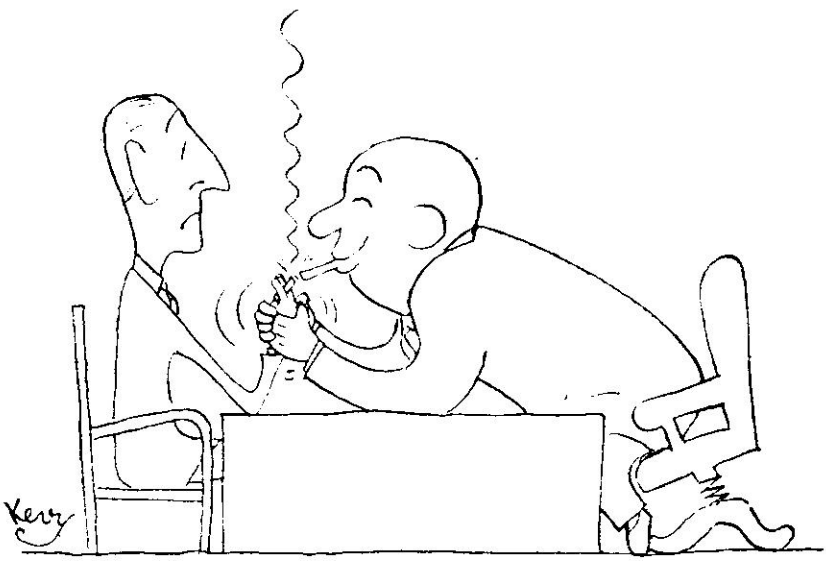
. . . Indeed it is well said that in every object there is inexhaustible meaning: the eye sees in it what the eye brings means of seeing . . .

—Carlyle



"Now, let me explain to you Fuel Efficiency:"

PRODUCTIVITY

Vol. VI, No. 4, Winter 1965-66

SPECIAL ISSUE ON FUEL EFFICIENCY

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COVER PAGE Shows the Ultimate in Fuel Efficiency

Vol. VI, No. 4, Winter 1965-66

Editor: DH Butani

PRODUCTIVITY

NATIONAL PRODUCTIVITY COUNCIL JOURNAL

FUEL ECONOMY:

Essential to High Growth Rate

that sparked off the Industrial Revolution was the possibility of run the machines of modern industry. Quite significantly, the s in the tempo of industry have been associated with historic economy. The internal combustion engine and the discovery eral oil, the dynamo and the mechanism of hydro-electric power, ues of nuclear fission have lifted bodily the supply curve of that if we want to build a highly productive economy, we and work out a high-supply, low-cost fuel economy—an growth rate.

ual growth rate (2 to 3% of which will be cancelled by our energy requirements will be, according to the findings of India Committee, 446 million tonnes (in terms of coal -71, 635 million tonnes by 1975-76, and 895 million tonnes by my is thus written in the very magnitude of these statistics, y consumption would be roughly 300 million tonnes (coal re- both indigenous primary sources and imports of crude oil, etc.

fuel economy is also imperative because certain diseconomies , in the very facts of Indian geography. Our coal resources are heavily concentrated in the Bengal-Bihar region, at a distance of nearly 1,500 kms from Bombay and Madras, and 1,000 kms from Delhi, so that every ton of coal means, in terms of cost, several hundred ton-miles of coal, transported in this country of continental size.

The hydel resources are equally maldistributed. Over 30% of the hydel potential is in Assam, whereas the rest of the Eastern Region has less than 7%. The Western Region is almost equally disadvantaged. The Southern Region, with almost the maximum disadvantage in coal, has a high hydel potential at nearly 20% of the country's aggregate.

Here it is that a balanced developmental fuel policy can lead powerfully to an optimisation of fuel supply and utilisation. Oil resources (to which reference is made in the following paragraph) and nuclear power are coming up in the Western Region, poor both in coal and hydel power.

This brings us to oil, which is the Achilles Heel of the Indian economy, particularly in the context of the Emergency. We have, of course, done remarkably well in oil exploration in recent years, but the statistics of consumption and production figure out, more or less, as a race between the hare and the hound. During 1951 to 1965, consumption of petroleum products (largely in terms of crude oil) has risen from 4 million tonnes to 14 million tonnes, and is likely to go up to 25 million tonnes by 1970. On the other hand, crude oil production may rise from the present estimate of about 3 million tonnes to 10 million tonnes, or, at best, 15 million tonnes, by 1975-76. By that year, we may need to import 30 million tonnes of crude oil, costing Rs. 200 crores in terms of foreign exchange.

This is an aspect of fuel economy which needs to be borne in mind, for the import content of electricity supply is also very high. And the demand in India for electricity by 1975-76 may be 4 to 5 times the current level of demand. This involves a tremendous expansion and modernisation of the whole organisation for electricity supply. Despite rapid progress during the post-Independence period, electricity is still provided by a large number of small stations – many of these are very small and very old, by modern standards, obsolete, operating at low fuel efficiency, and inadequately inter-connected. Because of the small average size of steam-generating units, efficiency has been, and is, very low. The average gross efficiency of utility steam electric generating stations is estimated at around 20% (Report of the Energy Survey of India Committee).

As we now propose investing on a large scale in electricity, and other energy-producing industries, we ought to do a good bit of research into the economics of fuel utilisation. By present standards, the capital costs would be extraordinary:

Estimated Gross Investment

	In Crores of Rupees at 1963-64 Prices		
	1965–70	1970–75	1975–80
Coal Mining	520	777	916
Oil	408	524	734
Electricity	2170	2520	4050
Work in Progress	177	465	499
TOTAL	3275	4286	6199

If we desire to make the most of these capital investments, we must take precautions ahead for their optimum utilisation, beginning from the point of production or generation to the point of utilisation in terms of heat, motion, etc. In fact, such economies may result in a curtailment of demand on capital resources, for as the Colombo Plan experts reported, 25% economy in fuel utilisation can be obtained even by elementary first-aid measures.

The economies of this are highly significant, and can be illustrated with telling effect. The Third Plan target for coal was nearly 100 million tonnes. Our output today is only 70 million tonnes at an annual rate. This means that even with the present coal output, given the other inputs, we could have reached the industrial targets of the Third Plan. This broadly indicates the enormous potential of fuel economy.

5 years ago..

...The anomaly by which labour is not interested in the enhancement of its own productivity lies in the lack of a straightforward analysis of the whole problem of productivity. Productivity essentially means the saving of time; and time cannot be saved, unless the persons involved are psychologically interested in the saving of that time. They will not be so interested unless it works to their advantage and the advantage of their class. Socially speaking, therefore, labour productivity has the best chance in a full employment, fair wage economy.

—from PRODUCTIVITY
Vol. I No. 4

We have so far not touched the enormous field of the rural economy on which 80% of our population subsists. The basic cause of the low productivity of the rural system is that the rural people have little 'power' associated with their work. While urban industry is largely coal- and partly oil-based, for agriculture, handicrafts, village industries, the people in the villages depend on non-commercial sources of energy. In fact, over 60% of the total energy of the country, even apart from animal power, is derived from traditional non-commercial sources. Firewood alone provides almost 40% of the energy used in the country. Rather more energy is consumed in the form of cowdung than in that of electricity. Thus fuel efficiency has implications of a widespread character for the whole of the social economy.

In fact, the whole future of the economy depends upon how quickly we can get out of the romantic illusions associated with the cowdung-bullock-cart economy; and now we have it on the authority of the Energy Survey Committee that bullock power is nine times costlier than electricity, *at present rates:* "...the irrigation cost per hectare per crop of paddy is reduced from Rs. 1,230 with bullocks to Rs. 205 with a diesel engine pump, and to Rs. 38 with an electric pump..." This at least gives a clue—one of the important clues—to the low productivity of the agricultural system.

Similarly, on an international basis, if we want to raise the productivity of our economy to a competitive level, we must modernise, reorient our resource-mobilisation and utilisation. It is only when our coal is mined, transported, and burnt with the maximum efficiency in terms of output that our coal-based economy will be able to compete with the world's oil-based technologies. We must, therefore, make the most of our coal by producing electricity with low-grade coal in coal concentration areas, and conserve high-grade coal for the steel economy we are building up, organise research in coal combustion, heat conservation, etc.; for by and large, for decades, Indian economy will be largely coal-based.

This, of course, is realism, but, in this context of an expanding economy, another abundant resource is opening up in terms of nuclear power. For many long years, some of the growth economists have lectured to us on the luxury of advanced techniques which we can ill afford to indulge in; and this at a time when Britain was building up nuclear power stations on an increasing scale. Now that the operating costs of nuclear power have been proved to be competitive in the context of Indian economies, and our proved resources of nuclear fuels are substantial, we can correct the geographical energy imbalance through nuclear power generation.* Besides 2.8 million tonnes of uranium ore in Bihar, there are deposits in Rajasthan and Madras. It is, however, in thorium that, to use the official language "... India is very well endowed. There are some 500,000 tonnes of thorium mainly in two deposits... *equivalent to all the world's known uranium in ore...*"

The country's future, undoubtedly, depends on a bold exploitation of nuclear power, while we, in the National Productivity Council, shall continue to assist industry at the ground level how to utilise best what we have in terms of coal and oil.

* "...large nuclear generating stations will soon be competitive with conventional thermal stations in areas far from cheap fossil fuels..." (Report of the Energy Survey Committee.)

LESLIE HOLLINGHURST

Chairman
National Industrial Fuel Efficiency Service, United Kingdom

Industrial Fuel & Efficiency of its Use

IT MUST be universally evident that no community can become an industrially powerful entity unless it has access to adequate fuel supplies. In fact, industrial development takes place parallel with the increasing extent to which use is made of the energy stored in natural resources. The growing use of artificial energy reduces the tedium of manual toil, raises living standards, and sets man free to work with his mind, rather than with his hands. It has rendered possible products and productivity which would otherwise be inconceivable.

The cost of production of fuel, particularly coal, depends largely on labour costs. Where the labour costs are low, fuel tends to be cheap. There follows the danger that some may think that fuel can be wasted without too great an effect on the economy, particularly if the fuel itself is not in short supply. But what is fuel shortage? Can it be said that rationing and control are indicative of any shortage if there is a wastage, on an average, of 20% ? Whatever the circumstances, it is a gross fallacy that any country can afford to waste fuel; and truth lies in the fact that the economic loss through wasting fuel or energy is greatly in excess of the cost of the wasted commodity. This fact was belatedly realised when a fuel famine threatened the United Kingdom, and fuel efficiency became a national necessity. But since then fuel efficiency, as an industrial pursuit and aid to higher productivity, has survived the period of stringency, and continues, with added vigour, now that fuel is available in plenty.

How can fuel and its relationship to the economy be placed in the true perspective in a country that has access to an adequate supply? To start with, it can be taken as read that, as the degree of industrialisation and living standards rise, wages will rise, and, with them, the cost of fuel. The latter will, therefore, loom ever larger in manufacturing costs in a developing country. Thus, the future may see fuel and labour costs occupy a position the importance of which is at present concealed. Fortunately, however, the proper use of fuel and energy supplies increases the productivity of labour, and, where both are given due consideration, the decrease in labour costs can offset rises in fuel costs. Manufactured goods can then be exported with the knowledge that they can compete in price in world markets.

Effects on Productivity

To take things a stage further, one may consider the less obvious effects of fuel efficiency on costs and productivity. These, though partially concealed, are profound, and the annals of the National Industrial Fuel Efficiency Service of the United Kingdom are full of instances of them. They consist, in essence, of the sort of thing that results when a highly skilled and critical survey is made of thermal usage in the process section of a factory. It is frequently found that by one of a number of measures, which include better heat usage, recovery, and reuse of heat, or modification of design, the output and quality of product from a production unit can be greatly improved. Thus, there is improved productivity of man and machine, a better return on capital invested in production plant, improved quality of product, and reduction of wastage. They spotlight the basic fact that sound energy usage is the key to high productivity, and to the door of world markets.

Fears that mechanisation and the greater use of artificial energy may lead to unemployment have been proved to be unfounded. It is clearly to be seen in the world that, where productivity has increased because of these things, living standards have become higher.

It is very gratifying to observe that a Fuel Efficiency Service has been set up in India, and NIFES is proud to have been, in some measure, associated with its foundation. If it develops in the way expected, it will make a notable contribution to the economic growth and development of the country. Time will prove that this growth and development will be to the benefit of humanity as a whole, for it will stimulate trade, and trade is not a "one-way traffic."

The task before a fuel efficiency service is multifarious and demanding much patience. Its advice is based on technical facts and, if it is to be acted upon, must appeal to industry. Thus, the value of the service may be expected to grow as industry itself becomes more able to evaluate the technical advice received, and its bearing on what might be called "business health." For this reason, if for no other, it is better to talk, where possible, in terms of money rather than in terms of heat units. One of the notable things that has happened in NIFES history is the way in which industry has grown to appreciate technical advice, and the way in which NIFES engineers have been able to present recommendations in a form that industry can appreciate and relate to the financial balance-sheet. Here then is one of the main objectives of a technical service—to make itself understood by businessmen, and to make recommendations in such a way and form as to be crystal clear in their implications and effects.

How may this be achieved? Ten years ago, when NIFES started, and before that, advice to industry tended to deal with the more obvious and simple measures that were relatively easily understood. Case histories illustrating the effects of fuel efficiency were used as publicity, courses for industrial personnel were provided, and the services offered were geared to the growing ability of industry to appreciate and value them. There is some doubt whether advanced technical advice that NIFES provides today would have been as readily understood by, or as acceptable to, its clients of 10 years ago. Equally is there doubt whether engineers could have tendered that advice with the accuracy and confidence that has grown with the experience of years.

Some idea of the growth of the service can be judged by the facts that during the first 11 months of operation, the total fees earned were £18,600, engineering staff at the commencement numbered 126, and instruments, valued at purchase price, amounted to £7,591. During the 10th year of operation, the total fees earned were some £335,000, engineering staff stood at 177, and instruments, at purchase price, were valued at £175,000.

Vast Scope

It is interesting to point out that in the early days of NIFES, the rate of charge to clients was materially less than it is now. At that time fuel was in short supply, and savings were of critical importance to the nation. This being so, it was logical that the cost of promoting fuel efficiency should be more heavily subsidised than it is today when fuel is in adequate supply. Today more advanced service is provided, and the financial advantages rest heavily on the client's side; he is, therefore, called upon to bear a greater proportion of the cost, by way of fees. However, neither the increased rate of fees, nor the increase in staff account wholly for the great increase in the total fees earned. The basic reason for this great increase must be attributed to the growth of the realisation that the correct use of energy is at the root of industrial progress and productivity, together with a growing regard for NIFES and the assistance it can provide.

It is important to remember that a fuel efficiency service consists of people, and that, quite apart from technical competence, the regard in which the service is held is much determined by the character of the individual. He must marry the principles he seeks to inculcate to the interests of the client, and, to do this, he must have a wide understanding of, and an honest devotion to, both. He must be completely impartial in his judgments and advice, and a person of the highest integrity. Only if this is so, can he hope to achieve success in his work. It has been a gratifying experience to see NIFES engineers earn the confidence of industry through these characteristics, and it will be a stimulating and exhilarating experience in store for those who will be responsible for moulding the service in India.

...The correct use of energy is at the root of industrial progress and productivity...The field for Fuel Efficiency work in India is very great, and is growing rapidly...

We, in NIFES, know that the field for fuel efficiency work in India is very great, and is growing rapidly. We have also good reason to believe that there are many factories where a service will be whole-heartedly welcomed. It remains only to wish the new service in India well, and to assure those who use it, and thus help to build it up, that they will find great, and often unexpected benefits.

Technological Advances

New Appraisal of UK's Fuel Policy

BRITAIN'S fuel needs are met by the nationalised coal, electricity, and gas industries, and by the oil industry. These industries employ, in total, about 1,000,000 men, or 4% of the working population. Their capital investment in 1965 will be in the region of £1,000 million—about one-sixth of the country's total investment—the annual turnover of the industries is about £3,000 million; and the value of their net output is about 5% of the national product.

Adequate supplies of fuel and power are essential for the community. Labour productivity is closely linked with the power at its disposal, and increasing quantities will be needed to support the growth of the economy, and the rise in living standards. The pattern of fuel supplies depends primarily on the requirements of the consumers. The size and nature, however, of the fuel-producing industries are such that the Government is inevitably involved. It is a task of the Government to ensure that national considerations, which even individual consumers would not otherwise take into account in their choice, are reflected in the situation. The Government must, for example, be concerned about the pattern of fuel consumption in relation to security of supply, long-term costs, and the balance of payments. In addition, the fuel industries have to be considered in the broader social context. The social problems arising from changes in the coal industry's structure are of particular importance. Moreover, the fuel industries, because of their size and nature, occupy a focal place in the planning of the economy, both national and regional. The Government has a more direct responsibility in the case of the nationalised fuel industries; in total, these finance about one-half of their investment by borrowings from the Exchequer, and their efficiency in the use of capital is of special importance to the economy.

Government policies in other fields—such as taxation, imports, land use, clean air, and distribution of industry—affect fuel policy, production, and use. Conflicts of policy are bound to arise from time to time, but these should be capable of more

In the post-war period, significant changes have occurred in Britain's Fuel Economy. As soon as Labour came to power in 1945, Parliament passed a Fuel and Power Act, which placed on the Minister of Power the duty of "securing the effective and co-ordinated development of coal, petroleum, and other . . . sources of fuel and power in Great Britain . . . and of promoting economy and efficiency in the supply, distribution, use, and consumption of fuel and power, whether produced in Great Britain or not.

The coal industry's varying fortunes under changing economic conditions, the increasing resort to oil, continuous and substantial rise in electricity demand, nuclear power development, and, above all, the serious difficulties experienced in connexion with the balance of payments, and the imperative demand to speed up the general growth of the economy—all these developments have radically affected the fuel position in Great Britain, and have, consequently, had a considerable impact on effected British Fuel Policy as well.

When Labour again came to power recently, for the second time in the post-war period, they have been under pressure to coordinate the fuel policies on the basis of the most productive utilisation of resources, and also to make these fuel policies fit in with their overall economic and social policies of a continuously higher growth rate, alongside a sufficiently fast development of the Welfare State.

