting away from it.

In order to achieve stability of operations and employment, the steps indicated are

1 Forecasting the long range and short range and seasonal patterns of sale by area and by product
2 Attenuating the patterns so arrived at by sales techniques, carrying stocks, minor or major capacity adjustments
3 Converting the attenuated pattern into a schedule of operations ; and
4 Readjustment for the fact that the level of operations in the assembly departments has to be matched with the level of operations in the previous departments over the past period and not over the present.

Over and above these, we have to consider and super-impose the pattern of availability of labour including absenteeism and variations in the purchase pattern.

Such a procedure, as is indicated above, is the only way to ensure that the detailed planning would work in a realistic atmosphere, wherein the company does not find itself struggling with unachievable target dates, unprecedented priorities, unaccounted capacity waste etc., factors which all lead the Production Planning Department into a vicious maze of endless conundrums.

However, forcasting is not a thing made out once a year and forgotten until the next. Forecasting is a continuous process. If any good results have to be achieved at all, annual forecasts and schedules of activities must be kept modified at least once a quarter in addition to whenever major factors are foreseen.

conclusion

I do not want to leave the reader with the idea that forecasting is a perfect tool and that 100 percent stability could be achieved by the above method.

Forecasting is not a 100 percent perfect tool; nor do we expect it ever to be so. But there is nothing like a 100 percent perfect tool that management ever can use. Every tool of management has to lie anywhere above the zero level of perfection and below the 100 percent level. Even if a 100 percent tool were available the extent of its use would be governed by the principle of diminishing returns. In other words, the extent to which forecasting has to be employed in any particular company is governed by the extent of the need felt and the costs involved.

But forecasting in some form or the other—followed by stabilisation of operations and employment—is being used by the cobbler at the corner and the sweet-vendor in the fair. The only change suggested is refining the method of forecasting to achieve nearer—realistic results, leaving the enterprise in a spirit of 'can-be-achieved' mood.

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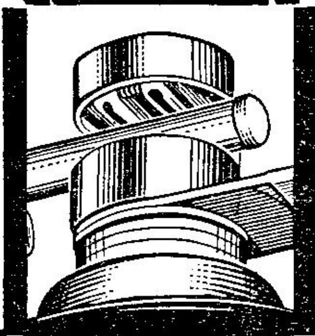

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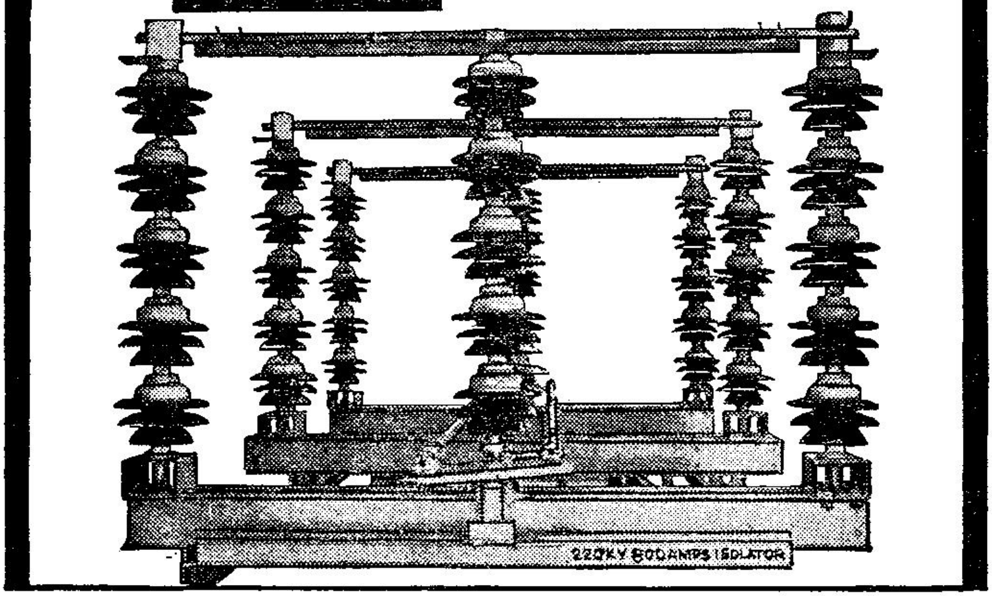