Consequently, in October 1965, the Ministry of Power issued a White Paper on fuel policy. The title of the White Paper, however, is a misnomer, because it is not so much a statement of policy as an attempt to think aloud as to what the right fuel policy should be. The better part of the document, however, gives a substantial background information in respect of the fuel position, in the retrospect as also the prospect. Certain extracts are printed here, because they bear significantly on future policies and developments in our own country. The substantial part that coal will continue to play in the industrial economy of India, alongside its gradual supersession by alternative fuels—oil, gas, and nuclear power—and, above all, the compulsion to increase electric power capacity, at the fastest possible rate, to provide power for industry and comfort for the people come in for analysis. Surprisingly, though the scales of the two economies (British and India) are at the moment different, the problems, difficulties, and possibilities look so analogous.

ready and orderly solution against the background of a coherent fuel policy.

On taking office, the Government put in hand a review to evolve a co-ordinated fuel policy. A new appraisal of policy, in the light of the recent technological advances, would, in any case, have been timely. New raw materials and processes are transforming the nature and prospects of the gas industry; the generation of electricity by nuclear power on competitive terms is now within reach; a large expansion of oil-refining capacity is in progress; the coal industry, though it has notable technological achievements to its credit, faces difficulties in covering its costs and holding its markets.

Fifteen years ago, British fuel economy was overwhelmingly dependent on coal, which supplied 90% of the country's needs. The electricity and gas industries were based almost entirely on coal. Of the relatively small amount of oil then used, about one-half was for transport, and the requirements were met largely by the import of products refined abroad.

Historical Background

At that time the impact which oil would have on the UK energy market was not generally foreseen. The National Coal Board's Plan for Coal, published in 1950, which was accepted by the Government of the day as an appropriate basis for framing the industry's development programme, foresaw a demand for coal in the period 1961-65 of 240 million tons a year, including 25 million to 35 million tons for exports. The Committee on the Use of National Fuel and Power Resources (with Lord Ridley as Chairman), reporting in 1952, thought this estimate too low. Following this report, the National Coal Board reviewed production possibilities, and formed the view that it might be able to increase output to about 250 million tons a year during 1965-70. The subsequent course of events, of which the salient points are given in Table I, belied these forecasts of demand.

The 1959-64 increase in UK's fuel needs was met primarily by oil, which increased its share of the total from 23% to 33%, with a corresponding decline in the share provided by coal. A similar shift away from coal has occurred in every major industrial country. In the USA, with its large indigenous resources of oil and natural gas, the development took place much earlier. In most European countries it began at the same time as here. In almost all of them the process has gone further than it has in this country. Thus, taking four of the largest coal-producing countries in Western Europe, the share of coal in the national energy market had declined by 1964 to 49% in Western Germany, 44% in France, 60% in Belgium, and 39% in Holland. The UK figure, on a comparable basis (which differs from that normally used here), was 69%.

Table II analyses the demand for coal and oil since 1956 in more detail. Oil used for road and air transport, and also as refinery fuel, has been shown separately because these are readily indentifiable sectors in which, broadly speaking, there is no competition between oil and other fuels. This is true also for the "non-fuel" uses, and for some of the fuel uses under "other purposes"—e.g., agricultural traction and coastal and river transport—but these are much smaller in comparison. In the other sectors in the Table, coal and oil are generally in competition with each other; at power stations both are also in competition with nuclear energy and hydro-electricity; and at gasworks with natural gas. The Table shows the steady growth of oil, particularly in the sectors in which it is in competition with coal, and the fact that power stations are the only major expanding market for coal.

Expansion of Oil Use

The expansion of oil use was accompanied by a rapid growth of the home refining industry, broadly in step with the increase in consumption. Refinery throughput, which was less than 10 million tons of crude oil in 1950, reached nearly 29 million tons in 1956, 39 million tons in 1959, 53 million tons in 1963, and 58 million tons in 1964.

While the share of the energy market taken by oil has been increasing, there has also been a marked growth in the use of electricity and gas, the two main secondary fuels.

Electricity consumption has grown at over 8% a year during 1950-1964, though the growth rate has been lower in the last

TABLE I

Inland Fuel Consumption in the United Kingdom

	Million tons coal equivalent (1)				
	1950	**1956**	**1959**	**1963**	**1964**
Coal	202.6	217.5	189.4	194.0	187.2
Oil (including petroleum gases) ..	22.2	37.5	56.1	85.3	93.3
Nuclear electricity	—	—	0.5	2.5	3.2
Hydro-electricity	0.9	1.3	1.5	1.8	1.9
Natural gas	—	—	0.1	0.2	0.3
Total inland fuel consumption (2) ..	225.7	256.3	247.6	283.8	285.9
Index of industrial production (1958-100)	83.1	99.3	105.1	119.0	128.2

TABLE II

Consumption of Coal and Oil in UK

	Million tons coal equivalent			
Coal:	**1956**	**1959**	**1963**	**1964**
For power stations	46.8	46.7	67.5	68.0
For gas works	28.1	22.8	22.4	20.5
For other purposes	143.1	119.9	104.1	98.7
Total	217.5	189.4	194.0	187.2
Oil (including petroleum gases)				
For power stations	0.7	7.2	8.7	9.7
For gas works	0.8	1.6	3.6	5.0
For road and air transport and refinery fuel	19.7	23.4	30.8	33.4
For other purposes	16.3	23.9	42.2	45.2
Total (1)	37.5	56.1	85.3	93.3

TABLE III

Use of Electricity and Gas in UK

	1950	**1955**	**1961**	**1963**	**1964**
Electricity (thousand million kilowatt-hours) (1)	47.8	69.7	113.0	136.8	143.4
Gas (million therms) (2)	2,371	2,616	2,618	2,925	3,014

two or three years (Table III). The industry has invested heavily to meet the increasing demand; but, as a result of past underestimation of the rate of growth in demand, and of the time required to increase capacity, the industry is still hard pressed to meet peak demands. Economics of scale and greater efficiency have resulted in substantial savings in costs: and this has been reflected in electricity prices. Consequently, over most of this period, the average revenue per unit of electricity sold has risen at a much lower rate than the average price of all UK goods and services.

Throughout the period, electricity production has been predominantly based on home-produced coal. Oil use at power stations, which reached a level of over 7,000,000 tons of coal equivalent by 1959, and of over 9,000,000 tons in 1960, has since remained at about the latter level. But in 1955 a step towards the development of a new primary fuel was taken, with the adoption of a programme for the construction by the electricity industry of 1,500 mW–2,000 mW of nuclear power stations for commissioning in 1960-65. This was greatly expanded in 1957 to a nuclear programme of 5,000 mW—6,000 mW capacity by 1965; subsequently, the date for the completion of this programme was put back in successive stages to end 1969. It is now expected that by end 1965 at least 2,500 mW of this capacity will be in service, and that the programme will be completed by 1969. A second programme, announced in 1964, adopted for planning purposes a figure of a further 5,000 mW of capacity to be installed in England and Wales in 1970-1975; this programme has since been revised upwards. At the time the first programme was drawn up, it was hoped that the cost of the power produced from the first commercial stations would be about the same as that produced from new coalfired stations; but this hope has been falsified, mainly by the unexpectedly high capital cost of the earlier nuclear stations, and the steep fall in the cost per kW of conventional generating sets, as these came to be built in ever larger sizes. None of the stations in the first programme is now expected to produce electricity as cheaply as conventional stations commissioned at the same time. But stations to be built under the revised second programme should produce nuclear power that is fully competitive with conventional stations.

Gas Industry Handicapped

As Table III shows, the gas industry has not expanded rapidly and continuously, like the electricity industry, over the years 1950-64. The gas industry was handicapped by the limitations of the coal carbonisation process, which was not capable of substantial further development, had high capital costs, and required special coals which were becoming increasingly expensive. Gas sales rose only slowly up to 1955, after which they remained almost static until 1961. But the industry had been making strenuous efforts to free itself from over-dependence on carbonisation coal. Two large plants employing the Lurgi process, for producing lean gas by the total gasification of cheaper types of coal, were built, and the industry also pioneered the import of Saharan natural gas by refrigerated tanker. Even more important has been the development of processes capable of producing gas cheaply from a variety of oil products. Although the full benefits of these new sources of gas are still to come, there has already been in the last two years a marked advance in gas sales, and the use of gas is now rising at a rate of about 8% a year—even faster than the present rate of electricity growth. There would be a further powerful stimulus to the growth of the gas industry if the search for petroleum in the British part of the Continental Shelf were to result in a substantial find of gas.

To complete the background for national fuel policy, it is necessary to assess the probable course of the demand for energy in total, and for the various fuels individually. The growth rate in total inland demand for fuel depends mainly on the growth rate of the economy, while the division of the demand among the different fuels is governed by separate decisions made by a great number of consumers—industrial, commercial, or domestic—who are influenced by the relative price, and suitability of the different fuels. Estimates about the prospective demand for energy must, therefore, be based on assumptions about the growth of the economy; about the success of each of the fuel industries in improving efficiency, in keeping down costs, and in selling its products; and about Government policies and other factors affecting the relative prices of the different fuels. It is assumed, as in the National Plan, that national output will grow 25% during 1964-70, an average of 3.8% a year. Recent experience of the complex relationship between the growth of energy consumption and of the economy as a whole, suggests that a change of 1% a year in the assumed rate of expansion in national output up to 1970 (in either direction) might affect the estimated annual demand for fuel by that year by about 11,000,000 tons coal equivalent. Other assumptions, and the consequences of variation in them, are even less susceptible of precise treatment; even if all the assumptions proved valid, the estimates would still be subject to a margin of uncertainty. While forecasting of this type is essential to formulate fuel policy, past experience has shown us how far our estimates can be, especially those relating to particular fuels. The estimates which follow should not, therefore, be looked on as more than broad indications of likely requirements on the assumptions adopted.

It is against this background, and in the light of these prospects, that the objectives of the fuel policy may be considered. The overriding objective is that the fuel sector should make its full contribution to the strengthening of the economy, and the balance of payments. The objectives may be more specifically stated thus:

(a) Adequate and continuous supplies of fuels of suitable quality should be available to sustain the desired rate of growth in the economy.

(b) The price of fuels should be such as will enable them to play their part in making UK's economy as a whole competitive, particularly in relation to other West European countries.

(c) The fuel industries should be technically progressive and viable.

(d) Imports of fuel, particularly of oil, which on any reckoning will grow fast, should be in the form that is

TABLE IV

Industries' Estimates of Fuel Demand in UK Resulting from the Industrial Inquiry for the National Plan

	Million tons of coal equivalent (1) 1960 (Actual)	1964 (Actual)	1970 (Estimated)
Coal:			
For power station	51.9	68.0	84
For gas works	22.6	20.5	10
For other purposes	122.2	98.7	81
Total	196.7	187.2	175 (2)
Oil (including petroleum gases) ..			
For power station	9.2	9.7	14
For gas works	1.9	5.0	14.5
For other purposes	54.4	78.6	115.5
Total	65.5	93.3	144
Natural gas	0.1	0.3	1.5
Nuclear power and hydro-electricity	2.6	5.1	16.5
Total inland demand for energy ..	264.9	285.9	337
Electricity (thousand million kW hours)	104.9	143.4	241
Gas (million therms)	2,636	3,014	4,635

least costly in terms of foreign exchange.

(e) Consumer freedom of choice, apart from being desirable in itself, is an essential guide to the efficient planning of supplies, provided that the prices paid by the consumers fully reflect all the relevant costs.

Some of the foregoing objectives conflict with others, so that the single-minded pursuit of any one objective, such as the supply of every fuel at the cheapest current price, will not necessarily be the best for the nation. The aim must be to secure the balance between the various objectives that is most advantageous, considering also social considerations and costs. For this, no static policy can suffice. The balance of advantage is continually liable to change, as a result of events which are neither predictable nor controllable. Technological changes, changes in the balance of supply and demand for fuel, and the discovery and development of new sources of supply, have all at times affected the balance in the past, and must be expected to do so again in the future. The fuel policy, therefore, must be flexible enough to move with the trend of events, and maintain all possible room for manoeuvre by refraining from making, earlier than is demonstrably necessary, major changes which it may be impracticable to reverse. The objectives outlined embrace all aspects of fuel supply and demand; fuel policy needs to be similarly comprehensive, and to be coherent in all its elements. It needs to be considered in its relation to the fuel policies of other countries, which can affect British overseas earnings.

Difficult Problem

The most difficult single problem in fuel policy is the health and size of the coal industry. It is, however, clear that indigenous coal will remain a main primary fuel. The Government has come to the conclusion that radical changes and substantial extra assistance are needed to enable the industry to provide the essential coal supplies in an efficient and economic fashion, and to make its optimum contribution to our economy generally and to the balance of payments.

The National Coal Board has been making great efforts to strengthen the industry's position, and to increase efficiency by better use of men and machines by concentration on the most economic pits. Productivity (output per manshift) rose by 5.3% a year over 1960-64, and is continuing to rise. The Board leads the world in developing the application of automation to mining, and is beginning to put a new series of techniques to large-scale use. But costs per ton in this labour-intensive industry have also risen, often for reasons beyond the Board's control. Proceeds per ton, on the other hand, have tended to fall. Markets for the higher qualities of coal have tended to decline, while the lower grades, which are in increasing demand for power stations, fetch much lower prices. The Board's difficulties have been aggravated by a burden of capital debt incurred through past investment designed to meet a level of demand which has not materialised. Moreover, the Board has had to aim to achieve a market big enough to absorb not only the maximum output obtainable from the economic pits, but also the output from collieries which continued in operation even though they could not cover their day-to-day running costs. In present conditions this aim can no longer be sustained. In the past year or two, the financial position of the Board has deteriorated. Improvements in the industry's productivity have absorbed increased labour costs, but have not been sufficient to offset the higher costs of materials and other expenses.

There are many reasons why a measure of protection should be given to the British coal industry.

Firstly, the coal industry, which

places no direct burden on the balance of payments, is a large import saver.

Secondly, it is desirable that the fullest economic use should be made of the large investment already made in the coal industry, and the social investment associated with it. At the same time in considering new investment in the coal industry, regard must be had to the possibility that the present scale of protection may not be continued indefinitely.

Thirdly, supplies of indigenous coal on the scale envisaged in the estimates, and perhaps on an even larger scale, are reasonably secure, provided that the industry is not disrupted by too sharp and indiscriminate a decline.

Remote Control

A substantial part of the coal industry has relatively low costs, and has been consistently profitable. Nearly 80% of coal is now obtained by mechanised methods, and an immediate improvement in the industry's fortunes could be obtained by a fuller use of machines already installed. The Board plans to increase the proportion of coal won by mechanised methods to over 90% in the next five years. For the future, the most promising new developments lie in the application of remote control to mining operations. At the first pit being developed to employ these new techniques, output per manshift is expected to be about eight tons, or over four times the present national average. With such developments, the sound heart of the industry can make an increasingly valuable contribution to the future health of UK's economy, and provide assured and well-paid employment for the men who work in the mines.

In 1964, oil contributed a third of the primary fuel supplies. Consumption, including non-fuel uses, is increasing at a rate of about 9% a year, and is expected to continue to increase, though perhaps at a slower rate. For many uses there is

UK Pioneers

World's Manless Coalface

The opening of Bevercotes Colliery, a new mine near Nottingham, in the English Midlands, is a sign that an era in coal mining is ending, and another has begun. It represents a revolutionary step forward in the drive to replace the old-fashioned hand-got methods by techniques which make mining at once safer and incomparably more productive.

The British coal mining industry, which was nationalised in 1947, has about 550,000 on its pay-roll, and is charged with supplying sufficient coal at the right price, and making enough money to meet its outgoing over good years and bad. During the last four years, the industry has made more rapid progress than at any time in its long history.

Among its more recent achievements over the last four years are a 23 per cent increase in productivity; an increase in mechanisation from 38 to 76 per cent; no increase in the price of industrial coal for more than four years; an increase in the average wages of miners by £3 (Rs. 40) a week, seven extra days' holiday for miners; 5,000 houses built for miners transferring from declining areas to those which are expanding; and pioneering the only manless coalface in the world!

no effective substitute for oil. These uses, where oil is not in competition with other sources of primary energy, account for about 40% of the total tonnage, and are increasing rapidly. For other uses—mainly steam-raising (including use for power generation), process work, space-heating, and water-heating—oil is in competition with other fuels. Among the uses where oil is in competition with other fuels, consumption of the light fractions (including the use of naphtha for gas-making) has been growing very fast in recent years. However, the biggest single item is the consumption of fuel oil. After a check in 1963-64, partly as a result of a reduction in use at power stations, the consumption of fuel oil is now going forward again, though at a rather lower rate than that of the light fractions. The rate of increase in demand for middle distillates has recently been held back by the strong competition of the gas industry in the heating market.

Home Refining

A major contribution to keeping down the cost of oil imports can be made by home refining. On an average the value of refined products imported into the UK is nearly £3 a ton higher than the value of the crude oil from which the products are refined. Moreover, home refining has other advantages in the national interest. It avoids dependence on refineries in foreign countries, and so promotes security of supply; it attracts foreign investment and orders for plant; its growth stimulates the development of secondary industry based on it. About 40% of the proposed refining capacity is to be sited in or near development districts.

In 1964 home refining did not even cover inland demand; but this should be corrected as new refinery capacity, recently commissioned, or on order, comes on stream. Plans for refinery construction which have been notified to the Ministry of Power will, when fully implemented, bring capacity up to 102,000,000 tons in 1970 (giving an output of products of about 92,000,000 tons). In practice, further additions are likely before 1970 from certain companies which have not yet completed their plans. The oil industry's estimate of refinery output in that year is 97,000,000 tons, compared with an estimated demand (inland and bunkers) of 93,000,000 tons. The objective should therefore be achieved at least by 1970.

Nuclear power has now been established as a reliable means of generating electricity on a commercial scale. It is characterised by high capital costs and low running costs; this means that nuclear stations once built, must be operated at the highest possible load factor to get the full economic benefit from them. The uranium or thorium needed to produce the fuel for nuclear stations is not mined in the UK and has to be imported. The foreign exchange cost depends on the form in which the fuel is imported, but is substantially less, per ton of coal equivalent, than the foreign exchange cost of imported oil. The fact that uranium deposits are widely scattered throughout the world, the highly-concentrated nature of the fuel, and the fact that a nuclear station, once fuelled, does not need frequent re-fuelling, combine to make nuclear power relatively immune to interruptions of supply by events overseas. Thus on balance of payments grounds and on grounds of security of supply, nuclear power stands closer to home-produced coal than to imported oil.

Although the earlier expectations about the economics of nuclear power have proved premature, there has been a steady fall in the capital costs of successive stations in the first nuclear power programme, and the tender (an Advanced Gas-cooled Reactor—A.G.R.) recently accepted for the second nuclear station at Dungeness (1,200 mW) suggests that it should give cheaper base-load electricity than future coal-fired stations on the present price of power station coal. The total generating costs from the second Dungeness station are estimated, on cautious assumptions, to be about 0.46d./kWh. This calculation is based on the discount rate of 7½% used by the Central Electricity Generating Board for the appraisal of investment; on a 75% load factor; and a 20-year life. However, all components have been designed to have a life of 30 years at 85% load factor, and these more optimistic assumptions would lead to an estimated cost of about 0.38d./kWh. These figures can be compared with costs from the coal-fired stations under construction or planned at Drax (4,000 mW) and Cottam (2,000 mW) of 0.52d./kWh and 0.54d./kWh respectively, and from the oil-fired station under construction at Pembroke (2,000 mW) of 0.52d./kWh or 0.41d./kWh without tax.

In the light of the encouraging tenders received for the second nuclear power station to be built at Dungeness, the Government has reviewed the nuclear power programme for 1970-75, which was announced in the White Paper on the Second Nuclear Power Programme (Cmmd. 2335) issued in April 1964.

In agreement with the electricity supply industry and the UK Atomic Energy Authority, the Government has decided that for planning purposes it should be assumed that, on average, over the six years 1970-75 about one nuclear power station a year would be commissioned, starting in 1970 with the Dungeness 'B' station of 1,200 mW, and possibly including a second Scottish station. The programme will be based on the Advanced Gas-cooled Reactor developed by AEA, but at this stage the possibility of another reactor type making a contribution is not excluded.

It is estimated that on these assumptions, and with further developments in nuclear technology and expected increase in the size of stations, a total of 8,000 mW might be in commission under the second nuclear power programme by 1975.

Saving in Coke at Tatas

Speaking at the annual meeting of the Coal Consumers' Association of India, in September last, Mr DC Driver said that, at Jamshedpur, Tatas had introduced fuel oil injection in all their blast furnaces, thereby saving in coke per ton of iron, and increasing the production of iron by more than 7%. They are at present using 5,000 tonnes of fuel oil per month. They find the higher cost of oil more than compensated by the increase of iron and decrease of coke consumption. They are also to experiment with oxygen in the blast and pulverised coal injection.

Use of Fuel in UK

Scope for Planning & Coordination

THE BRITISH Fuel Policy, enunciated in the preceding article, has come in for a good deal of criticism. We print a sample below from Mr Michael Posner's article in the *New Statesman* (Nov. 19, 1965).

If planning can work in any sector of the economy, it should work for fuel. The need is evident—the fuel industries spend about one-sixth of our annual investment. The facilities for planning exist—two-thirds of our primary fuel supplies come from public-owned coal, and both our secondary fuel industries (electricity and gas) are also nationalised. The 'coordination of fuel' is a long-standing Socialist demand.

'Coordination'—whether for fuel or transport—has often meant no more than protection for vested interests. Some people have suggested that decisions should be taken about, for instance, future coal output, without asking which fuel would be cheapest. The coal lobby has wanted coal at all costs, *the scientific lobby has cried for the more rapid use of nuclear power.* But the fact that mines exist is an argument for getting coal only if the avoidable costs of the extra tons of fuel is lower than using another source, and the fact that atomic power is technically advanced does not ensure its economic attractiveness.

At a time when even Eastern Europe is beginning to recognise the importance of cost minimisation through some sort of skeletal price mechanism, we should recognise the substantial if limited merits of the case for 'planning through competition' that some socialists and many non-socialists have been pressing for 30 years. According to this case, we must first establish the true total costs of different forms of fuel (or different means of transport);

following the principles of 'cost integrity', relative prices can then be made to reflect differences in costs; and the user can then be left free to choose, according to his own needs, the form of fuel which gives him the maximum benefit.

Price Mechanism

Without nationalisation, prices would reflect more monopoly power than costs of production, and efficiency would be hindered by division of ownership. Without conscious government policy, the costs of the individual fuel industries would not measure true costs, but would instead be influenced by a host of temporary and partial causes. Apparent gas 'costs' are low, because fuel oil for electricity generation is taxed while methane for gas-making is not; the short-term gains to be made from closing some of the uneconomic pits obscures the long-term losses that may result from the permanent loss of coal-getting capacity; and the possible gain to the balance of payments through economising oil imports must be weighed centrally.

Planning through the price mechanism, therefore, requires that the government adjust the price signals to which the fuel industries react, that it remove these industries from dominance by individual capitalists, but that the competitive game be then played fairly and freely. Such, broadly, is the view taken by the new White Paper.

On the whole, however, this type of planning achieves the same result as a textbook competitive system. There are two major shortcomings of this price mechanism planning; it leaves the general level of prices (as distinct from the pattern of *relative* prices of different products) substantially undecided; and it tells us nothing of the proper way to plan investment. These two problems are inter-related, since the 'profitability' of investment depends in part on the price level at which fuel is to be sold in the future.

The 1961 White Paper wanted future investment to be made only where the yield was expected to be high—an aim we should applaud; it wanted a higher proportion of investment funds to be financed out of the prices charged by the nationalised industries—an aim which may be desirable but requires examination; and it wanted a reasonably high 'yield' to be earned on existing nationalised assets—a target for which there is no shred of economic justification. Under the 1961 policy, targets have been imposed—for the most part in the form of 'target rates of return on capital' for the public corporations: these targets differed quite arbitrarily from case to case and their net result has been to induce rises in the prices charged by nationalised industries.

In any case, there need be no inflexible connection between price policy and investment policy. All the fuel industries are in rough agreement about total energy requirements in 1970-75; they differ, however, on the likely way in which the sovereign consumer will carve up the market. The new White Paper reminds us of past errors. If the 'plans' of the past were so poor, surely it would be better to let the market decide in the future.

But this is mistaken. By 'letting the market decide' we can only mean letting individual fuel producers lay down new capacity on their own estimates of their future share of the market. These estimates are just as likely to be mistaken as are collective, national estimates, and in addition involve the secondary uncertainty created by the unpredictability, for any one concern, of its competitors' reactions.

Thus, despite its masochistic evocation of the pleasures of market discipline, the White Paper rightly reserves to the Ministry of Power final decisions about the allocation of investment between industries—including, we must insist, oil refining.

But here we find the central unreality of the whole discussion. In making their decisions today about creating new capacity five or 10 years ahead, the Ministry of Power are guessing how consumers might choose on the basis of prices that might be offered to them. No doubt it might be informative to judge, on the basis of shortages and surpluses that eventually appear in the market, how successful the decisions and guesses have been, but the guesses must be made, and made many years in advance of their testing.

Thus, whether we like it or not, planning necessarily involves 'Whitehall knowing best'. If this is so, the exact correspondence of prices to costs, and a fortiori, the right 'rate of profit on capital' to be imposed on the public corporations, becomes much less important. What is important is that the calculations are made publicly, and publicly criticised.

Poor Even in Coal Consumption

The report of the Energy Survey of India Committee says that at present the output and consumption of coal in India as a whole is equivalent to about 0.13 tonnes per head per year. The report adds that this may be contrasted with coal production per head of about 2.1 tonnes in the USA (where oil is the principal fuel), 3.7 tonnes in the UK, 1.1 tonnes in West Germany, and 1.1 tonnes in France. More nearly comparable countries include Japan (0.6 tonnes per head), and Spain (0.5 tonnes per head). In part, the low output of coal per head in India has reflected the low degree of industrialisation of the economy rather than lack of resources.

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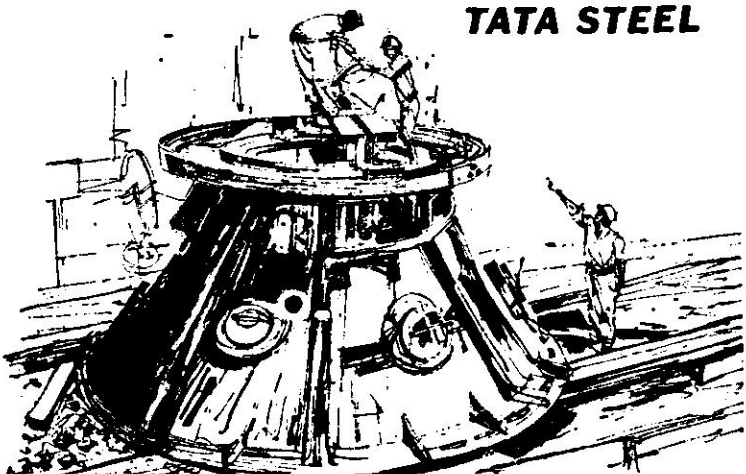

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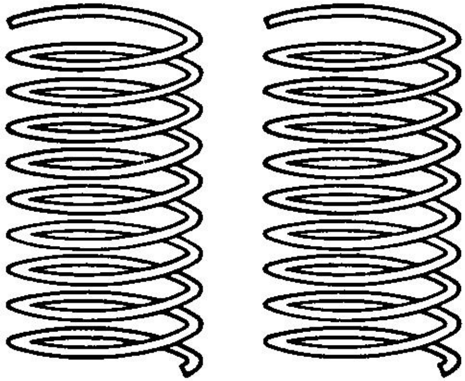

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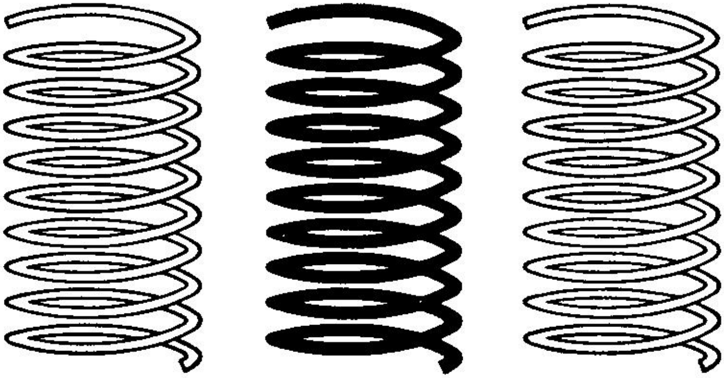

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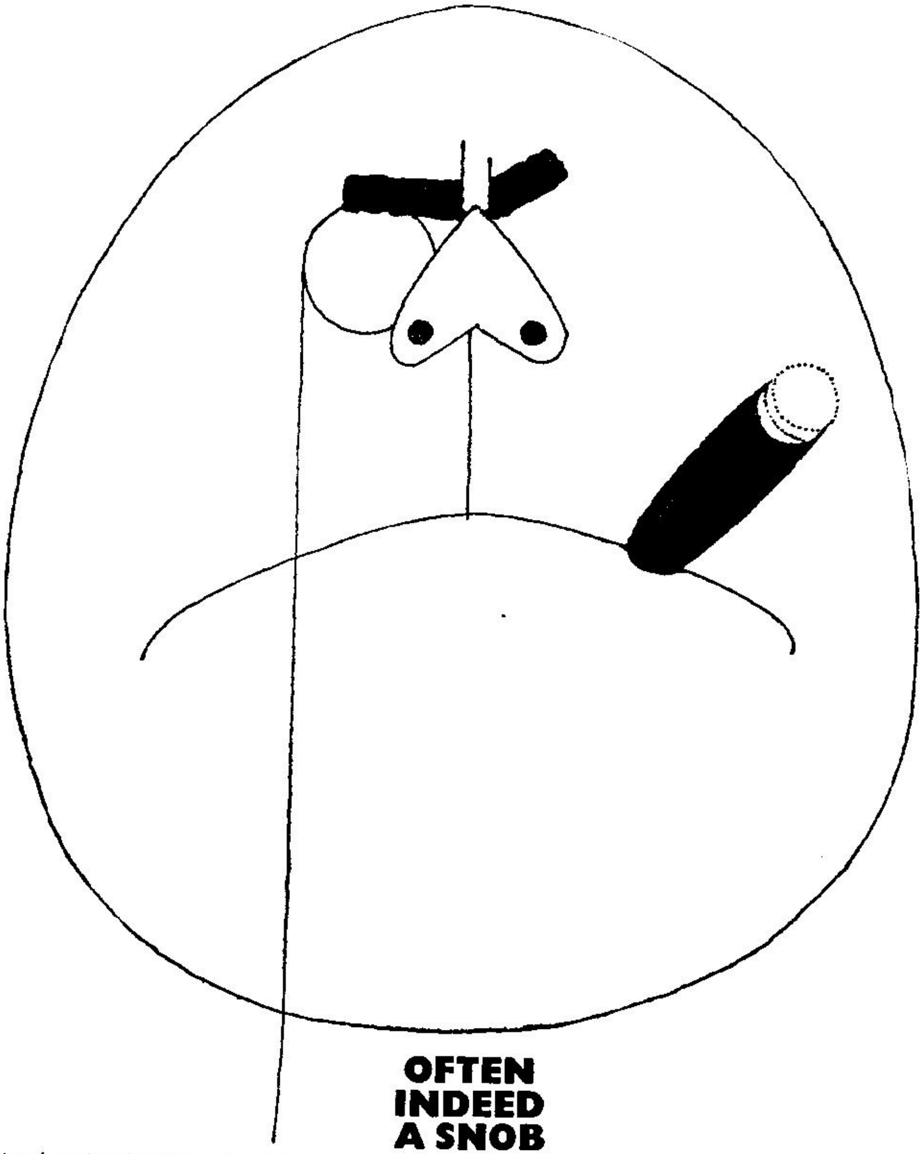


OFTEN INDEED A SNOB

But that is only when we must insist on a specified raw material rather than compromise with a non-standard substitute.

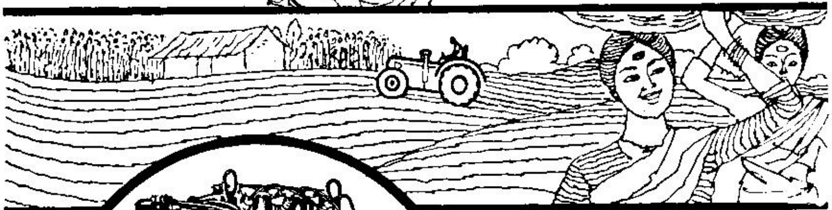
Or when we must reject what our own factories have produced, which do not conform to specifications.

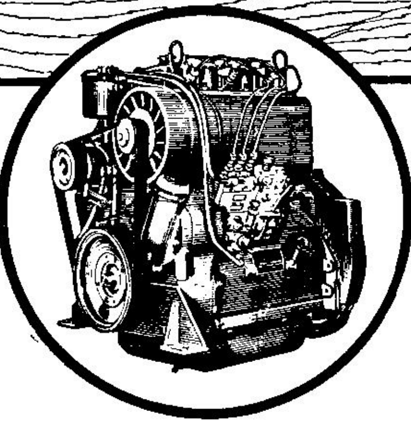
Or when we must recommend to industry new methods of using our products and processes rather than preserve the old ways, which obstruct standardisation.

Or when we must question the ultimate quality of what we make, as we continually do. Yes, we are snobs, of a sort......

INDIAN OXYGEN LIMITED IOL


TOM & BAY/KOEL/E-163





DH BUTANI

National Productivity Council

India's Fuel Demand

Need to Develop New Sources of Supply

THE PROBLEM of fuel economy needs to be reviewed in the world perspective, in the context of the new technologies. In fact, this country is already in the stream of research in respect of productive utilisation of nuclear and solar energy. We have, probably, not yet made an attempt to exploit the energy from sea water. Within a decade or two, various countries doing research in the field (particularly UK) will get immense quantities of energy from sea water. It is estimated that there are 40 billion tons of deuterium (heavy hydrogen for producing nuclear energy) in the ocean, and each ton is equal, in terms of heat, to 8,000,000 tons of coal.

If our industry and agriculture are to operate on a modern standard of living, then we shall have to make an investment into these new techniques of energy generation. This should be the long-term fuel efficiency policy of this country, if we are going to make the most productive utilisation of our resources.

The per capita energy utilised from all sources—coal, oil, gas, hydro-power, nuclear fuels—is equivalent, taking the world's average, to 1½ tons of coal per year. In advanced countries the per capita energy utilisation is as much as five tons to seven tons, and at the other end, in the poor countries, to 1/20th of a ton: i.e., in terms of energy utilisation, the advanced countries are at a level hundred times the position in the most backward countries. This creates a vicious circle, for the availability of energy limits the utilisation of resources.

Taking a long-term view, the world demand for energy fuels is increasing at a compound rate of over 5% per annum. Historically, the statistics would work out as follows in terms of billion tons of coal:

1960	4.2
1980	9.4
2000	21.5

On the supply side, the world's current estimate of coal, oil and gas reserves would hardly carry us into the 21st century. So far as India is concerned, our demand will rise steeply, because we yet have to accomplish a real revolution both in industry and agriculture, as also in the people's standard of living. On the other hand, while our supplies of low-grade coal are extremely large, our supplies of oil and gas on any scale have yet to be proven.

We have, therefore, necessarily to look immediately to other sources of energy, also because of the cost of location. The reason why we have located our Fuel Efficiency Service at Bombay is that every ton of coal saved at Bombay really means a total saving of over 1,700 ton-miles of coal, for that is the distance over which every ton of coal has to be hauled before we can use it in the Western region. Other sources of energy, like nuclear power, do not suffer from the same handicap; and on the basis of today's technology, we can extract 10,000 times as much energy for one ton of nuclear fuel as from coal. In fact, the idea now is to extract uranium and thorium from ordinary granite: thus it should be possible to burn the ordinary rocks of the earth to get from each ton, energy equivalent to burning about 50 tons of coal.

There are other experiments which are already on the cards. In the Gemini aircraft, for example, electricity is produced from the fusion of oxygen and hydrogen. Incidentally, water is also produced. Thus all that we have to do is to break up water into oxygen and hydrogen—energy is, of course, required for this electrolysis—and then fuse oxygen and hydrogen to generate electric power. By this process, we can even run a car without petrol.

Then there is the sunlight. Several experiments are already on, to concentrate or store this diffused energy supply, so that it can provide us with electricity. Every second the earth receives, from the sun, energy equivalent to 50 million tons of coal. The energy to be derived from sea water has already been referred to; and we have one of the longest coast lines stretching from the Arabian Sea to the Bay of Bengal.

While the National Productivity Council is doing its best in advising industry on how to cut costs on fuels, and how to make fuel supplies go a long way, our fuel efficiency policies need a long-term orientation in the context of our resources, and the possibilities thrown out by the new technologies.