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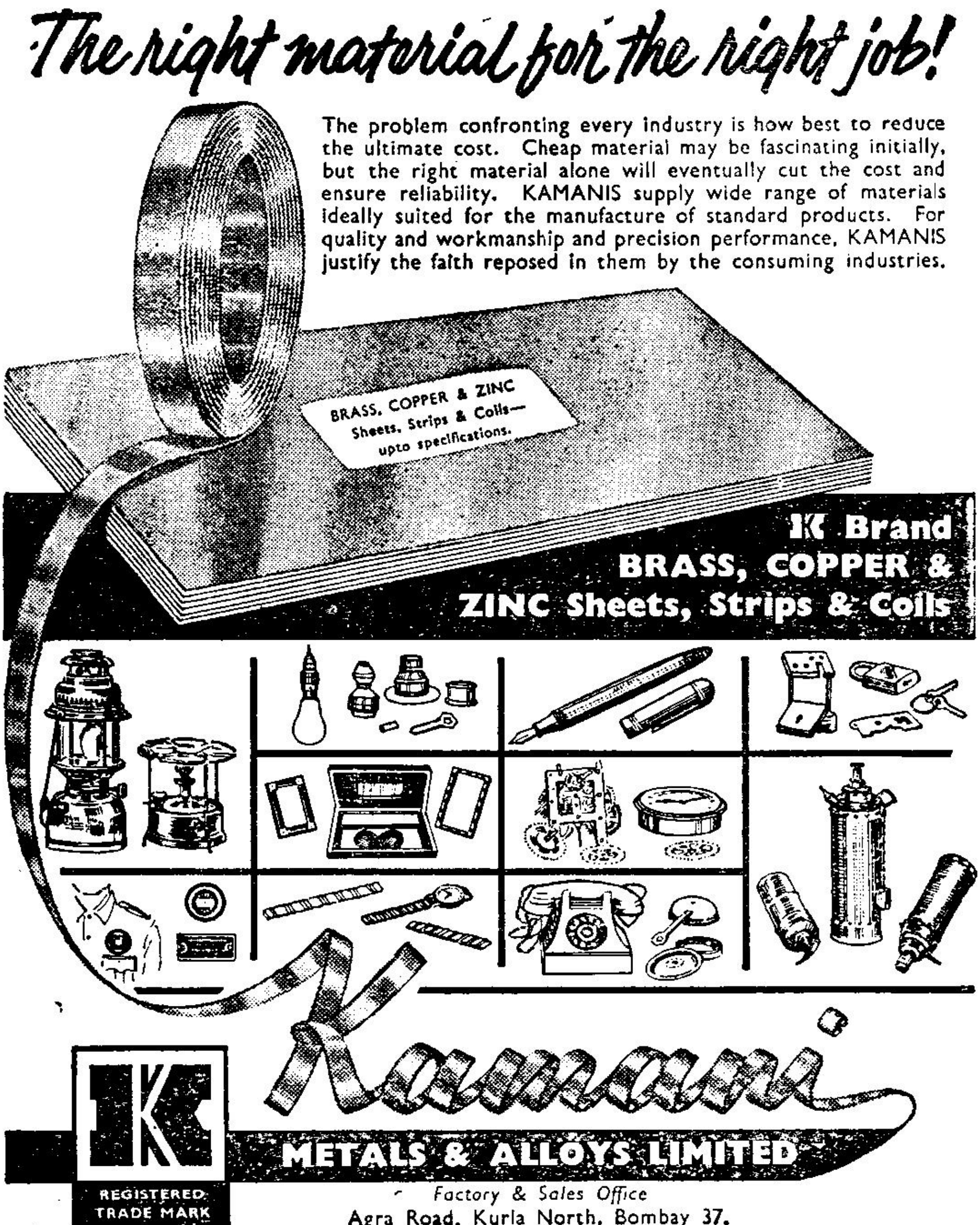
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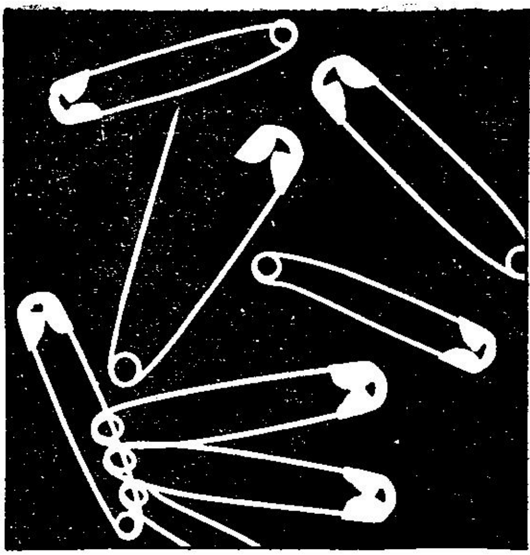

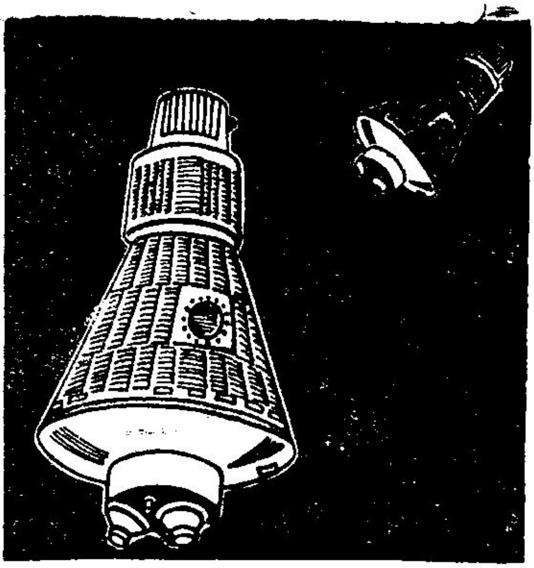

FURNACES AS PRODUCTION UNITS

RAP MISRA

Chairman and Managing Director, Indian Furnace Company, subsidiary of Wild Barfield Electric Furnaces, with whom the author has been associated since 1946. The author studied science at Ewing Christian College Allahabad; served as engineering apprentice withDe Havilland Aircraft (England) and worked in their laboratory (1935-46); Associate Fellow of the Royal Aeronautical Society; Associate of the Institution of Metallurgists; member of the Institution of Production Engineers (England)

INDUSTRIAL FURNACES MAY BE DIVIDED INTO

1. PRIMARY TYPES

Namely those which are used for the manufacture or extraction of primary metals and alloys from their ores: typical examples being blast furnaces for the manufacture of pig iron, open hearth furnaces for making steel and reduction Cell Furnaces in the aluminium industry.

2. SECONDARY TYPES

These consist of heat treatment and foundry furnaces where the object is to heat and cool the charge under controlled conditions to produce desired properties, or to melt metals and alloys with a view to alter their shape by casting. It is the second type of furnaces with which the average production engineer is generally concerned, and this paper will be mainly dealing with these types which are most commonly found in engineering works.

To have a clearer understanding of the subject, further sub-division of furnaces may be made according to the source of heat, and they are broadly classified as

(a) *Electric Furnaces* which include resistance, induction and Arc type furnaces.

(b) *Fuel Fired Furnaces* These include coal, coke, wood, gas oil or any other furnaces in which any combustible fuel is burnt in solid, powdered, liquid or gaseous state.

Electric Furnaces have made great progress during the last 30 or 40 years, particularly in the precision heat treatment and certain other fields such as vacuum melting, and heat treatment where other forms of heating are not suitable. But when large quantities have to be heated, *the higher cost of electrical energy used as heat is a disadvantage.* This explains why probably 90% of the Industrial Furnaces continue to be fuel fired even to this day. Electricity with its convenience and cleanliness has an inherent attraction,but in large scale installations, all aspects such as capital cost, operating and maintenance cost and technical suitability must be considered, to reach a sound decision on choice of fuel. Sometimes, the ready availability of a certain fuel as a by-product which cannot be otherwise sold, settles the matter: a typical example being the availability of coke oven gas in steel works, where most reheating furnaces and ingot soaking pits use this as fuel. In passing, it may be mentioned that the term furnace is generally applied to heating apparatus which consists of a chamber operating at temperatures above red heat (approximately 600 C) Units operating below these temperatures are referred to as Ovens. This distinction is however not very strictly observed, as coke ovens operate at temperatures over 1000 C, and most equipment used for tempering in the low temperature range (below 600 C) whether of the Forced Air Circulation type or Liquid Bath type are generally referred to as Furnaces.

types of furnaces

There are really numerous types of furnaces, and a detailed description or discussion is beyond the scope of this paper but they can broadly be divided into two categories.