Valuable part of US Mineral Wealth

The report on Fuel Conservation of the Anglo-American Council on Productivity says that detailed estimates of US fuel resources were ascertained during the course of a study made by the Committee of Interior and Insular Affairs in 1950. The object of the study was to obtain definite information as to the available fuel resources in relation to present and probable future rates of consumption. It is clear from the committee's report, published in 1951, that in spite of the rapid expansion of the oil and natural gas industries, coal remains the largest and most valuable part of the total mineral wealth of the USA. In fact, US coal deposits represent about 40% of the world's known total.

National Industrial Fuel Efficiency Service, United Kingdom

CECIL AJ PLUMMER
and
BRINLEY R ADDICOTT

State of Fuel Efficiency in India

The authors, Mr Cecil AJ Plummer, Area Engineer of the National Industrial Fuel Efficiency Service of the UK, and Mr Brinley R Addicott, Senior Engineering Assistant of the NIFES, were invited by the Government of India (under the Colombo Plan of Technical Assistance) to advise Indian industry and the Government of India on fuel economy. They toured India for six months to investigate the wastage of fuel in specified fields of usage. They paid visits to fuel-consuming industries in the main industrial centres of the country: 60 establishments were covered, the scope for fuel-saving was surveyed, and practical technical advice on fuel efficiency measures was given to managements. In this article, it is endeavoured to draw a sketch, in their own language, based on actual experience of fuel consumption in India.

THE FACTORIES we visited were associated with the following industries: Textiles, chemicals, foundries, glass, cement, ceramics, paper, food, leather, rubber, engineering, and electric power. It is reasonable to suppose that the establishments visited represented a typical cross-section of Indian industry. It has been found that there is great scope for fuel saving. A few factories have been visited where savings of less than 15% of fuel consumption are possible, and some have been encountered where 50% of the fuel burnt can be saved. The average savings possible amongst all factories visited are as high as 25%. The scope for fuel saving, has been found to be greatest where the cost of fuel, delivered on site, is least, i.e. nearer the coalfields.

Generally the older factories, working 'traditional processes', and deficient in personnel with technical background, tend to greater waste of fuel. It must be said, however, that in several relatively modern factories engineers have been found to be insufficiently acquainted with the principles of good fuel and steam utilisation.

Bad maintenance has been found to be the widespread cause of fuel waste. Managements are widely aware of the need for high production, but are not everywhere enlightened regarding the relationship between scheduled maintenance, productivity and production costs.

In a majority of cases industrial managements are not sufficiently conscious of the need for fuel efficiency, and few factories were found where heat consumption per unit of production received any attention. The facts that energy derived from fuel is a tool of industry, and that efficient use of that tool not only conserves fuel, but also increases productivity, improves product quality, and reduces manufacturing cost, were appreciated in but a small number of instances. It is possible to save much fuel by what may be called First Aid measures. These involve such expediencies as lagging and thermal insulation, recovery of condensate heat, prevention of steam leakage, economical loading of heat-consuming plant, and the use of steam at the lowest possible pressure. These measures involve little by way of capital expenditure, and industry can do much to help itself in this field. It is probable that 10% of fuel used could be saved rapidly by such elementary measures.

Basis of Efficiency

In many instances there was a lack of adequate instrumentation for the proper control of combustion, steam-raising and thermal processes. The ultimate basis of efficiency is measurement, and it is difficult to see how processes can be economically, and efficiently, carried out if operators are expected to undertake "blind driving".

What was particularly disheartening was to find a great amount of industrial measuring equipment in an unserviceable and/or unreliable state. A large amount of this equipment was relatively new, and nearly all of it represented an expenditure of foreign exchange.

In many instances, it was averred that equipment was unserviceable because of lack of small spare parts, or charts, and difficulties associated with the import of such items. The expert was not in a position either to refute, or substantiate, such statements. What was very clear to him, however, was the fact that instrument maintenance personnel are inadequate, and that it will be greatly in the interests of India to stimulate both the indigenous manufacture of industrial instruments, and the training of competent instrument engineers, and maintenance personnel, in the technical institutions.

The wider use of boiler feed water economisers and mechanical stokers would save much fuel. An efficient hand-fixed Lancashire boiler, operated without a feed water economiser, and burning 100 tons of coal, would, if fitted with a mechanical stoker and economiser, burn less than 85 tons, if properly operated. The majority of Lancashire boilers in India could make savings of at least this proportion. This would, in the aggregate, amount to a large tonnage of coal indeed.

To achieve savings of fuel on a boiler plant, it is necessary that the operator should be practically trained, and have suitable instruments to guide him. We have found a need for the more practical training of persons employed on stoke boilers. The lack of instrumentation applies to boilers as much as to process plant.

The distribution of coal and its price structure are features having a bearing upon fuel economy. Any Indian fuel efficiency organisation will perforce have to be concerned with coal sanctioning. The price structure of coal neither reflects its value in the national economy, nor offers an incentive to industry to use the poorer qualities in better supply. The spectrum of prices, grade to grade, is not broad enough.

The size of coal despatched from collieries requires deeper consideration. It seems quite illogical that at some fuel-consuming plants (e.g. gas producers) fines are screened out and rejected, whilst on others (e.g. water-tube boilers with travelling stokers) coal has to be crushed to make it small enough. There seems a case for screening plants at the pit head, so that various classes of consumers can be delivered an immediately usable fuel.

No matter how efficient a boiler plant may be, the efficiency is of little consequence if steam is subsequently wasted, or inefficiently used. We have found it true in India, as in the United

Kingdom, that there is more fuel to be saved on steam-using plant than in the boiler house.

Bad steam utilisation has more ill-effects than the mere wastage of fuel. These include:

(a) Poor productivity of steam-using plant

(b) Increased production costs

(c) Poor quality and even perhaps wastage of product

(d) A demand for an increase in the number of boilers, and steam-using units, above what is really necessary.

These have a deep-rooted effect on the ability of the factory to enter competitive markets with its products, and swell the demand for items of capital equipment that may only be obtainable at present from foreign countries. All these effects have been encountered by us.

In a number of instances it has been found that the distinction between the need of maximum employment of labour and production efficiency methods is not

"Don't recognise me? I'm your visiting expert just back from an inspection of your boiler plant soot blowing system."

drawn clearly enough. For instance, mechanised handling of fuel and of its products (e.g. stock from a furnace) brings advantages that outweigh the mere economy of labour. Some of these are increased output from the producing units, quicker 'turn round' of rail waggons, and reduced cost. The factory should not be denied these advantages even though required to employ redundant labour elsewhere (e.g. on improving approach roads).

Other than in its specialised fields of use, fuel oil is burnt mainly in the locations remote from the coalfields. This is a logical measure, but in the majority of instances the principles of efficient utilisation of the fuel are not known, or not applied. This field of fuel utilisation needs to be covered by any fuel efficiency organisation that may be set up, and the fuller cooperation of the oil industry in providing an 'after sales' advisory service should be sought.

Amongst the foundries visited, only the large ones were operated with any regard to efficiency. In the smaller foundries cupolas were of poor design; charging of metal, limestone, and coke was not controlled or recorded; and there appeared to be a disregard of good practice. There can be no doubt that there was considerable waste of coke.

Lack of Publicity Material

Owing to difficulties of supply of spare parts castings, small cupolas have sprung up as part of the site maintenance amenities of many factories, whose main products are totally unrelated to the foundry industry. These cupolas are operated for a few hours at very infrequent intervals, are of poor design, and operated by people who have little 'know-how'. The loss and wastage of coke at these sites must be considerable, and it is probable that, at least in larger factory centres, benefits would accrue to the setting up of a single jobbing foundry and maintenance machineshop, under proper control, to serve the full needs of a whole group of factories. Such a unit could be given an economical work load.

Throughout the tour of industry we were struck by the lack of publicity material, and propaganda aimed at bringing home to the industrialist and factory worker India's great need for fuel economy. The present extent of organised fuel efficiency work in India is much too small to make any impression on the problem. One self-help organisation—the South Indian Steam Users' Association—was encountered during the tour, at Madras. Whilst the practical work of such organisations is necessarily limited, they should be encouraged as a means of spreading knowledge and providing a vehicle for publicity. Appendix I (A & B) is a coded summary of findings during visits made to fuel-consuming plants.

We summarise below the conclusions which may be drawn as a result of our observations: Taking the factories visited as typical of industry throughout India, 25% of the fuel at present burnt can be saved. This figure rises to 30% in areas where coal is cheapest.

To secure these savings, it is necessary to set up an organisation dedicated to the provision of a fuel efficiency service to industry. This service should be backed by a vigorous national campaign. The service must perforce initially be concerned with coal sanctioning (see Appendix II), but must be single-minded in its aim to secure fuel efficiency, and manifestly remain a service intended to help industry.

The supply of fuel efficiency equipment to industry must be prompted, and facilitated, preferably by indigenous manufacture of such items as feed-water economisers, mechanical stokers, heat exchangers, and industrial indicating and recording instruments.

Technical institutions should provide more courses for the training of instrument engineers, and it should be ensured that engineers entering industry are given a basic training in combustion engineering, and in the principles of correct steam utilisation. Engineers already in industry should be encouraged to attend refresher courses in these subjects. All courses should be of a practical and theoretical nature.

Bodies such as industrial trade research associations, government research establishments, and industrial self-help organisations, should be asked to help in the campaign, and in training.

No nation seeking to take its place amongst the industrial nations of the world can afford to be prodigal in the use of its fuel resources, no matter how plentiful the resources may appear to be. Fuel Efficiency contributes, in a great measure, to overall industrial efficiency, and should be a continuing effort. A sound Fuel Efficiency Service will be a practical contribution to the healthy growth and sustenance of India's industry.

Work of NIFES

The truth of the above principle has been recognised by industrialists in the United Kingdom. About 25 years ago, the UK was faced with industrial fuel starvation, as India now is, and an organisation to promote industrial fuel efficiency was called into being. Today, in the absence of fuel shortage, the organisation, in the form of the National Industrial Fuel Efficiency Service, is in greater demand by industry than ever before. Furthermore, in its industrial survey work, it is approaching a position of financial self-support on account of the fees industry is prepared to pay for its services.

The fuel supply position, and the scope for saving, make it essential that an organisation should be set up in India now and the predominance of the national interest renders it necessary that it should be supported during its initial years from public funds.

Rapid Savings

The Service should work initially to the end of securing the most rapid savings of fuel possible. This can be done by tackling obvious waste and malpractice in the most prolific fields. It should seek to stimulate, by practicable means, the fuel efficiency consciousness of industry, and promote industrial self-help.

The obvious effects of the Service will be to save fuel, and ease the strain on transport. The less obvious, and longer term, effects of the Service will be:

(a) To reduce the need for capital expenditure on additional production capacity by securing more production from existing plant.

(b) By improving productivity, to reduce costs, and facilitate competition in the foreign markets.

(c) To improve and standardise product quality. This again will facilitate exports.

(d) To stimulate improvement in the standard, and 'know-how' of engineers, and other workers in industry.

(e) As experience grows, to set bogey figures for industrial processes, and to provide industry with information regarding the right type and size of plant to install for specific purposes.

We are of the opinion, based on observation, that these things are of vital importance to India's future.

A sound fuel efficiency service would be able to give very valuable help to the government departments responsible for promoting the development of industry. It would be in day-to-day contact with industry, and could also give sound advice on such matters as priorities relating to import licensing.

Recruitment of Personnel

It is not considered possible to recruit 'ready-made' personnel into any proposed fuel efficiency service, because it is doubtful if people of suitable 'background', and experience can be found available in India. It will be desirable to recruit young men with sound training, and professional qualification in Chemical Engineering, Mechanical Engineering, Fuel Technology, or related engineering sciences, and to provide 'on-site' training.

The quality of the man is more important than the particular field of engineering science in which he has studied. He should be enthusiastic to undertake the work; prepared to undertake practical site work, and get dirty in doing so; ready, and able, to learn, accumulate experience, and become authoritative; and of high integrity, and capable of commanding the respect of industry.

Lower in the scale should be recruited technicians of similar personal characteristics, but potentially, or already, capable of giving practical instruction in the stoking of boilers and furnaces with coal, by hand or mechanical stoker, or with oil. They should also be capable of assisting professional grades in their survey work. In the United Kingdom the Engineer Petty Officer and E.R.A. grades of the Royal Navy have been the background of a number of suitable technical assistants, and stoker demonstrators.

Several technical assistants should be recruited with the object of training them as instrument maintenance personnel. It is certain that there would be danger in endeavouring to inaugurate a service on too grand a scale, or in a number of centres. Better to plant a small tree, and stimulate its healthy growth of branches, than to plant too large a tree whose branches may wither by reason of lack of root. The more important matter is that the personnel should be trained in the field, and amongst the conditions in which they will work—i.e. in India.

At the outset, the organisation should be trained in the basic principles that will enable it rapidly to provide 'First Aid' advice to industry. For this purpose, no more instruments than those suggested in Appendix III will be required. Such simple advice should secure the most easily and rapidly achievable saving of fuel (See Appendix IV).

As the training—and experience of the service—grows, its instrument resources can be built up to enter into the more advanced techniques of fuel efficiency work. Then also the staff can be screened to provide nuclei to set up branches in other centres, and reinforced by recruitment to expand the service to a size commensurate with the need and demand. Clerical and administrative staff will be required, but should be kept to a minimum, and should not, under any circumstances, outnumber the technical staff. A good publicity and campaign officer should be included. The Service should be backed by a vigorous publicity campaign, and the cooperation of such bodies as industrial research organisations, productivity councils, chambers of commerce, and professional bodies should be enlisted to spread the message and purpose of industrial fuel efficiency.

So closely related is fuel efficiency to general industrial efficiency, that it is considered that an organisation to promote it should be linked with a department responsible for industrial development rather than one with a rationing department.

APPENDIX II

The Price Structure of Coal

It has been remarked that fuel efficiency is, on an average, at its lowest in areas where coal is cheapest. This indicates a tendency on the part of managements to value coal by what they pay for it, rather than as the lifeblood of industry.

The expert ventures to say nothing more than that the price of fuel should reflect its value in the national economy, in so far as it should discourage industry from being prodigal in its use.

As regards grade to grade price increases, these are so small as to encourage a clamour for the better grades of coal where they are not always essential. Thus there is a tendency for good coal, in short supply, to be burnt to offset inefficiency.

Our conviction is that the spectrum of prices should be opened out, so as to induce industry, wherever possible, to seek cheaper coals in more plentiful supply.

The matter of the coal industry supplying coal of a size range that can be used by industry as delivered, has received mention. If and when this becomes possible, a further factor will arise to be taken into account in the price structure.

APPENDIX III

Instruments required for 'First Aid' Work

The need in this field of work will be for portable indicating instruments to enable the engineers to measure temperature, pressure, draught, and carry out gas analysis. A few recording instruments would however be helpful. The requirements that would be desirable are as listed below:

1.A Temperature

- 8 Mercury in steel indicating dial thermometers, range 0-1000°F, 5 ft. long.
- 4 Pyrometers direct deflection indicating type for use with Chrome-Alumel thermocouples, range 0-1000°C.
- 20 Chrome - Alumel thermocouples (complete of various lengths 1 foot to 6 feet).
- 2 Surface pyrometers, hand-type, range 0-500°F.
- 20 Thermometers, mercury in glass, with brass protection cases, various ranges of 0-240°F, 0-360°F, 0-500°F, and 0-760°F.
- 3 Thermographs, Bimetallic type recording, range 60-120°F.
- 2 Combined temperature and CO_2 indicators (Cambridge Scientific Co. type).
- 1 Potentiometer (with potential source)—Cambridge Type.

1.B Pressure

- 8 Pressure gauges, ranges 0-50 p.s.i.g., 0-100 p.s.i.g., 0-200 p.s.i.g., and 0-300 p.s.i.g.
- 2 Pressure recorders, ranges 0-150 p.s.i.g. and 0-300 p.s.i.g. (24-hour circular chart type).

1.C Draught

- 2 Draught indicators, multirange type (Airflow Developments).
  4 Vernier draught gauges (pocket type) range 0-2" w.g.
- 3 Draught recorders, ranges 0-1" w.g., 0-2" w.g. and 0-6" w.g. (24-hour circular chart type).

1.D Gas Analysis

- 4 Orsats, three-bulb type with spares and chemicals.
- 4 CO_2 indicators (e.g. Mono portable tester or Fyrite).
- 1 CO_2 recorder chemical absorption type (e.g. Mono).

Instrument Requirements for Survey Work

When the time comes for the service to undertake detailed survey work, it will be necessary to provide it with additional equipment for training and site work purposes.

The minimum requirements are listed below, and it is natural to expect that the services holding of instruments will increase, as its activities increase.

2.A Temperature

2 Six-point temperature recorders, each twin range 0-1000°F and 0-1200°C C/A Potentiometric type.

2 Optical pyrometers.

1 Suction pyrometer C/A range 0-1200°C.

2.B Pressure

2 Pressure recorders, range 0-200 p.s.i.g., 0-500 p.s.i.g.

2.C Gas Analysis

2 Two-point CO_2 recorders. Thermal conductivity type.
1 Single-point CO_2 recorder, Chemical absorption type.

2.D Flow Measurement

1 Ring balance meter. Max. diff 4" w.g. recording for air or gas flow.

3 Steam flow recording meters (e.g. Kent K.U. type) complete with three sets of spare range tubes for 0-25", 0-50", 0-100", 0-200" head diff. Selection of orifice plates and carrier rings from 2" to 8" dia. (Consult manufacturer for ranges or max. flows.)

3 Two-inch Shunt type steam flow indicators with adjustable range.

1 Three-inch as above.

1 Steam flow recorder for use with pitot tubes (Curnon manufacture 6 x 9 size) complete with set of test plugs 1½" to 3".

2 Water meters ¾" Semi-positive displacement type.

2 Water meters 1½" Semi-positive displacement type.

3 Water meters 2" Shunt type, adjustable range.

1 Water meter 3" Shunt type, adjustable range.

4 Oil meters ½" Semi-positive displacement type.

2 Oil meters 1" Semi-positive displacement type.

2.E Moisture Testing

1 Speedy moisture test kit.

All electrically-operated equipment will have to be supplied for the prevailing voltage and frequency of the single phase A.C. supply available in the areas to be covered by the service.

Squares, charts, and consumable items, such as compensating lead and rubber tubing, will have to be obtained.