1. *Batch Type* or sometimes called In and Out Type.

2. *Continuous Type.*

The Batch Type furnace is the simplest design, and well suited for a large majority of applications. A simple schematic diagram is shown below. In this type, the charge to be heated is placed in the furnace and the door closed till the work reaches the proper heat treatment temperature, when the door is opened and the charge is either quenched for hardening, air cooled for normalizing or cooled in lime or sand for slow cooling to anneal the charge. Sometimes, the charge may be cooled in the furnace before removal. The great advantage of a Batch Type furnace is its basic simplicity and versatility. It is *the most economical type from the capital cost point of view, and also reliable in operation* as there is no mechanical gear to cause trouble. It must not be imagined that a Batch type furnace is less efficient than a Continuous type. On the contrary, a Batch type electric furnace engaged in a long period heating operation like box carburising, can show the highest degree of efficiency possible for any furnace plant. Thermal efficiencies of 80-85 percent are often attained under these conditions. Batch type furnaces are used in all temperature ranges from tempering, heat treatment to forging, their great advantage being that a mixed charge consisting of articles of varying thickness can be treated by altering the process cycles. It may even be possible to treat such articles in one batch, if the thickest ruling section is used for determining cycle time. If the material is sensitive to prolonged soaking at temperature, the thinner section articles can be removed before the others.

bogie hearth furnace

Also known as Car Bottom type furnace. This type of furnace is used for annealing or normalizing or forging of heavy work pieces which would otherwise be difficult to handle in a batch type furnace. The hearth of the furnace is built on a bogie which moves on rails. From a thermal efficiency point of view, this is an inefficient design, because on every cycle, the heat contained in the furnace is

*See Appendix on Process Temperatures at the end

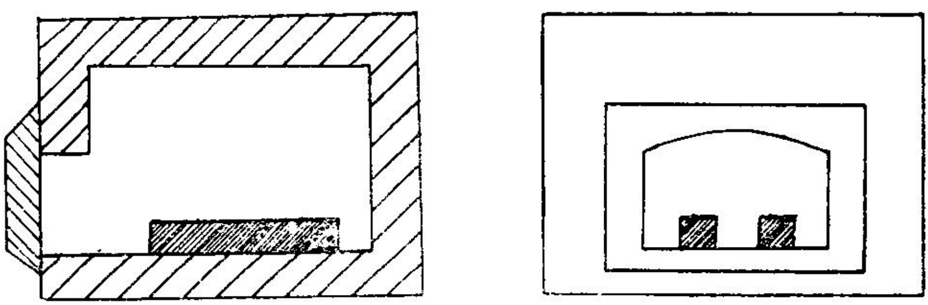

Fig. 1. Batch Type Furnace

lost. Whilst this is no great objection in the case of furnace for annealing, in the case of a furnace being used for normalizing or forging, these losses can be quite appreciable. However, the usefulness of this furnace in the handling of heavy charges, ensures its continued popularity. This furnace is shown in fig. 2.

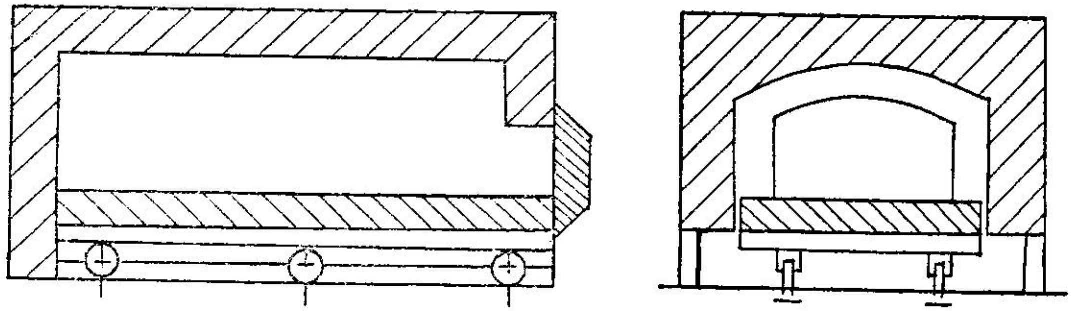

Fig. 2. Bogie Hearth or Car Bottom Furnace

bell type or hood type furnace

In this type of furnace, the charge is placed on a refractory insulated platform, and covered with a top hat type container which rests in a sand seal. This is essential if protective atmosphere is to be used. The top hat container is covered by a bell shaped or hood shaped furnace which may either be electrically heated or may be heated by radiant tubes with gas firing.

In certain designs, heating may be from combustion chambers located in the base, with the products of combustion coming out through ports. In certain cases, a forced air circulation fan is arranged inside the inner top hat cover to ensure rapid and uniform transfer of heat to the charge. There are variations of this type of furnace, and in some cases the charge itself is raised up into the bell and in others, vacuum is used in place of protective atmosphere. This type of furnace is often used for bright annealing of non-ferrous wire. The furnace is shown in figure 3.

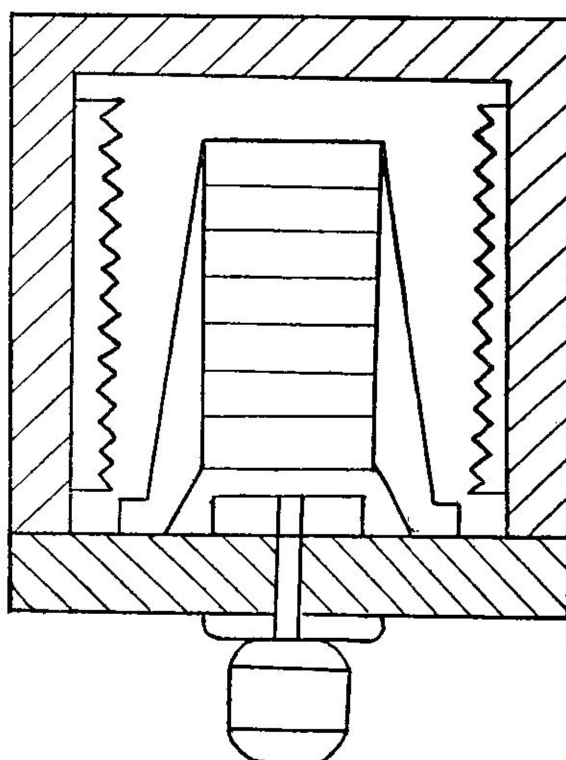

Fig. 3. Bell or Hood Furnace

pit type furnace

This consists of a pit usually a circular in section with either electrical heating elements along the walls or gas or oil burners usually arranged to fire in a tangential action. The furnace may be used with an annealing pot also of circular section in which work may be packed. The seal in which the pot cover rests may be filled with some material giving off Carbonaceous gases to prevent scaling of the charge. Such furnaces are used quite often for annealing of mild steel strips and wire. A Pit Type Furnace is illustrated in figure 4.