APPENDIX IV

Instrumentation and Fuel Efficiency Work in India

At the outset it must be understood that the present notes were compiled at an early stage of our mission to assess the scope for fuel efficiency work in India. Our experience is limited to that accumulated in a relatively few factories we had visited and, even though we had endeavoured to avoid contentious points, the notes must be viewed in that light.

The functions of an instrumented service (similar to that provided by the UK National Industrial Fuel Efficiency Service) are:

(a) To measure process variables such as fluid flow, temperature, pressure, humidity, and draught.

(b) From the measurements to take out heat balances for individual sections of plant, e.g. boilers, driers, evaporators, furnaces, etc., or for complete process e.g. paper mills, chemical works, and breweries, where heat is transferred from one process to another in the line of manufacture.

(c) From the heat balance to consider wasted heat and seek means of recovering it for some useful purpose, either by improved operating procedures, or by re-use. Re-use includes use of heat in hot reject fluid to pre-heat cold feed by means of heat exchange.

(d) By providing accurate figures, to enable the economics of fuel-saving schemes to be established beyond reasonable doubt. Thus the justification of capital expenditure on fuel-saving plant can be fully and accurately explored.

(e) To provide basic data for the design and development of efficient processes. This includes accurate sizing of boiler and other plant as well as logical heat flow schemes.

Quite clearly measurement must be within the limits of industrial accuracy standards. This implies that instruments must be maintained in good condition, and periodically checked, and set for accuracy. It also means that the personnel using instruments must be thoroughly familiar with their use, limitations, interpretation, and with the particular process under investigation.

The degree of 'know-how' and training required by 'testing staff' may be judged from the fact that a university graduate or other professionally qualified engineer joining NIFES is under training for an initial period of six months, and even thereafter is exceptional if he can take full responsibility for a large survey within 18 months. During the whole of these periods the trainee is working alongside experienced engineers.

Enormous Scope for Economy in Use of Fuel

The choice of fuel in Gujarat, Maharashtra, and South India must include some consideration of the distance involved in the transport of coal, and of fuel oil.

If attention is confined to the use of coal, and if it is assumed that the effect of fuel efficiency measures in Gujarat and Maharashtra may be approximately the same as it has been in the United Kingdom, it is found that in any one year 43,000 wagons of coal have been transported across the country for no useful purpose at all, and that nearly Rs. 52 million have been uselessly expended.

Considering India as a whole, these figures become even larger amounting to 510,000 wagons and Rs. 612 million. The total monetary saving would be even greater, since an amount of fuel is used merely to drive the trains. Labour charges are also involved in the mines, on the railways, and at the destination. It is probable that the average savings in the textile industries would not be less than 22%, in chemicals 19%, in ceramics 24%, and in paper 17%, and that, therefore, half a million tonnes of coal can be saved in the textile mills, 2½ million tonnes in the iron and steel industries, and 150,000 tonnes in glass and chemicals. These are targets well worth aiming at.

It is worth pointing out that before the appearance of Fuel Efficiency Mobile Testing Units (now superceded by NIFES) in the UK an intense fuel efficiency drive had taken place over a period of some six years. Since the Fuel and Power Ministry's 'Fuel Efficiency Bulletins' had been published, much Government Publicity and Propaganda had been devoted to fuel, and nearly all coal-consuming factories had received service and advice from temporary and/or part-time engineers, who possessed relatively few basic instruments to supplement their experience. Thus industry had been educated to the necessity for such basic fuel efficiency measures as thermal insulation (lagging) of steam pipes and boilers, recovery of hot condensate for boilerfeed, correct steam trapping and air venting, correct methods of stocking and maintaining boilers, gas producers and furnaces, before the more elaborate Mobile Testing Units took the road. The latter were really a logical development from the more rudimentary service, and the operating personnel of the MTU developed alongside the growing instrument resources. Industry, moreover, had 'tasted' the benefits that fuel efficiency practices could bring, and were the more ready to accept an advanced form of instrumented survey.

The foregoing has 'set the stage' for considerations regarding the needs of India, and the best means of meeting them at present. Our limited experience leads us to suspect that there is a great deal of fuel to be saved by the application of the basic principles of fuel efficiency in the Calcutta area. Evidence has been found that industrial concerns do not realise the unnecessarily high expenditure that lack of recognition of basic principles is causing them. This expenditure is not purely in respect of fuel bills, but in one or two cases may extend to the purchase of unnecessary additional plant.

It is conceded that in some of the factories visited, plant was reasonably well-maintained and fuel wastage was not quite as obvious. It was, however, apparent to the experienced eye. In these more advanced factories a well-instrumented and experienced survey team could do very valuable work. The question is whether this, more time-consuming, and costly, service should be afforded when a field for more rapid and equally great savings exists amongst the less progressive consumers where faults are more obvious.

Our early impressions lead us to the opinion that the time is a little premature for a highly instrumented technical service. A pioneer service is desirable at present in Calcutta and the West Bengal area, equipped with reliable flue-gas analysers (CO_2) and thermometers, chemical thermometers, stop-watches and scales (to determine condensate discharge), a few water meters ¾" up to 2", scales for weighing coal, and possibly one CO_2 recorder or plain dial continuous indicator. (Initially water meters and CO_2 recorder should be of a make having maintenance facilities in Calcutta).

This pioneer service should clear away the undergrowth of obvious inefficiency, and gradually develop both in instrument resources and in training and experience to enable it to tackle more advanced work.

The initial service should ideally consist of sufficient engineers to enable every consumer of fuel of 20 tons per week and above to be visited once per annum. These engineers should be trained men of professional status with an interest in the work, and should work predominantly where they are able to convince industry and secure its cooperation.

Each professional engineer should have a technical assistant capable of demonstrating correct firing of boilers and furnaces with coal, either by hand or by mechanical stokers. Possibly Naval-Stokers leaving the service could receive training on the lines provided by the British Navy at Portsmouth to meet this need. They should not only be willing to take over and demonstrate stoking of boilers, but should be able to give very rudimentary advice regarding the more obvious deficiencies of steam distribution and utilisation.

The service should have considerable mobility for its equipment and personnel to enable the most rapid coverage of industry effected.

Unquestionably a considerable Government propaganda drive should be inaugurated and maintained in order to inculcate consciousness of the need for, and benefits of, fuel efficiency.

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Elements of Combustion Control in Furnaces

IN BURNING fuel, whether wood or coal, many of us are by nature extravagant and wasteful—or, shall we say, lavish and generous. From man's earliest days he has probably taken delight in 'making a fire,' and in the blaze, the warmth, and the 'company' of a fire, especially of a camp-fire. Indeed, we often "keep the fire going," whether we need it or not. The camp-fire at night had no doubt its uses in warding off animals, and it also created a sociable and companionable atmosphere. If fuel were plentiful, why not have a *good* fire? If most of the heat were going up to the sky, why worry? There was "plenty to go at," and presumably wood fuel was cheap.

The magic of fire, of burning, of flame, is thus in our blood. It was natural for the Greeks to relate how Prometheus stole fire from heaven, and gave it to man. Fire was divine: it was one of the 'four elements.' Ancient India also took fire as an 'element'. Only when the heat and the blaze got out of control was fire an enemy: otherwise, it was a friend. Fire also fascinated the early chemists—Priestley, Lavoisier, and Davy. In fact, it was largely through *their* interest in combustion that the nature and the composition of air were discovered, and that an insight was gained into what really happened when fuel was burning. In other words, they began to see that the fuel was combining with some of the air, and forming new products, in addition to providing heat and light. We shall briefly examine this process of combustion (in simple terms), as a first step towards understanding how to control the consumption of the fuel, and how to avoid waste.

Combustion in Air

The early investigators found was essentially a mixture of two oxygen and nitrogen—present portions of about one volume four volumes of nitrogen, and that it was only the oxygen (1/5th of the air) which took part in combustion, i.e., in burning. As the essential constituent of all commercial fuels is *carbon*, we shall consider first the burning of carbon in air. The process may be indicated chemically by the equation:

$$\frac{C + O_2 + 4N_2}{\text{air}} = CO_2 + 4N_2$$

(heat emitted=14,500 B.t.u./lb.C.) The required Atomic weights are C=12, O=16, N=14.)
From the above equation (which is rounded off for simplicity) the chemist deduces the following:

(a) 12 lb. of carbon require 360 c.ft. (one lb. mole or 32 lb.) of oxygen to burn it. Hence, one lb. of carbon needs 30 c.ft. of oxygen (at s.t.p.), which implies about (30 x 5) or 150 c.ft of air. All gas volumes will be expressed at s.t.p., i.e., 0° C and 760 mm. mercury pressure, which is the same as 32°F and 29.92" mercury. At s.t.p., the lb. mole occupies 358.5 c.ft. Here, we shall take this volume as 360 c.ft., which would be true if the temperature were 34°F, and not 32°F, a nearly negligible difference.

(b) Since one lb. air occupies 12.4 c.ft. at s.t.p., the weight or mass of air needed to burn one lb. of carbon is 150/12.4=12 lb. approximately. (The true figure, when using precise values for air, is 11.6 lb.) But even at this stage we may note that the air is, if anything, more "massive" than the fuel, since we burn (or use) 12 lb. of air for every one lb. of carbon.

(c) The flue gases, or products of combustion, will consist of 30 c.ft. of carbon dioxide (CO_2), and 120 c.ft. of nitrogen (N_2)—and no oxygen. Hence the volumetric composition of the flue gases is ... 20% CO_2, and 80% nitrogen.

...verting to (b) above, it *should* ... beginner to find that carbon needs a minimum (M) *of 12 times its own weight of air to burn it.* (One lb. of high quality coal requires about the same amount, i.e., 12 lb. air to burn it). If we were to supply 2M, (i.e., twice the minimum), we should of course obtain complete combustion, but the flue gases would not be simply CO_2 and N_2: they would also contain some oxygen (O_2) from the extra quota (M) of air, unconsumed chemically in the burning process. Looked at in separate volumes, the flue gases from one lb. of carbon, when an air supply of 2M is used, would consist of:

Combustion Products		Air (Excess)
30 c.ft. CO_2		30 c.ft. O_2
	plus	
120 c.ft. N_2		120 c.ft. N_2

This gives a total of 300 c.ft. and the overall composition by volume would thus be: 10% CO_2, 10% O_2 and 80% N_2.

(e) Similarly, if we supply 3M, (i.e., three times of minimum air), the volume of flue gases become 450 c.ft., and the volumetric percentage composition of the flue gases becomes: CO_2 6.67%, O_2 13.33% and N_2 80.00%. For an air supply of 1½M, the values become: CO_2 13.33; O_2 6.67; N_2 80.00.

It will be seen that the nitrogen percentage in the flue gases is constant at 80—and in actual practice, with coal and most solid fuels, this is substantially true—the range being from 81 to 79.5 or so. The amount of CO_2, however, varies considerably: it is largest (at 20 per cent) when M only is supplied, and *falls* as the surplus air *increases*. In fact, the CO_2 is given by the expression 20/n, where n represents air supply in quotas of M. Thus if 2½M be supplied, n is 2½, and CO_2 becomes 20/2½=8%. The oxygen, on the other hand, rises as the surplus air is increased, being zero at M. With 2M, the O_2 in the flue gases becomes 10%; with 3M, 13.33% and so on. The O_2 per cent is thus given by the expression $\frac{20(n-1)}{n}$. The changes are shown in Fig. 1 on page 532. From an examination of this graph, basic ideas can be gathered of how the composition of the flue gases changes as the air supply is increased beyond the theoretical minimum, M. The whole concept is quite elementary, but it is often missed by the student at college, perhaps because the graphs are not worked out or drawn by him. The matter, nevertheless, is of fundamental importance in the study of combustion control. Actual graphs using coal and oil as fuel are shown in Figs. 2, 3, and 4 later—using the true composition of the air, i.e., O_2 = 20.93% by Vol.

The above (combustion) equation shows also that one lb. of carbon in burning gives out heat to the extent of 14,500 B.t.u. In other words, one lb. of carbon in burning gives enough heat to raise the temperature of 14,500 lb. (6.5 tons) of water by 1°F, or 1 ton of water by 6.5°F.

This amount of heat is given out whether we supply M, or 2 M, or 3 M, so long as the C burns entirely and becomes CO_2. But the temperature of the products will not be the same in each case. In fact, with 2M, the temperature rise of the products of combustion will be about one half—and with 4M one quarter—of that attained when using M. This can be shown by rough calculation, assuming that the average sp. heat of the flue gases is 0.24 and that all the heat developed is used to heat up the gases. The weight of flue gases when using M is the weight of the air supply (12 lb.) plus one lb—as one lb. of carbon goes to CO_2. The heat given out is 14,500 B.t.u. Hence the theoretical temperature rise is roughly

$$\frac{14{,}500}{13 \times 0.24} = 4{,}650^\circ F\ (2{,}600^\circ C)$$

With 2M, the temperature rise would be:

$$\frac{14{,}500}{(12+13) \times 0.24} = 2{,}400^\circ F\ (1{,}340^\circ C)$$

and with 3M, it becomes:

$$\frac{14{,}500}{(12+12+13) \times 0.24} = 1{,}630^\circ F\ (900^\circ C)$$

These are only rough values for temperature rise: they are not attainable in practice, because: (a) the sp. ht. of the gases increases with rise of temperature, (b) the gases dissociate at high temperatures and (c) heat is 'lost' by radiation to the surroundings. But the calculations are useful in showing the adverse influence of using an undue excess of air.

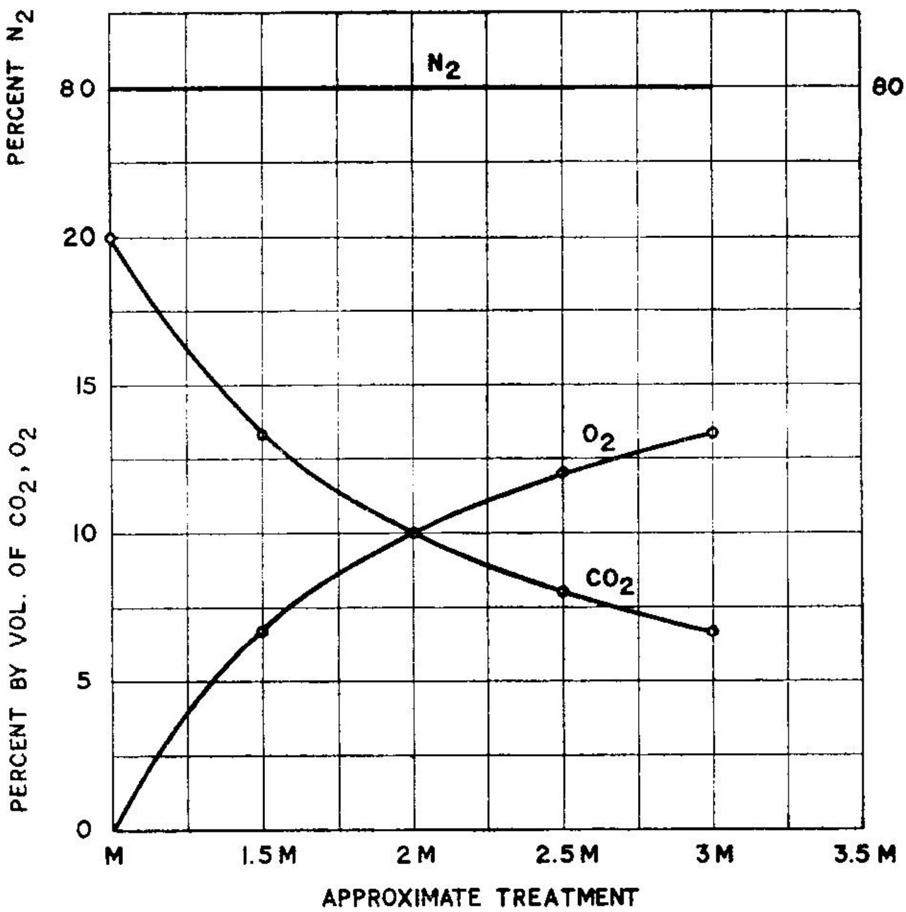
Unskilled Firing

It always pays to employ a trained man, says a pamphlet on 'Fuel Conservation and Productivity' issued by the British Productivity Centre.

An untrained man, the pamphlet adds, can waste up to 30% of the total fuel consumed. It has even been estimated that in certain circumstances an unskilled fireman can, in a single day's working, cause a waste of more coal than a miner can produce in that time.