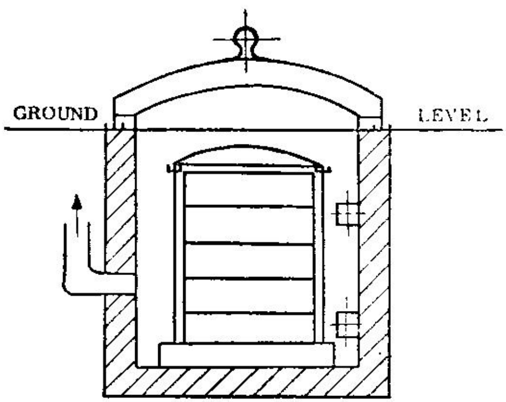

Fig. 4. Pit type Furnace

twin chamber furnace

These are a variation of the batch type Furnaces, but consists of two chambers which may be maintained at different temperatures. This type of furnace is often used for the heat treatment of high speed steel tools which require pre-heating at a temperature of 850 C in one chamber, and they are then transferred to the hardening or finishing chamber which is maintained at about 1280 C. In many fuel fired furnaces, the pre-heating chamber is heated from waste gases of the hardening chamber. Such an arrangement is illustrated in figure 5.

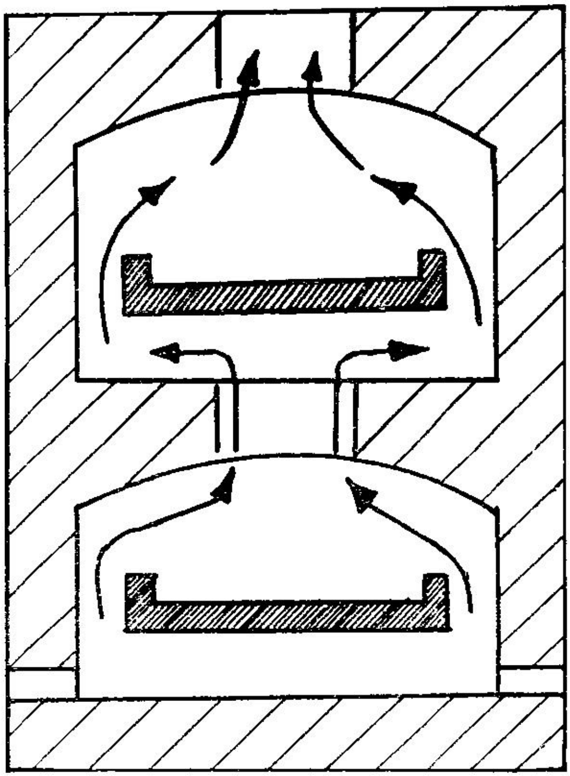

Fig. 5. Twin Chamber Furnace

continuous operation of batch type furnaces

Sometimes it is possible to use Batch Type Furnaces for continuous operation by arranging special charging and discharging cycle. For example, if a Furnace charge consists of 10 billets and the total cycle time in the furnace is 1 hour 40 minutes, by charging one billet at every 10 minutes interval, the first billet will be ready for taking out when the tenth billet is charged. If it is arranged to place a fresh billet in the furnace, when the number one billet is taken out and the same process repeated for all the other billets, a continuous operation can be obtained. Where the forging time for the billets is also under 10 minutes, this method of operation has an obvious advantage in as much as idle time for the operators is eliminated. Greater uniformity of production is achieved, and there is no excessive scaling due to some billets remaining in the furnace longer than others.

heating up time

It has been established by practice and confirmed by theoretical calculations, that with steel, a piece is heated uniformly in a furnace at the rate of about 5 minutes per 1/8" thickness. This figure appears to be independent of the temperature, because at higher temperatures the heat transfer by radiation rises rapidly and compensates for the higher temperature to be attained. At a lower temperature range below 600 deg. C, it is necessary to use a high velocity forced air circulation to ensure rapid transfer of heat from the furnace to the charge and to ensure uniformity of heating as heat transfer by radiation is not very effective particularly at the low end of this range. Another method of ensuring temperature uniformity and rapid heat transfer is to use a liquid bath which may consist of oil, salt or molten metal bath. This ensures uniformity of temperature by formation of convection currents in the bath and by rapid transfer of heat from the bath to the charge.

Different mixtures and grades of salt are required to cover various temperature ranges from 150-1350 deg. C. A liquid bath can be used for the following room temperature range: (i) Oil Bath (250 deg. C maximum); (ii) Salt Bath (150-1350 deg.C); (iii) Lead Bath (330-1000 deg. C).

continuous furnaces

These furnaces consist of a variety of types of different designs, but the basic feature is that the work passes continuously through the furnace. Sometimes there may only be the material which passes through the furnace, such as is the case with wire patenting furnaces and no charge carriers are involved. Such a furnace is shown in outline in fig 6. It consists of a long tunnel type furnace in which high carbon steel wires are heated to a patenting temperature of about 870-900 deg. C and they are then quenched in a molten lead bath. This results in a high carbon steel wire which is capable of further drawing, and results in a product combining a high tensile strength with a remarkable degree of ductility.

rotary hearth furnaces

When the size of the article to be heat treated is fairly large, it is easier from the handling point of view to charge them and discharge them in a rotary hearth furnace from the same point or from two adjacent doors, one of which is used for charging and the other discharging. The rate of rotation of the hearth is so arranged that the time taken for one revolution of the hearth is sufficient to bring the work to the heat treatment temperature. There is considerable saving of manual labour in operating a Rotary furnace, as compared with a batch type. A greater degree of uniformity is also possible.

The Rotary Hearth furnace is also suitable as a forge furnace for heating large size

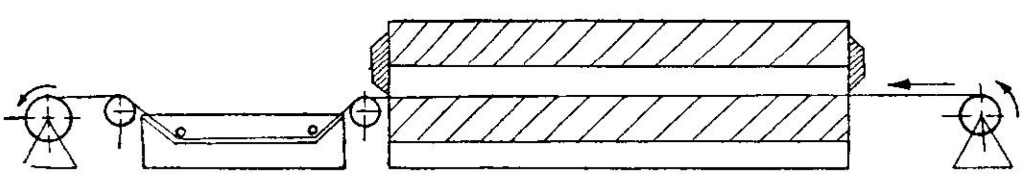

Fig. 6. Wire Patenting Continuous Furnace

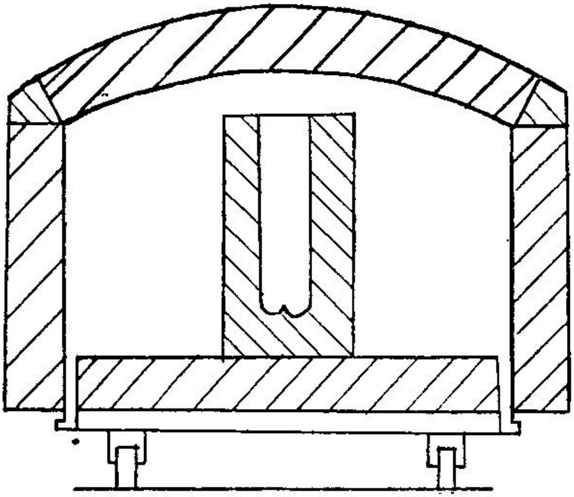

Fig. 7. Rotary Hearth Continuous Furnace

"cheeses" cut from billets used for the forging or pressing of such things as railway wheels. In such cases mechanical means are employed for charging and discharging the furnace. Figure 7 shows a Rotary Hearth furnace.

walking beam type furnace

This is a continuous tunnel type furnace in which the hearth incorporates beams which are driven with an eccentric motion. They rise above the level of the hearth, move along the hearth and again go below the level of the hearth. This process which is carried out at variable speeds, can move trays for carrying work along the length of the furnace. Such furnaces are used for the annealing, normalizing of forgings. An outline of this furnace is shown in figure 8.

mesh belt conveyor furnace

As the name indicates this is a continuous type furnace in which the mesh belt passes through the furnace tunnel and is driven by means of an electric motor. The speed is generally variable. The articles to be treated are either placed on work trays or in some cases they may be placed directly on the mesh belt. This type of furnace is used for annealing, normalizing and sintering of the lighter type of components. The same construction is also used in annealing and decorating lehrs for the glass and pottery industry. This is shown in figure 9.

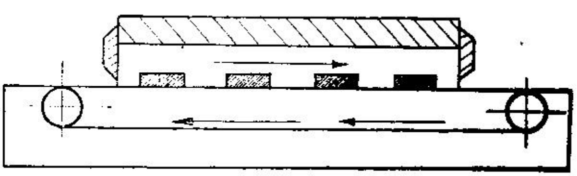

Fig. 9. Mesh Belt Conveyor Furnace

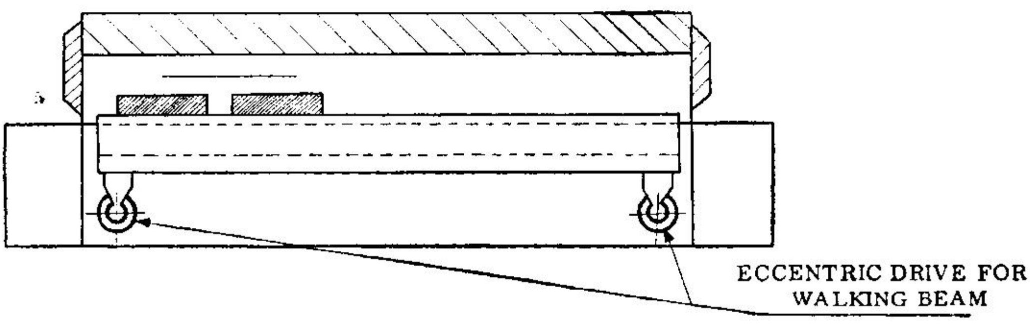

Fig. 8. Walking Beam Continuous Furnace

pan conveyor furnaces

These are similar to mesh belt conveyor furnaces, but the working pieces which are generally of a small size are carried through the furnace on a conveyor consisting of a number of pans hinged together. The pans can be arranged to tilt and discharge the work in a quenching tank. This type of furnace is often used for the hardening of nuts and bolts and is illustrated in figure 10.

rotary drum furnaces

These furnaces consist of a rotary drum usually made from heat resisting alloy which is externally heated. The work passes along a helical groove inside the drum as it rotates and is quenched or discharged when heated to temperature. There are other variations of this type of furnace, and in some cases the charge is placed in the drum with carburising compound for case hardening. In other designs, carburising gas atmosphere may either be used alone or with Amonia to produce gas carburising or Carbonitriding. This type of furnace is shown in figure 11.