Note on Heat Transfer

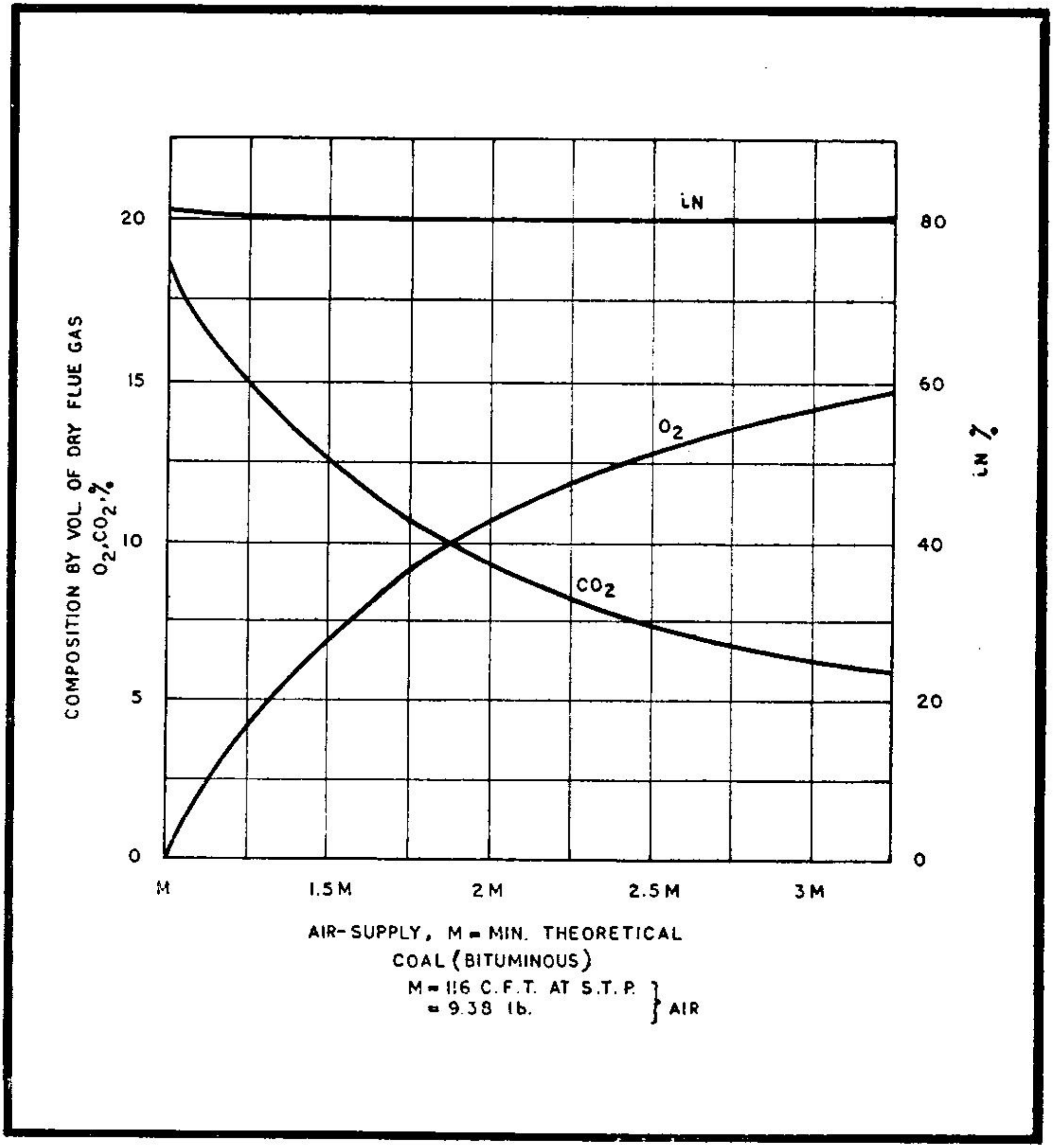
It must be borne in mind that an efficient boiler is not a calorimeter. A boiler has to absorb the heat generated by the burning fuel *at a certain time rate* (i.e., time is of importance), whereas with a calorimeter the time factor is negligible. Now the *rate* of heat transfer depends upon the temperature-head, i.e., temperature difference, between the surfaces of the bodies exchanging heat. The greater this temperature difference, the more rapid is the heat transfer. The relation is not a simple or direct one: thus, for radiation, the heat transfer is proportional to $(T^4_1 - T^4_2)$ where T_1 & T_2 are in degrees



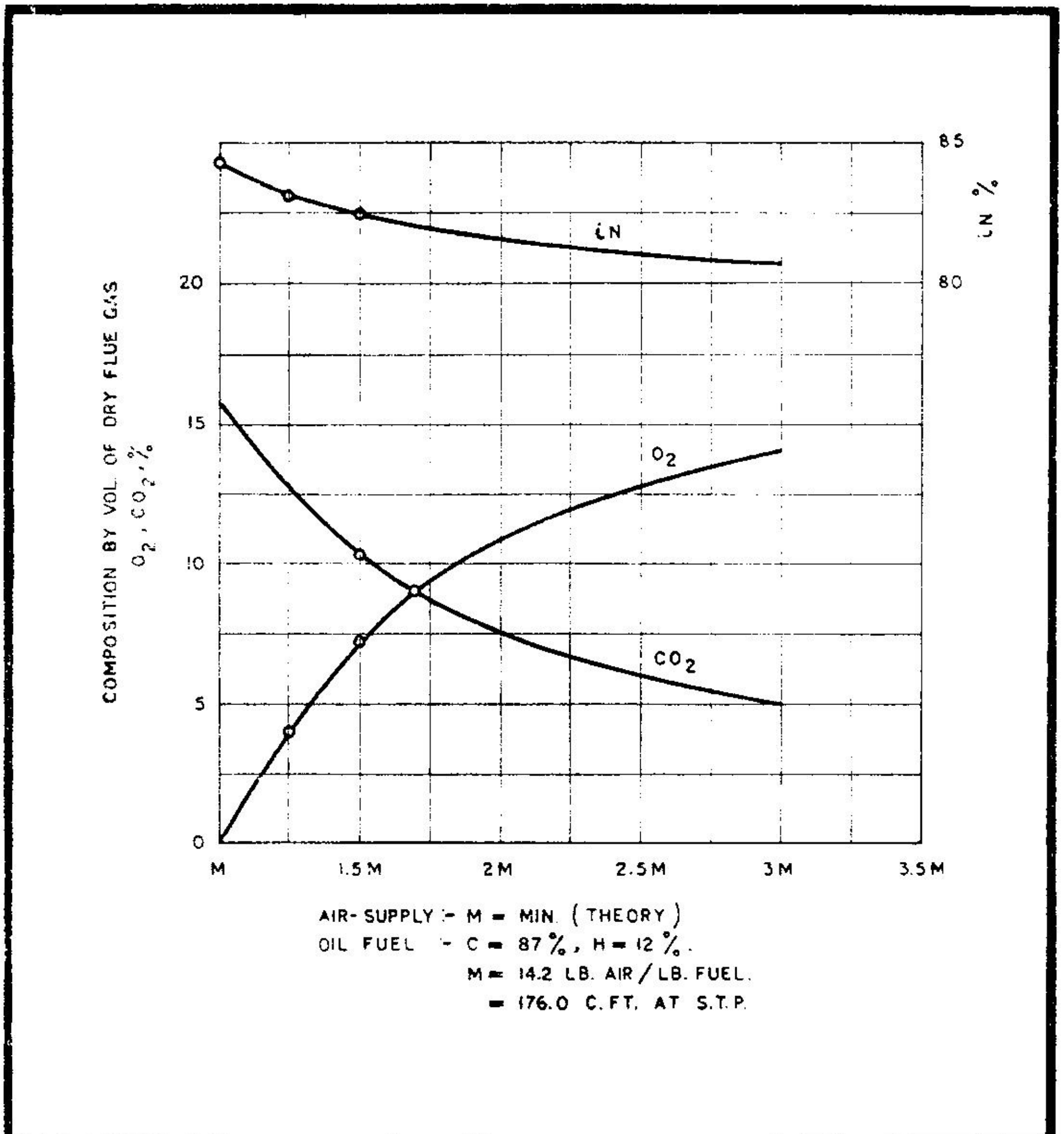
FLUE GASES FROM COMBUSTION OF CARBON IN AIR ASSUMING AIR TO BE O_2,20% & N_2,80% BY VOL.

absolute; while for convection, heat transfer is roughly proportional to the temperature-head ($t_1 - t_2$).

But in all cases, the greater the temperature-head, the better the heat transmission, and this is especially so with



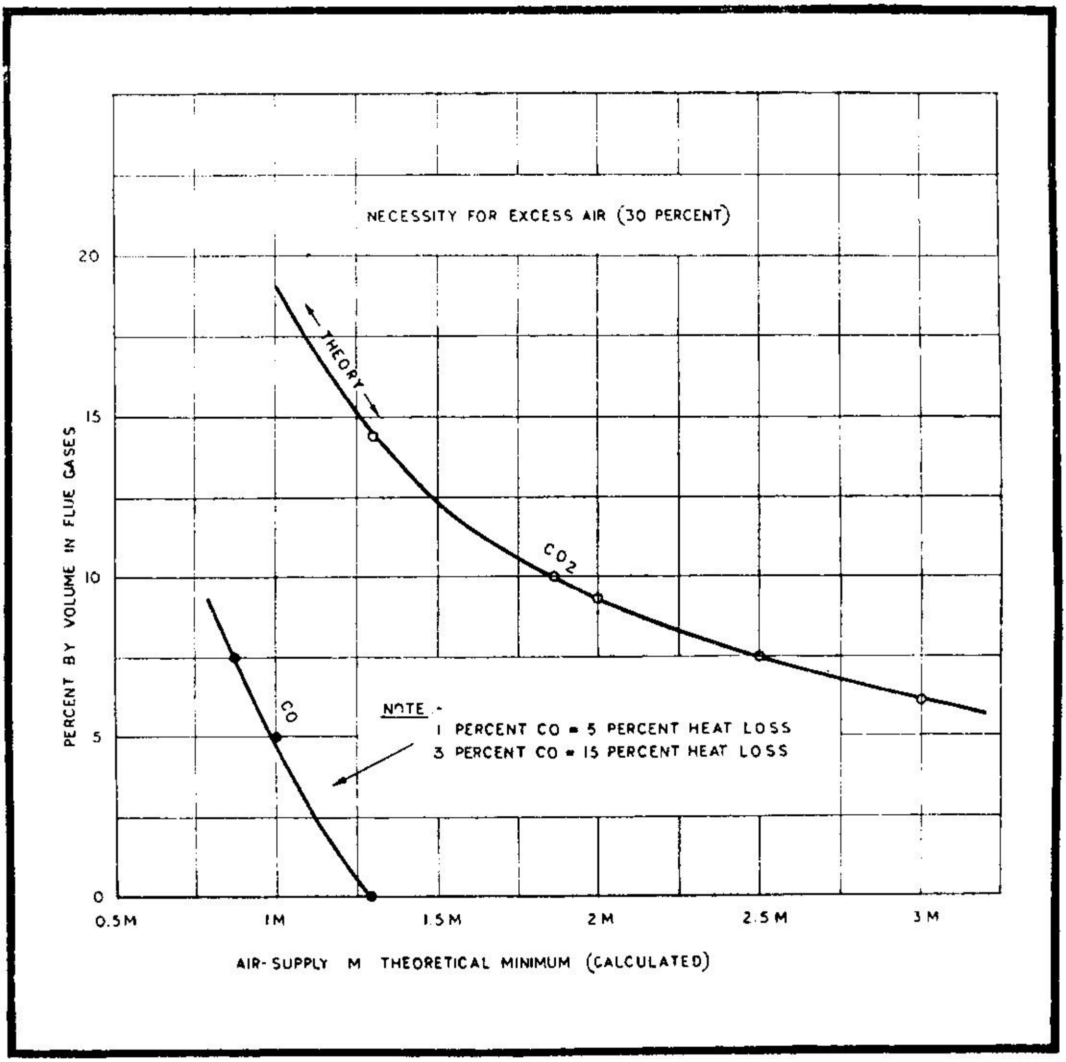
radiation transfer which varies as the fourth power of the absolute temperature. Hence for good heat transfer it is necessary to avoid undue excess of air, and to maintain the highest temperature practicable in the furnace. More heat is then transferred by radiation than by convection; though useful as a supplement, convection is not so efficient as radiation. As a corollary to the above, it is often found that when the



air supply is increased, and the furnace cooled (somewhat), temperature of the flue gases, after they have finished their useful heating travel, is not lowered appreciably. Enough heat has not been transferred by radiation in the furnace.

Need for Excess Air

Some excess air, however, is necessary to ensure complete combustion to CO_2, and thus to obtain the full 14,500 B.t.u. per lb. of carbon. Otherwise, part of the



carbon is not completely burnt, and this results in producing either carbon in the cinders, or CO (carbon monoxide) in the flue gases—or both. If five per cent of the carbon of the fuel appears in the cinders, this means that there is a clear loss of five per cent of the heat simply on the score of unburnt fuel. If CO appears in the flue gases, there is a further loss, as the heat given out when one lb. of carbon burns to CO is only 4,300 B.t.u., instead of the 14,500 B.t.u. emitted when one lb. of C burns to CO_2. In other words, we lose 10,200 B.t.u. for every lb of C burnt to CO instead of to CO_2. As an example, if in the flue gas there is (by volume) one per cent of CO and 14% of CO_2, then the ratio

$$\frac{\text{C burnt to CO}}{\text{C burnt to } CO_2} = \frac{1}{14}$$

Hence, 1/15 lb. of the C is being burnt to CO, and the loss for every lb of fuel is 1/15x10,200 B.t.u.=680 B.t.u. With two per cent CO in the flue gases, the loss is roughly doubled. Moreover, in burning coal or oil, when CO is found in the flue gases, there are also small amounts of other unburnt gases–as well as smoke. Often, the full loss due to unburnt gas (including CO) is two to three times the simple CO loss itself. Incomplete combustion can, therefore, mean large heat losses, most of which, however, are avoidably by attention to the air and fuel supply, and the combustion conditions (notably turbulence) in the furnace.

Sensible Heat Loss

Assuming, however, that combustion is complete, a large amount of heat, of necessity, escapes to the chimney; in fact such heat is partly useful in creating the necessary draft for the air supply by the chimney (convection) pull. The amount of heat so lost as sensible heat in the flue gases is not difficult to assess. Let us assume complete combustion with 2M, and let the temperature of the flue gases be 472°F and that of the air be 72°F—a difference of 400°F. Then the heat carried away as sensible heat by the escaping gases is given by [(12+13) x 0.24 x 400] B.t.u., i.e., 2,400 B.t.u. or $\frac{(2400 \times 100)}{14,500}$ = 16.5%, if the fuel to carbon or has the same heat value (14,500) as carbon. Under the same conditions, but using M, the loss would be almost halved, since 13 x 0.24 x 400=1,250 B.t.u., or 8.6% of 14,500. With 3M, it becomes 3,560 B.t.u. or 24.6% of 14,500. The sensible heat loss is obviously not a small one. Thus with 3M (which is not uncommon in practice we loose one quarter of the heat in the fuel—under the above conditions.

The importance of air control should now be clear, and also the importance of the graphs of the type of Figs. 1 to 4. From these graphs we may find M at once, by reference to the proportion either of CO_2 or of O_2 found in the flue gases. Sampling and analysis of the gases will of course be necessary, and careful work is called for. The gases should be sampled immediately after they have finished their useful heating travel, at a place in the flue where they have maximum velocity and turbulence. (Perforated sampling pipes placed across the flue are not as desirable as many people think). There must, of course, be no inward leakage of air, i.e., infiltration of outside air into the flues. This must be ensured thoroughly at the start of the test by careful inspection and use of a taper flame, or the like.

Once, however, when we know the composition and temperature of flue gases, we can take M from the graph, and then calculate the sensible heat loss as above. As a check on the precision of the gas analyses, it should be grasped that for any one fuel (of given composition there must be "correspondence" between the value found for CO_2, and that found for O_2. In other words, for any one value of CO_2, say 9.0%, there is one (and only one) true value for oxygen, if combustion is complete. This can be seen from Fig. 2 on page 533 (for coal), which has been drawn from calculations, based on the composition of the coal, and taking into account the true composition of air, i.e., 20.93% oxygen by volume.

Flue-gas Analysis

Flue-gas analysis also shows whether any carbon monoxide is present—and how much—and thus enables us to find the CO loss, and indeed any similar loss due to traces of other unburnt gas often present, e.g., H_2 and CH_4. Any solid carbon (unburnt) in the cinders is estimated by analysis of the cinders, and loss calculated per lb of fuel supplied, as already stated.

For many reasons, therefore, we require accurate sampling and analyses, not only of the fuel and the cinders, but also (and mainly) of the flue gases. So important is the composition of the flue gases that at large thermal plant the analysis of the flue gases and their temperature are recorded automatically and continuously by instruments designed for the purpose.

For simplicity, we have considered mainly the burning of carbon, and we have taken the volumetric composition of air as 20% oxygen, and 80% nitrogen. But in practice we have to use (a) the true composition of the fuel, and (b) the true composition of air, which, fortunately, is remarkably steady at 20.93% oxygen by volume, or 23.12 per cent oxygen by weight. Moreover, if we are to treat the lb mole as 360 c.ft. (which is convenient, instead of 358.5), we must adjust s.t.p. to q.t.p. (qualified temperature and pressure), which means that we convert all volumes of gases to 34°F (1°C), instead of 32°F (0°C). This simplifies the arithmetic.

Regarding the composition of coal, there is in average coal (as burnt) about 70% of carbon, 4.5% of hydrogen, and 3% to 6% of (organic) oxygen. The remaining 20% or so consists of one to 10 of moisture, and 15 to 18 of mineral matter in Indian coals. There is also one per cent of nitrogen, and small amounts of sulphur and phosphorus—all of which may usually be neglected. It is to be observed, however, that when burning coal we are not burning pure carbon, and that the full analysis of the fuel (coals vary) is necessary for accurate work. We must further know the heating or calorific value of the coal in order to assess the percentage heat losses—of the type discussed above.

Fig. 2 shows a typical graph for the combustion of coal in air.

It is the Hydrogen (H) of the coal (or of any other fuel), however, which deserves special consideration. Hydrogen modifies the combustion calculations, because (1) H is itself a fuel with a higher calorific value of about 62,000 B.t.u. per lb; (2) H requires oxygen to burn it, to the extent of 8 lb of oxygen (34.6 lb air) per lb of H. Moreover, the whole of the organic hydrogen, H, in a coal is not "available" for combustion, if there is also some oxygen in the coal already. The "available" hydrogen, H, is given by $\frac{\text{H-oxygen)}}{8}$ where H, is the total hydrogen. Thus, if there is four per cent oxygen present in the coal, and the H is 4.5%, the amount of available hydrogen, H is (4.5–4/8), i.e. 4.0%. In the combustion of hydrogen, steam (H_2O) is formed, but such steam is not registered in the flue gas analysis, as the steam condenses (when cool) to water and occupies a negligible volume. The combustion equation for hydrogen in air is (approximately) $H_2+\frac{1}{2}O_2+2N_2 = H_2O$ (water)$+2N_2$, the heat emitted (gross value) being 62,000 B.t.u. per lb of hydrogen.

The flue gases or products of combustion of hydrogen in air, when cool, consist, therefore *only of nitrogen*, but there is a drop in volume, in the ratio of 2½ volumes of air supply to 2 volumes of flue gas, since the hydrogen when in a solid or in a liquid fuel occupies a negligible volume. In other words, 2½ volumes of air becomes about 2 volumes of N_2—or, more simply, ½ volume of oxygen which disappears and becomes water.