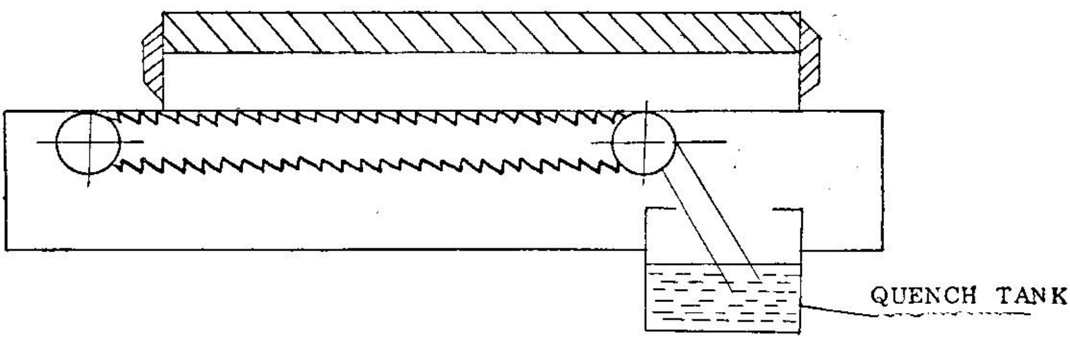

Fig. 10. Pan Conveyor Furnace with quench tank

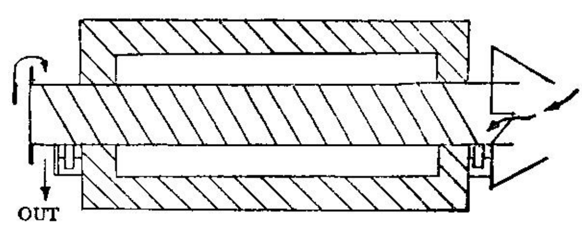

Fig. 11. Rotary Drum Furnace

shaker hearth furnaces

This design is an interesting development and is particularly suitable for the heat treating of small articles in large numbers, like typewriter parts, ball bearing races and balls. The furnace consists of a heat resisting alloy hearth which is given a special motion by means of an electrically driven gear and is generally spring loaded in one direction. The hearth moves slowly in the direction of work travel and then moves rapidly back under pressure of the springs. This causes the work pieces to be left behind by inertia. Thus at every stroke of the hearth, work pieces advance about an inch. To ensure that round articles like rollers, balls etc will not roll backwards or forwards the hearth is provided with shallow grooves in a direction at right angles to the travel of the hearth. The work, after it has reached heat treatment temperature, falls off the end of the hearth into a quenching tank from where it is generally picked up either by travelling baskets or a pan conveyor. This furnace is shown in figure 12.

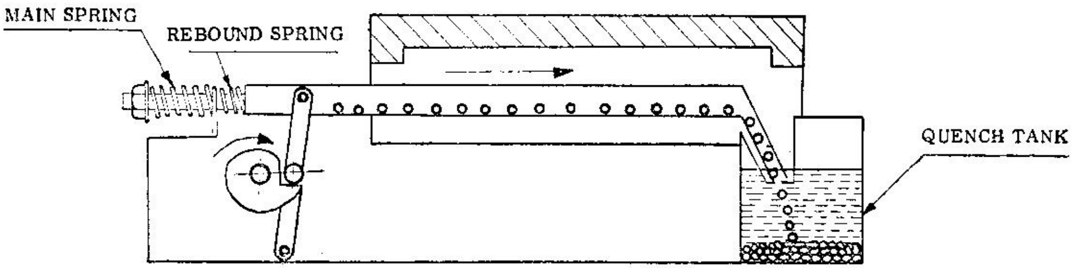

Fig. 12. Shaker Hearth Hardening Furnace

roller hearth furnaces

In this type the work is carried through the furnace by being placed on rollers which rotate along the axis and pass the work through the furnace. It may be heated electrically or fuel fired. This type of furnace is used for annealing of tubes and similar articles. The illustration in fig. 13 shows an IFCO G.W.B. Furnace made in India by the Author's Company to the design of G.W.B. Furnaces Ltd. for Devidayal Tube Industries at their Extrusion Plant at Kanjur near Bombay. The furnace is 125′ long and has an output of 1½ tons of brass and copper tubes per hour. It is provided with a protective atmosphere generator of 4000 cu. ft. capacity, using Burshane as fuel. The rating of the furnace is 225 kilowatts. Temperature range—400-700 deg. C.

output of furnaces

Owing to the various factors involved, it is difficult to forecast the output of all types of Furnaces accurately. In the case of fuel fired Furnaces, the following may be taken as a rough idea.

1 Batch type heat treatment furnace, operating upto 1000 deg C. Output in lbs per sq ft of hearth area—30 lbs approx.

2 Batch type forging furnace, operating upto 1300 deg C Output in lbs per sq ft of hearth area—40-50 lbs.

3 Continuous type Forge Furnaces, with top and bottom firing and operating upto 1300 deg C.

   Output in lbs per sq ft of hearth area 50-60 lbs.

In a short paper of this type, it is not possible to describe or even mention each individual design of furnace or their numerous variations. But the Author hopes that the information given here will be of some value to those Production Engineers, whose duties bring them in contact with Industrial Furnaces.

bibliography & sources of information

Industrial furnaces by W Trinks & MH Mawhiney. Technical information supplied by the following British companies *Gibbons Brothers*, *GWB Furnaces*, *Thermic Equipment* and *Engineering Wild Barfield.*