The net result of the presence of hydrogen (along with C) in a fuel is, therefore, to increase somewhat the percentage of N_2 in the flue gases, and to reduce the proportion or percentage of CO_2 present. Calculations show that, for all coals, the volume per cent of CO_2 with M is $18.6+O.2$, N_2 being $81.4 \pm O.2$ per cent. Indeed, for most coals we may take the value for CO_2 as 18.6 per cent by volume, when the air supply is M; and for 2M, the CO_2 becomes (18.6/2=) 9.3 per cent; for 3M, (18.6/3=) 6.2 per cent. Curves showing the amounts of CO_2 O_2 and N_2 in flue gases for coal are given in Figs 2 and 4. They should be studied carefully. For fuel oil, similar curves are drawn in Fig. 3 (page 534). The H in fuel oil is about 12 per cent, and the oxygen negligible—so that all the hydrogen is available for combustion. Calculations show that, with an air supply of M, the percentage of CO_2 in the flue gas for fuel oil is about 15.7 (and N_2 84.3). With 2M, CO_2, becomes about (15.7/2=) 7.8; with 3M, about (15.7/3=) 5.2. More accurately these values for CO_2 are: for 2M, 7.65; and for 3 M, 5.04 for the oil considered (12% H). The corresponding oxygen values may be read from the graph. The N_2 falls from 84.3 per cent to about 81 per cent for oil, when the air supply is increased from M to 3M, and consequently the sum of the (CO_2+O_2) is not quite constant—for oil. Even for coal where the H is about 4 per cent only, it will be recalled that differences arise, though they are smaller.

. . . Coal burns in two major stages, unless it is powdered, when the two stages tend to fuse into each other. Most coal is burnt, however, in lump form and the two stages of combustion then stand out. Stoking can be intelligently done, only if the stoker is aware of the double nature of this combustion . . . Moreover, in stoking an excessive amount of coal must not be thrown on to the fire, or the fire will be chilled unduly . . .

CO_2 and O_2 In Flue Gases

We can choose either the CO_2 value or the O_2 value in the flue gases to measure the air supply. Formerly, the CO_2 value alone was commonly used, since the CO_2 determination by analysis is relatively simple, quick, and accurate. The CO_2 value, in fact, is still used today (in most small plants), but the oxygen value is equally good as a measure of the excess air, and is perhaps preferable as it is a direct measure of such excess, the only source of oxygen being the air supply. In modern practice, and especially in a large thermal plant, the oxygen figure is used more and more; new instruments have become available for its rapid determination, to within 0.1 per cent. One may, however, use both CO_2 and O_2 values for greater reliability. Formerly, also, it was usual to operate furnaces with 50 per cent excess air (i.e., 1.5 M), to ensure complete combustion of the fuel. Now-a-days—with better control of draught (fans), better combustion conditions (e.g., greater turbulence) in the furnace, and the adoption of powdered coal as fuel (or atomised fuel oil) and the use of preheated air—it has been found possible in large plants to cut down the excess air more and more, and to operate with an oxygen content as low as one per cent (or even less) in the flue gases. This means only 4 per cent to 5 per cent air excess—say 1.05M—a remarkable achievement. Modern boilers working under these conditions may show thermal efficiencies of 85 per cent to 90 per cent . In these statements, it is to be noted that much depends upon whether we express the efficiency on the gross calorific value (G) of the fuel or on the net value (N), the relationship being (in B.t.u. per lb) N=G-95 H, where H is the percentage of (total) hydrogen in the fuel. This formula is derived by deducting from the gross value that latent heat of the water vapour (at ordinary temperatures) —i.e., 1,055 B.t.u./lb vapour. If one lb of fuel contains H/100 lb of hydrogen, it will form on combustion 9H/100 lb H_2O; and, as $9H/100 \times 1.055 = 94.95\,H$, we may take the difference between G and N as 95 H. Discrepencies also arise, depending upon whether we credit or debit (or omit) the heat energy required to operate the auxiliary plant, e.g., fans and pulverisers. In any report on the thermal efficiency of a plant the assumptions made should be stated.

Loss due to H_2O in Flue Gases

What happens to the steam formed from the combustion of the hydrogen of the fuel —and even from any moisture in the fuel? Such steam clearly passes off at the flue gas temperature of, say, 472°F, and carries away its latent and its sensible heat. The pressure is atmospheric, the sp.ht. of steam is 0.45, and its latent

"I appeal to you in the name of fuel efficiency not to get hot under the collar so often."

heat 970 B.t.u. per lb, so that the amount of the loss for one lb of steam is [(212–72)+970+0.45 (472–212)] which evaluates to some 1,230 B.t.u. per lb of steam (H_2O) present in the flue gases.

If there is 4.5 percent of total hydrogen in the coal, it will form $\frac{(9\times4.5)}{100}=0.405$ lb steam. If there is present also 5% of moisture in the coal, it will yield per lb of coal 0.05 lb of steam; and in the foreign or mineral matter there will also be a small quantity of H_2O (of constitution)—generally equal to about one-tenth of the ash. Thus, with an ash percentage of 15, we shall have 1.5 of water in the mineral matter—i.e., 0.015 lb per lb of coal. The total steam in the flue gas is thus per lb of coal: (0.405+0.50+0.015), or 0.470 lb. Hence, the heat loss on this score becomes 0.470 × 1,230=580 B.t.u., which is nearly 5% of the coal's calorific value, (say) 12,000 B.t.u./lb. This loss, however, is practically unavoidable, and consequently many engineers prefer to employ the *net* calorific value of the fuel rather than the gross. With the fuel oil, where the hydrogen constitutes from 10% to 13% of the fuel, the differences between the gross and net calorific values is not small; it lies between 950 and 1250 B.t.u., whereas with coal the difference is only about 400 to 500 B.t.u. Incidentally, there are small heat losses arriving from heating the water vapour in the air (about one per cent by weight), but these can generally be neglected. They amount in all to about 1/3 of 1 per cent of the heat of the fuel.

General

(a) The above treatment of air supply and combustion losses is by no means the only one employed in assessing the performance of a furnace, and other forms of calculation may well be used as a check. But the graphical treatment has the great merit of showing what happens to the composition of the flue gases as the air/fuel ratio is increased or decreased; and as the full realisation of this concept is important, the graphical method has much to recommend it.

(b) In drawing Figs. 1, 2, and 3, it was assumed that all the carbon was burnt completely to CO_2. In practice, unless there are special arrangements for fuel and draught control (e.g., fans, preheated air, etc.) as in modern thermal plant, all the C does not burn to CO_2 on the contrary, traces of CO and of other unburnt gases are found in the flue gases, especially when the air supply falls below 1.3M, i.e., 30 per cent excess.

Fig. 4 (page 535) shows this, and also shows that more and more CO is produced as the air-supply falls. Carbon-monoxide is seldom alone as the one unburnt gas: there is usually also some H_2 and some CH_4 as well as smoke (mainly C). Experiments have shown that often the ratio by volume of the gases is $CO:H_2:CH_4=3:2:1$ (approx), One per cent of CO causes (of itself) a loss of about 5 per cent of the heat of the fuel as shown earlier. Actually, it is often accompanied by a further loss of 5% or 6%, due to the H_2 and CH_4 accompanying the CO.

Smoke Reduction

Coal burns in two major stages, unless it is powdered, when the two stages tend to fuse into each other. Most coal is burnt, however in lump form (small pieces), and the two stages of combustion then stand out. Stoking can be intelligently done, only if the stoker is aware of the double nature of this combustion. To clarify the matter, let us picture what happens when a shovelful of coal is thrown on to a hot fire. First, the moisture and the volatile hydro-carbons (with tarry matter) are liberated. In other words, the "volatile matter" distils off in the form of gases and tarry vapours. In order to burn these gases and vapours, we require for every one lb of coal (which gives about 3 c. ft. of such gases and vapours) nearly 100 c. ft. of air roughly half the total air supply—since a moderate excess is necessary. This means that, *immediately after firing*, there must be an *ample supply of (secondary) air over the fire*, i.e., enough to burn the volatiles, and preferably, this air should be hot. First of course, we must have a fire-bed, at a high temperature, but secondly, it is imperative that the stoker should *not* close down the fire-doors immediately after stoking, but should *keep them open* or half-open for a short while (2 or 3 minutes) depending upon the amount of coal thrown on to the fire. The volatiles must get enough air to burn them. Moreover, in stoking, an excessive amount of coal must not be thrown on to the fire or the fire will be chilled unduly, and the temperature (above the fire) will fall below the ignition point of the volatiles and tarry vapours. No matter how much secondary air is then supplied, combustion of the volatiles will not occur. On the contrary, *large volumes of smoke* with much unburnt gas and vapour will be produced, and *correspondingly large heat losses arise*. If the volatiles are not burnt at all, the magnitude of the heat loss can indeed amount to 30% or 40% of the calorific value of the fuel: Stokers require instruction in this matter, and careful explanation must be given of the elements of the burning of coal: the stokers must be given clear reasons for frequent skilful stoking, and for stoking relatively small quantities of coal at any one time, explanations and demonstrations should be given especially of how to avoid smoke and incomplete combustion. The necessity for allowing extra, but not excessive, secondary air for the combustion of the tarry vapours and gases emitted as soon as coal is put on the fire, is all-important, and is generally overlooked.

If the furnace door is left wide open for a long period after stoking, excessive (secondary) air passes over the fire and the efficiency of the heating process falls. There is first the wastage of heat in warming up the undue excess air (which is of no value); and, secondly, the furnace temperature is lowered which, in turn, reduces the rate of heat transmission to the boiler.

Following the period of two or three minutes allowed for the liberation and combustion of volatiles from the coal, the furnace doors should be half-closed in order to reduce, but not to cut off, entirely, the secondary air supply. The combustion which now occurs is mainly the combustion of solid carbon (coke) on the grate. Carbon monoxide, however, is (even then) produced at the top of the fuel bed, and such CO must be effectively burnt to CO_2 by allowing a moderate supply of secondary air over the fire. One c. ft. of carbon monoxide requires only $2\frac{1}{2}$ c. ft of air to burnt it—whereas one c. ft. of methane gas requires 10 c. ft. of air, and the higher hydrocarbons (tarry vapours) require far more.

Mechanical Stoking

With mechanical stoking it is comparatively easy to adjust the air supply to an optimum quantity since the rate of feed of the fuel is slow and regular; but at small plant, mechanical stokers are not usual, and in many cases are not justified economically. The stoker himself has to be instructed in the elements of combustion and in the simple techniques he should follow. Proper stoking means far less labour for him, and less fuel for him to handle. This applies also (and especially) to the stoking of steam locomotives where the unnecessary waste of both human and fuel energy can often be observed, even at the railway stations.

K HIGGINSON

Fuel Efficiency Adviser
National Productivity Council

How to Avoid Wastage of Fuel

DOES such a thing as fuel efficiency in industry exist in India? Has the Indian industrialist any idea of what fuel efficiency is, what it means, and if he has, does he bother himself about it at all? Maybe there are some millowners or managers to whom the wastage of fuel or heat, and the attendant higher costs of production of their chosen article, does not matter. If so, my advice to them is either to go home or to stop reading; we have nothing in common, and are mutually wasting each other's time.

The Report on Fuel Efficiency submitted to the Government of India, in 1961, by my predecessors, stated that a saving of at least 25% could be made in the amount of fuels of various types used in industry: this was their conclusion, as a result of visits to 60 factories in various parts of India. It is not unfair to suppose that the mills chosen were not the worst in the country, but were, in fact, some of the better ones: it is only human nature to try to keep your skeletons hidden in the cupboard, and not to parade to the visitors the worst you can show.

The tour that we have undertaken has included visits to nearly the same number of premises, spending a little longer time in some in order to teach fuel efficiency, but the opinion still holds good that the potential for fuel saving is at least 25% and may well be greater. Again, the tendency must be to suggest visits to those mills and factories which have well known names, and where there is a relatively large and trained staff. The present sample does include a few of the smaller foundries in the Greater Bombay area; it includes some of the bigger textile concerns, chemical works, and one of the most advanced scientific projects of this age. Only once, so far, has the team needed to think hard to find points where fuel and heat are being wasted. In almost every case waste has been distressingly obvious to the casual eye, though on further investigation the quantity of waste has been astonishing.

In fairness to Indian industry, only once, so far, has the factory personnel been completely unresponsive to the efforts to help to save expense on fuel, but this was a man who was so big-headed that no one could ever expect to teach him anything; it was incidentally just about the worst mill we have seen. The nearest approach to this attitude came from another mill where the engineer in charge was not an Indian.

Limited Coal Reserves

India is not one of those countries blessed with large fuel reserves, easily obtainable, and with a low internal demand which results in large exports of fuel, and the whole of the local population owning three or more Cadillacs. Instead, India has only limited coal reserves, of low quality, placed in an awkward part of the country, and a rising demand. Her demands for fuel oil supplies are rising, and each new demand increases the need to import, with an international currency situation which must produce headaches even for politicians. Yet, India wastes coal and fuel oil with gay abandon, to do what: partly to keep up the temperature of the atmosphere, and partly to provide what must be some of the most valuable and the hottest drains in the world.

Some extra point may have to be added to my remarks, by the announcement last August when the tax on fuel oils used for industrial heating purposes was increased by Rs. 40 per metric tonne. Harsh as they may seem, especially to those of you who will have to pay the extra duty, reflection may enable you to think as I do, and to welcome the salutory effect the tax may have upon your appreciation of what goes on inside your own mills and

. . . An average of 25% wastage of fuel is occurring in all mills, large or small, of any and every type of product, and irrespective of the number of staff and their training. Much of this wastage is just plain carelessness... We have seen so many examples of steam leakage . . . most of them so great that they can be seen from yards away and heard from the same distance . . .

factories. Whilst those who pay taxes cannot be in sympathy with the new proposals, I am delighted to find that those who waste the most fuel oil will be the hardest hit. If I could have my own way, I would impose a tax on all fuels, even on waste product fuels, but the tax would be on a sliding scale, hitting hardest at those mills where the state of fuel efficiency was low, and removing entirely the tax from any mill where our team of fuel efficiency experts could not suggest some savings in fuel. At least this would make for some real thinking about fuel and heat, and would have the added virtue that any mill which slipped back into the bad old habits, would promptly receive a very smart switch of the cane.

Wastage

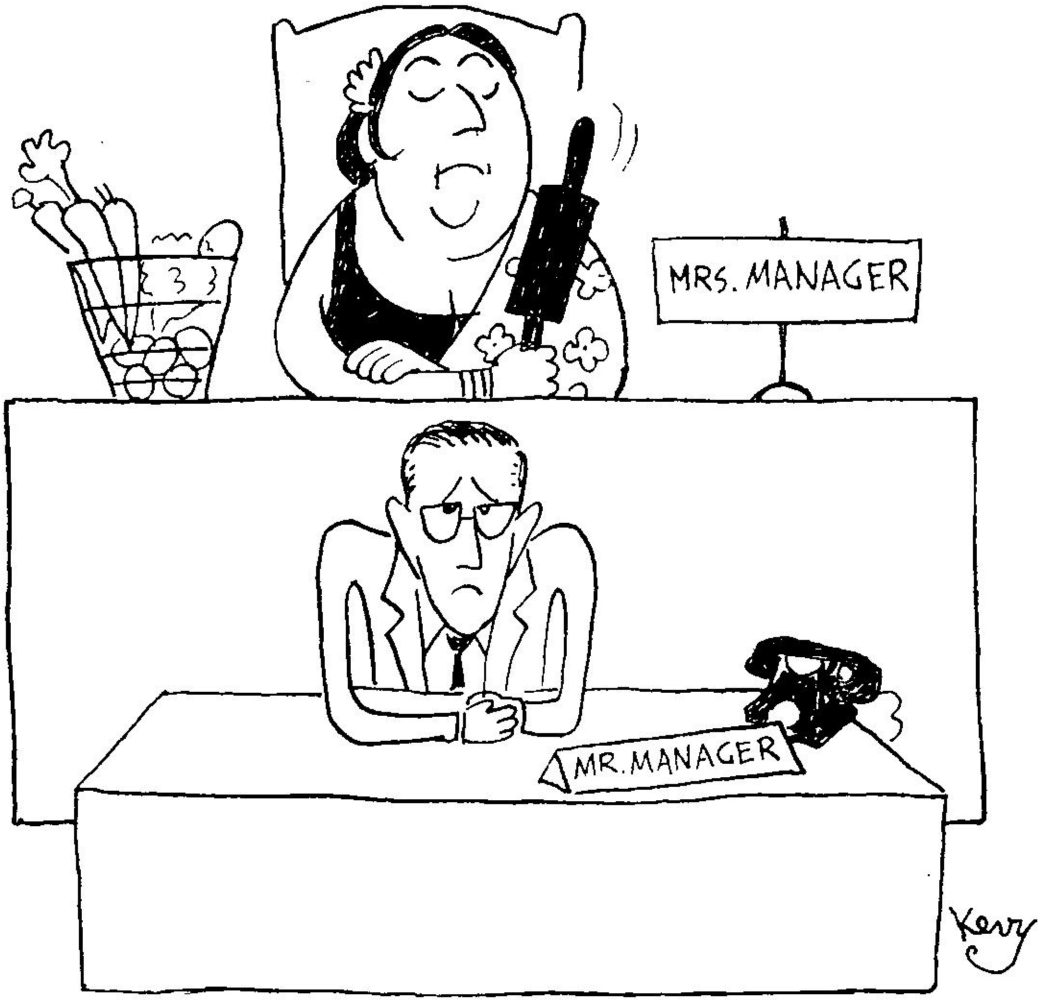
Compared with the state of fuel efficiency in the United Kingdom around the years 1941 to 1948, India is not much worse than we were; equally well it is no better. An average of 25% wastage is occurring in all mills, large or small, of any and every type of product, and irrespective of the number of staff, and their training. Much of this wastage is just plain carelessness, for which both top management and departmental heads must share the blame. We have seen so many examples of steam leakage, from faulty valves or from flanges, most of them so great that they can be seen from yards away, and heard from the same distance. Do Indian managers never walk around the factory looking at such things; do they never fire off a rocket at the man who permits such things to happen?

Many mills have, in the past, spent considerable amounts of money buying equipment for boiler houses, things such as steam flow meters, gas analysis recorders, and temperature equipment. Most of these are by now derelict, lying idle because of faulty maintenance. Some are still working, but I have yet to find one which could be trusted. For example, we have tried to effect a mechanical test zero on steam and CO_2 recorders, and found them to be far out; yet this is a test which should be made almost every day. Where the instrument is still working, the charts are changed regularly, but what happens to them? If anyone tries to work out performance figures from them, with a faulty zero, he is just wasting his time. So is any one else who looks at the performance figures. We have even had evaporation ratios quoted to us of 10 or 12 on fuel oil, when it was quite apparent that the boiler efficiency could not exceed about 45%. In one case, we were told that the ratio was about 10 to 1, but that on occasion the records showed that they got 24 lb or 26 lb evaporation per pound of fuel oil: a figure which was so utterly impossible that it could only mean that for each gallon of fuel oil which passed through the burners at least two were recovered from the top of the chimney. Why bother to buy instruments if you are going to let them rot? Frankly, many a housewife, used to buying in the best market, and making sure that the full value is got from what she buys, would make a better job of running a factory.