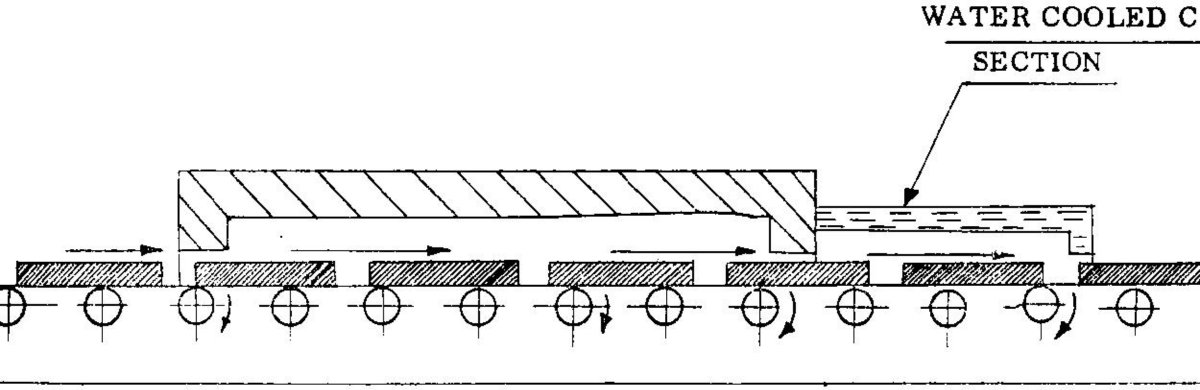

Fig. 13. Roller Hearth Annealing Furnace

APPENDIX ON PROCESS TEMPERATURES

1. Drying of lime coated steel wire (150); 2. Stove enamelling (150-175); 3. Japanning (lacquering) (85-230); 4. Baking of sand cores for iron castings (150-230); 5. Blueing (tempering of polished steel to get a blue finish) (260); 6. Hot dip tinning (260); 7. Tempering in oil (260); 8. Tempering high speed steel (560); 9. Annealing aluminium (395);10. Cracking petroleum (398); 11. Heating aluminium for rolling (455); 12. Nitriding Steel (510); 13. Annealing brass (537); 14. Annealing Glass (621); 15. Annealing copper (621); 16. Annealing German Silver (649); 17. Enamelling (West process) (649); 18. Strain relieving (650-705); 19. Annealing cold rolled steel strip (675-760); 20. Porcelain decorating (760); 21. Heating brass for rolling (788); 22. Annealing nickel monel wire or sheets (800); 23. Annealing high carbon steel (815); 24. Heat treating medium carbon steel (845); 25. Patenting wire (870); 26. Box annealing steel sheets (870); 27. Vitreous enamelling steel sheet (870); 28. Annealing malleable iron long cycle (870); 29. Heating copper for rolling (870); 30. Forging titanium (commercially pure) (870); 31. Annealing steel castings (900); 32. Normalizing steel pipes (900); 33. "Calorizing" (Baking in Aluminium powder of MS parts to confer heat resistance (925); 34. Heating sheet bars for rolling (925); 35. Normalizing sheet steel (955); 36. Carburising (900-955); 37. Pack heating steel sheet (955); 38. Short cycle annealing of malleable iron (980); 39. Cyaniding (900-950); 40. Glazing porcelain (1000); 41. Vitreous enamelling cast iron (1010); 42. Bar and pack heating stainless steel (1040) 43. Normalizing stainless steel (925-1100); 44. Rolling stainless steel (950-1235); 45. Forging titanium alloys (870-1065); 46. Annealing manganese steel castings (1040); 47. Heating tool steel for rolling (1040); 48. Heating sheet steel for pressing (1050); 49. Heating spring steel for rolling (1100); 50. Glost fiiring porcelain (1200); 51. Hardening high speed steel (1205-1280); 52. Bisque firing porcelain (1230) 53. Heating steel blooms and billets (1240); 54. Heating steel for drop forging or die pressing(1300);55. Calcining limestone (1370); 56. Welding steel tubes from preformed skelp (1400); 57. Burning firebrick (1340-1480); 58. Burning portland cement (1430); 59. Glass melting (1430); 60. Steel melting (1675); 61. Melting chromium steel (1785); 62. Making synthetic graphite by graphitizing petroleum coke; (2900).

SURFACE QUALITY CONTROL AS A PRODUCTIVITY FUNCTION

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The importance of Surface Quality Control can be judged from the fact that many of the failures of components (particularly aircraft parts) are now believed to have been caused by inadequate surface quality. In many cases it has been possible to improve the performance of engineering components, by improvements in surface quality of parts used. An example is the electro-hydraulic valve, used for automatic control systems. The spool and the orifices in this valve are finished to a high grade of surface quality to meet the demands of modern space flights. The author has therefore taken the trouble of reviewing the problems associated with the production and control of *desired* surface quality : desired from the point of view of improved performance, but not necessarily for improved appearance.

THE QUALITY OF SURFACES USED IN MACHINES has seen rapid developments alongside the progress of technology in general. The concept that the surface quality of bearing surfaces influences the performance of a bearing, is relatively an old one. Recently, more light has been thrown on the functional importance of surface quality by investigations carried out in various parts of the world. The relationship of surface quality with friction in bearings, strength of parts subjected to cyclic stresses, flow of liquids through precision orifices and many other engineering situations, has been scientifically proved, and is widely used as a basis for design machines, precision control instruments and engines.

The first attempt at setting a standard for surface quality was to specify it by the process of production. Notes such as rough finish, ground finish and lapped finish, were ascribed to faces, as a representation of the desired surface quality. The procedure is still used very widely in many design offices. This method, however, has been found to be inadequate where much variation in surface quality cannot be tolerated.

The production process is rather a very broad classification when specifying surface quality. There are many parameters within the realm of the production process and it is possible that two surfaces produced by identical process may not give the same surface performance. The surface performance, if taken as a standard of surface quality, needs a better yard stick than the specification of the production process.

Another attempt at specifying surface quality was to do so in terms of the light the surface would reflect. This standard though independent of the production parameters has not been shown to be related in any way to the performance of the surface in any application. The light reflection standard was very popular for a long time, till it was replaced by the modern standard which uses the geometrical profile of the surface as its basis. This basis has come to be accepted as it bears relationship with the performance of a surface. There are many geometric characteristics of a surface profile, and it is necessary to describe the surface by one parameter, so that comparisons may be possible. The problem, however, of resolving as to which parameter of the geometrical shape of the profile is most representative, has not yet been satisfactorily solved.

Many experts in the field have suggested that the parameter should depend upon the application the surface is going to be put to. This is an extremely important view point; however, it does not lend itself to standardization on a wide basis. Different nations have adopted different parameters to represent surface quality. In Europe†, the working standard is the maximum height (h) from the lowest to the highest point on the surface: *h* max. In the UK it is the Centre Line Average: *h CLA*; and in the USA, the Root Mean Square: *h RMS*. There is at present no international standard; and these standards are in themselves not comparable, their validity being dependent on the application and type of industry. We may now examine why surface quality needs to be controlled.

(*a*) *Surface Quality affects the fatigue strength of parts*

Experiments have shown that the strength of metals under cyclic stresses, depends on the surface of the test piece. The explanation given for this is that the minute cracks on the surface or what is usually called surface irregularities act as stress raisers. The stress on the edges of the cracks becomes much higher than what it would be if the cracks were absent. A failure thus occurs at a lower load, if the surface is comparatively rougher. In applications where high fatigue strength is essential, surface quality has to be strictly controlled, or a fatigue failure may have to be faced in due course.

All modern machines, particularly aircraft engines, use components that are subjected to extremely high frequency of stress reversal. Such components have to be finished to a suitable standard to expect a reasonable performance.

(*b*) *Surface Quality affects the performance of bearings*

While calculating the bearing area needed for a particular bearing we assume that the total surface is in contact with the bearing or oil film in case of lubricated bearing. If we look at the surface profiles of the two mating parts, after magnification, we will find that the contact is not complete. The surface irregularities reduce the area of contact thereby increasing the bearing stress per unit area. The lesser the contact area the more the bearing stress, and less the lift of the bearing.

The same is applicable to slide ways. The modern machine tool which is required to perform to a very high degree of accuracy has to have very fine surface quality on slide ways. A bad surface would cause high rate of wear and impair the accuracy of the machine tool in a short time.

(*c*) *Surface Quality affects the performance of a cutting tool*

Experiments conducted at the Research Establishment of Cincinnati Milling Machine Company in the USA have shown that *the surface quality of the top face of the cutting tool is a radical factor* affecting cutting tool wear and the resulting surface quality of the cut surface. This is because the friction between the chip and the cutting tool is high when the top face of the tools rough. the chip-tool interface friction sustains the formation of build-up edge, which results in deteriorated surface quality on the cut

British Standard:
Centre line Average $= X_1+X_2+X_3+X_4+\ldots\ldots X_5$*
American Standard:
Root Mean Square $= \sqrt{n_1^2+n_2^2+n_3^2\ldots\ldots\ldots\ldots \times N^2}$

*Addition of Numerical values irrespective of the sign.

surface. The chip-tool interface friction also increases crater wear on the face of the tool due to increased temperature. It is thus necessary to control the surface quality of the top face of the tool to get better cutting performance both in terms of tool-life and surface quality of the cut surface.

(*d*) *Surface Quality affects performance of precision flow controllers*

The hydraulic valves used in precision control devices, along with electronic detection equipment, are required to operate with almost negligible effort. The valves have also to control flows, to a very high degree of accuracy, and are required to have efficient response to varying frequency signals. To achieve this, the surface quality of the spool piece, main barrel and orifices of the hydraulic servo valves, has to be controlled within very narrow limits. Experience has shown that nothing more than 5 micro inches (h CLA) can be tolerated.

(*e*) *Surface Quality affects the erosionability of the surface*

In instruments where a constant impingement of liquid takes place against a surface the profile of which must have a particular shape, the surface of the impingement plate must have a certain quality to insure accurate working of the instrument for any length of time. The erosion increases with the roughness of the surface of impingement.

The decision as to what quality a particular surface should have rests with the designer. The designer has to be extremely careful in deciding this question. *Like any other type of quality, surface quality also costs*, and to produce extremely good surfaces can be a quite expensive operation. Nothing better than what is really required should be specified. There should be *no quality give away*. To give an example of the economic side of the improvement in quality, it cost an American Company nearly $ 50,000 to develop a process of finishing to reduce the surface roughness from 1 micro inch to 3/4 micro inch.

Having decided that a particular surface should be finished to a specified quality, we come to the question, how this quality can be produced most economically. Almost all surfaces, where surface quality is specified are produced by machining. Machining is a process, where metal is removed in the form of chips from a parent base. What is left on the base forms the surface. The quality of this surface depends very much on the process of chip removal. Very interesting points are revealed regarding the characteristics of the machined surfaces as we probe into the mechanics of chip formation. The figure printed below shows a tool cutting a metal face. The chip formation near the edge of the tool is also shown. The dark spot on the top of the tool end is the built-up edge. It is really the built-up edge which does the cutting and as it is fragmentary in nature, gives a very irregular surface to the base metal.

In machining processes like turning, boring and milling, cutting is done by an edge which has a relative movement with respect to the base stock, which is termed cutting speed, and has a feed in a particular direction to cover the surface, that has to be machined. If the cutting tool just left an imprint of its shape on the finished surface, the contour will be the ideal finish that can be expected. The ideal finish will be a function of tool geometry and the feed. The surface will look like the figure printed below. No machining surface, however achieve the ideal face. They differ because, of many reasons, and one of the main reasons is that the built-up-edge rather than the cutting edge does the cutting and fragments of this edge are left embedded in the surface. The profile of the surface also takes its shape from the built-up edge.

It may be noted that in order to achieve good surface quality from any of the conventional machining operations, conditions which do not allow the formation of built-up edge should be attained. The best quality is, of course, limited by nose radius of the tool and feed.

Cutting speed has been found to be a very potent factor, affecting the formation of built-up edge and in turn the surface quality. Experiments of Chisolm[1], Prof Sawin & Ernst[2] confirm it.

In actual practice the speed at which built-up edge disappears can be found by testing surface machines at different speeds. The speed at which any further increase in speed fails to improve surface quality is the critical speed for built-up edge.

The other important factor in the controlling of surface quality is the machine tool on which machining is done. The vibrations in the moving parts of the machine tool if not properly isolated from the cutting tool and the spindle, will result in deteriorated quality. The chatter of the tool is one of the most common causes of bad surfaces particularly finished at high speed.

Several studies have been made to know more about the causes of chatter and one of the most exhausting is by Arnold.[3] It has been shown that the *chatter is a function of tool geometry*, tool holding set-up and machine itself. In a particular situation, one must try to experimentally arrive at conditions which will eliminate chatter and set standards for operation, if surface quality has to be controlled.

In the design of modern machine tools, hydraulics is finding an increasing application, because of the shock absorbing property of oils. Hydraulic drives, and jacks transmit very little of the fluctuations at the driver end to the driven end. This is very useful for machine tools designed to produce very fine surfaces.

The cutting tool geometry is yet another factor that will affect surface quality. Some investigators believe that it is essential to have a particular tool gemoetry to attain a better surface. In the opinion of the writer, the tool angles may influence the life of the tool in relation to surface quality, but as far as just producing the surface quality is concerned, there may be little difference between the finishing and the roughing tool. A mention may here be made of a tool used by Russians, which did roughing and finishing simultaneously. This was achieved by changing cutting edge angle near the tip of the tool, and using the tip as the finishing end. It is claimed that the use of this tool cut down the production time on the same job by as much as 35 per cent.

The following table gives the effect of certain machining variables or surface finish.

Variable	*Effect on surface finish of a large increase*
Cutting Speed	Large improvement
Feed	Large deterioration
Depth of cut	Slight deterionation
Tool Angles and Shape	
True rake angle	Large improvement
Nose radius	Large improvement

The physical properties of the work material will also affect the surface quality that will be produced. As a general rule, high hardness strength and low ductility result in good surface finish. Micro structure of the material also affects the surface quality. In case of brittle materials like cast iron, the surface finish is directly related to micro constituents.

super finishing

Super finishing is a process superimposed on all the other types of dimensional metal surface finishing methods, such as turning, honing, machine grinding and lap grinding. The process converts the non-crystalline surface, or smear metal condition, which is left by a dimensional finishing process into a crystalline, geomatrically smooth surface. This is achieved by the combined action of proper bonded abrasive, low abrasive speed, light abrasive pressure and combination of multi-random motion, short abrasive stroke, variable work or abrasive speeds, and variable abrasive pressure all in combination with a lubricant of proper viscosity, whereby non-crystalline and fragmented metal is removed leaving a crystalline base metal. Surfaces with a surface finish of less than one micro inch have been produced by this method.