A greater quantity of fuel or heat is wasted inside the factory; roughly twice the amount that is wasted directly within the boiler house. The sources of waste are fairly well confined to the following:

First, the lagging of steam mains is very often faulty. In some cases, new mains have been put up, commissioned, and never lagged. In others, alternations have been made necessitating the removal of lagging which has never been replaced. Again, the lagging has received accidental damage, and has never been repaired. Possibly the best solution to this is to use moulded sectional insulation, which is easily removed when necessary, and can be replaced after alteration, or recovered and roused when a pipe becomes redundant. Incidentally, it is strange how few are the occasions when a redundant pipe is removed; generally it is left hanging, still with steam on it, and doing no useful work.

Secondly, in this hunt for heat waste, very rarely in India does one find a condensate return system; instead, all condensate is poured away to waste down the nearest drain. Worse still, it is often discharged on to the floor of the factory increasing the ambient temperature and the humidity, and making working conditions worse than ever. This condensate is hot water which, if returned to the boiler house, will reduce the load on the boiler,



...Many a housewife, used to buying in the best market and making sure that the full value is got from what she buys, would make a better job of running a factory than many of you do...

...Too often it is said that fuel efficiency is only for the big works with a large consumption of fuel and ... larger potential for waste. This is not true, and our most recent case study (see page 548) shows what may happen on the not so large mill...

and is pure water which will not give rise to further scale formation. It does not require further chemical treatment.

Frequently, steam pressures are far too high. The lower the steam pressure which will do the job, the higher the latent heat, and hence the lower the quantity of steam which will be used. Where any steam must be used at high pressures, then the condensate from those vessels will be at high temperature, and at the same pressure. That condensate can be passed into a flash vessel, from which perhaps 10% may be flashed off and used at lower pressures for some other purpose, thus saving a part at least of a live steam load, and reducing some of the disadvantages which may occur in the boiler house when high temperature returns may cause feed pump troubles. Stenters accompanied by a set of can driers are an obvious example of this type of fuel-saving.

Cardinal Point

Air venting of steam spaces should be studied in detail. By the Dalton law, any air present within a steam space must exert its own partial pressure, thus reducing the effective pressure of the steam. Also, the air present may form a heat resistant film, reducing the rate of heat transfer. Air venting, carried out properly will save steam, and increase the throughput.

To find a place where heat can be recovered from a waste product, or from a heated material which must be cooled, is possibly the most rewarding thing in the life of the fuel efficiency engineer. But the cardinal point is that it is no use recovering heat unless a use can be found for it. Examples of heat recovery potential can be found in many chemical works where a distillate must be cooled and condensed; or where a liquid which has been boiled down to concentrate must be cooled for further process or for storage. In the textile world, the effluent, from jiggers, and from keirs can readily be used to provide hot water for the next batch. Where the process is intermittent, some storage is essential, and that storage tank or vessel must be well insulated.

Drying is used in many industries—textiles, chemicals, fertilisers, sugar, paper, to mention only a few. It can be expensive; it can be abused. There is no sense in drying paper or cloth to bone dry, when within a few days or even hours the material will have absorbed moisture again from the atmosphere. Moisture sensors should always be built into the drier, continuously testing the moisture content of the material. When the drying medium is heated air, as in so many cases, the humidity of the exhaust air should be tested regularly, if not continuously, and recirculated if the humidity is low. The exhaust is always warm, and as such is wasted heat.

Many industries find it necessary to hold liquids at set temperatures for long periods. Provided that the temperature required is not the boiling point of the liquid, thermostatic control will save heat, but no thermostat can control at boiling point. A small point: even a thermostat should be checked at reasonable intervals of time to ensure that it has not got out of adjustments.

These then are some of the things which industry can do if they will, to save fuel, to save money, and to enable them to laugh in the face of taxation on fuels. Most are simple, some require expert help. All are a little time consuming, and if you don't have the time, again you need help. All require that you should be able to make a critical examination of your own plant, and of your own methods; if you can't, if you are too blind to see, you

New Coolant Clarifier

A new British equipment for removing ferrous swart from machine tool coolants was shown for the first time at the recent European Machine Tool Exhibition. It has been designed for use in milling, drilling, hobbing, and similar machining processes, and is particularly suited for use with automatic machines, says 'The Hindu' in a despatch from its London Engineering Correspondent. The following are extracts from the report:

Swart is separated from the coolant by means of powerful permanent magnets, and a conveyor system automatically transports it to a waste container. A low inlet and adjustable discharge height allow the equipment to be used with a variety of machine tools.

In operation, contaminated coolant flows into a hopper situated at the base of the clarifier, from where it passes through an intense magnetic field. The magnets are in the form of horizontal assemblies which are carried on an endless chain conveyor enclosed in a stationary sheath of non-magnetic stainless steel. The swart does not come into direct contact with the magnets but, under their influence, slides up the stationary steel surface to the discharge point. Any coolant entrained with the swart drains back to the inlet hopper.

In one hour, the equipment can handle 3,000 gallons of soluble oil/water coolant, and remove up to 250 lb of swart. The drive is obtained from an 1/8 h.p. 3-phase geared motor, and the total weight of the equipment is approximately 112 lb.

need help. If you are too complacent, you don't need help, you need a miracle.

Only too often it is said that fuel efficiency is only for the big works with large fuel consumption, and, therefore, dare we say, larger potential for waste. This is not true, and our most recent case study shows what may happen on the not so large mill.

A Case Study

This case concerns a textile mill in the Greater Bombay area, a mill which does processing of cottons on a commission basis. The mill is situated in a congested area, and although the trade is increasing rapidly, there is no space for expansion. Further increase in trade will almost certainly mean a need for a bigger boiler plant, for which there is insufficient room. What can be done?

The boiler plant is a single shell type boiler, oil fired, with a vertical boiler, not at present on its mountings, as a stand-by. At pre-budget prices for fuel oil, the fuel bill was about Rs. 2,18,600 per annum, a large sum for a small works. With the increase in tax of Rs. 40 per tonne, recently imposed, the new fuel bill, without any improvement in the works, and without fuel efficiency would be Rs. 2,73,030 per annum. With fuel efficiency, and still paying the new tax on fuel oil, the annual fuel bill can be reduced to only Rs. 95,380, thus showing a saving of 65.1% over the cost with the new tax.

The improvements are listed below, in the order that saves most money.

1. Replacing existing boiler plant with a modern high efficiency package boiler.
2. Stopping all steam leakages.
3. Flash steam recovery from condensate.
4. Lagging of Ager.
5. Condensate recovery and return to the boiler.
6. Lagging of keirs.
7. Heat recovery from waste liquor from keirs.
8. Flash steam recovery from keir liquor.
9. Lagging of cylinder ends on drying ranges.

How many of these items apply to your works? How long can you afford to let these items go on robbing you?

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"We know that Chairmen of companies in the United Kingdom have little difficulty in recruiting members from either House of Parliament as directors, but we also know that direction of companies is something which can be done in any idle moment. According to the Conservatives' election literature, one of their members is a director of several companies in Kenya and farms there as much, which shows what a busy man can do when he puts his mind to it. Chairmen of companies are also able to engage the services of MPs as public relations consultants and political advisers, duties which happily can be fulfilled at any hour in any well-stocked bar..."

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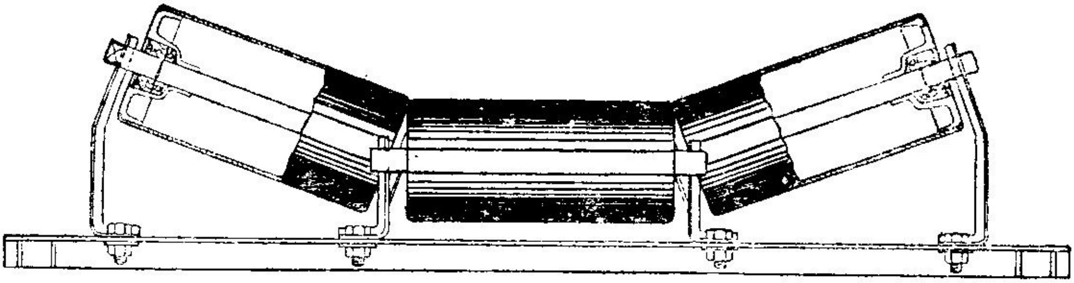

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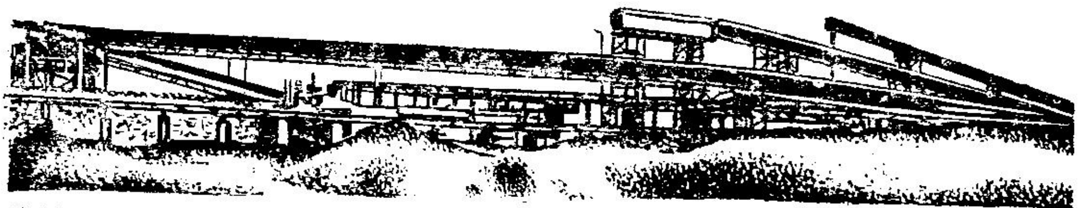

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Shilpi DYN-97

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But the work will never be quite over...There are newer ideas a-brimming...new themes...new schemes...throbbing impulses...masterful techniques...And weaving through it all, a rich, bold streak—*Kamani quality!*

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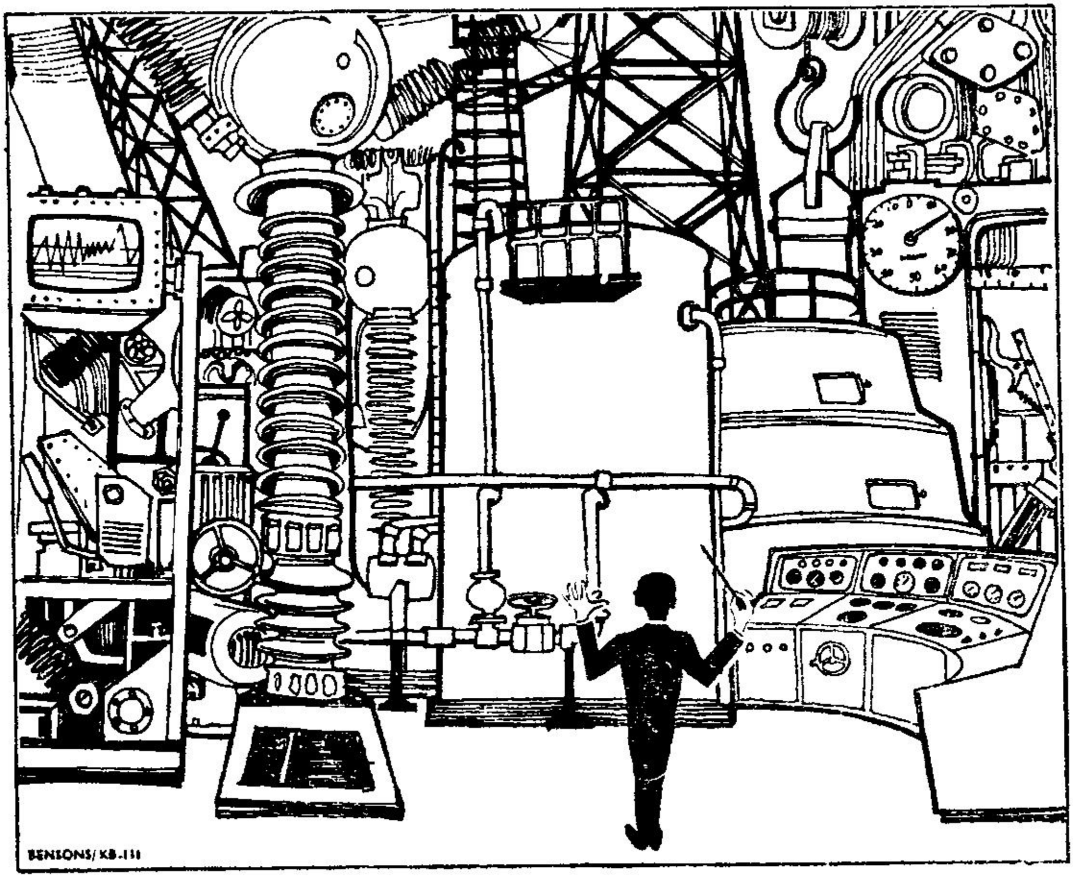
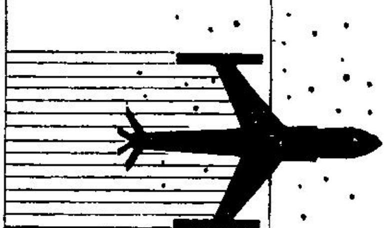


Here... the shoe that reflects the latest trend



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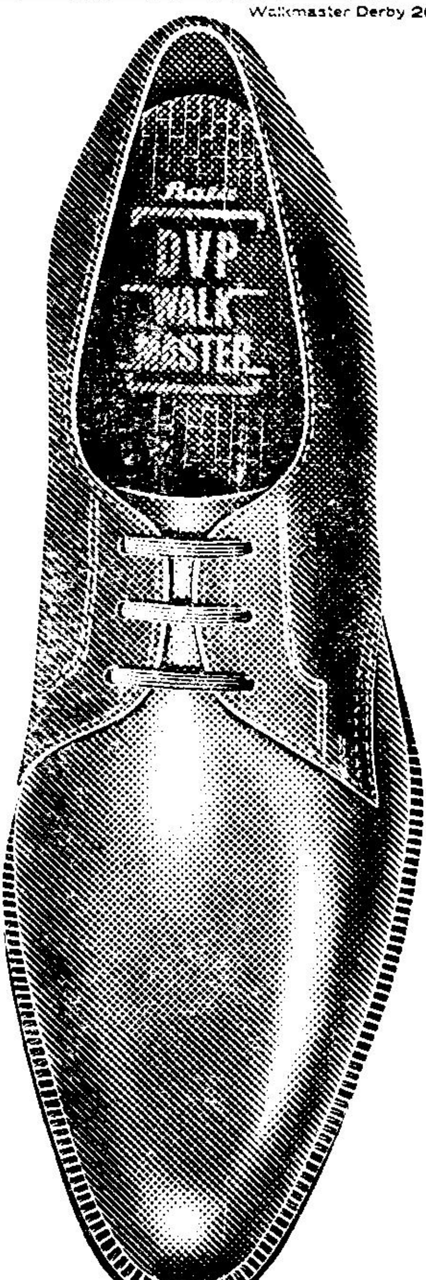

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DARAB C DRIVER

Coal Consumers' Association of India
Calcutta

Application of Fuel Efficiency to Indian Coal

THE application of fuel efficiency to Indian coal has its limitations. First, the ordinary consumer generally does not care about the wastage of coal, or about its use in excess of requirements, because coal is so cheap in India, whereas in the UK, where the cost of coal would be about Rs. 80 to Rs. 100 per ton, plants, however small, have to be careful about any wastage or excess consumption.

Secondly, small factory owners in India have not heard of fuel efficiency, and those who know about it are doubtful what beneficial results can be obtained by its practice, with the kind of low-grade coal they actually get, mixed with muck and dirt.

Thirdly, the experience of non-coking coal consumers is that they generally get a lower quality coal than they specify and pay for. Either theft in transit, short loading at the colliery end because of the short time allowed for loading by the railways, or insufficient weigh-bridges at collieries, especially for box-wagons, may be responsible for the shortage in tonnage railed to them. Thus the losses suffered on these counts weigh with them much more than possible small economies which fuel efficiency practice may effect in coal consumption in their plants.

Fourthly, the main difficulty in the practice of fuel economy by large industrial consumers of coal is that coal of a steady quality—with more or less a constant percentage of ash—is not available. The ash content varies with a wide range which makes any adjustment for fuel efficiency almost impracticable. Sir Biren Mookerjee, Chairman of the Indian Iron & Steel Co., in his annual statement, said:

> "...As examples of some of the problems with which we are faced, the ash content of our coking coal currently averages about 19%, compared with 16% 10 years ago, but what is worse is the wide range between the maximum and

minimum ash content at 24% and 14% respectively...."

Experience of other steel works is the same as regards the raw coking coal they have to use along with washed coal. Hence the importance of washed coal which tends to keep the ash content at a steady low level.

New Experiments

In spite of this varying range of ash in unwashed coking coal, steel works in general have succeeded in reducing the coke required for one ton of iron by more than 10% by sintering of iron ore, and injection of oil in blast furnaces. Experiments are being made now by using oxygen in blast furnaces.

Other important industries, like cement and paper, have the same complaint about the deterioration of the quality of coal supplied against better grade coal ordered, and the varying range of the ash content from consignment to consignment, making the practice of fuel efficiency difficult.

As regards middlings, resulting from washeries, which are used in power houses especially adapted to burn coal up to 45% ash, though the ash percentage is more or less steady, the moisture content varies seriously.

The moisture content of Karanpura coal is also high and variable, ranging from 8% to 12%, and going up to 15% in the rainy season, which presents a serious difficulty in achieving any useful result by the practice of fuel efficiency or economy.

Thus, it can be generally said that the main purpose of fuel efficiency as regards Indian coal, is barred by the inconstant nature of its important contents, and their wide range. In the circumstances, good results can be expected from subsidiary factors of fuel efficiency which can be expected to be profitable, such as stoppage of leaks in pipes and boilers, proper insulation, etc. Also, coal in its gaseous form would be more amenable to good results. The Fuel Research Institute at Digwadih is conducting experiments on a large scale on high pressure gas from low grade coals under the Lurgi and the other processes. Already the West Bengal Government's Durgapur projects are supplying 5,000,000 cubic feet of coke-oven gas per day to M/s Oriental Gas Co., Calcutta, and with the expansion of the coke-ovens at Durgapur, the supply of gas to Calcutta will be more than doubled.

With increased supply of coke-oven gas, and the good prospect of gasification of our low-grade coal, and with the existing oil refineries in Assam, Bombay, Visakhapatnam, Barauni, and the proposed refineries at Calcutta and Madras, we feel the approach of a Gas Age in India, which will pave the way for effective fuel efficiency and economy.

Then and Now

Just two decades ago, the highest pressure of steam was 200 lb per sq. inch and the largest capacity of the boiler was perhaps 1,000 lb per hour, whereas today the highest steam pressure and temperature achieved are 5,000 lb per sq. inch and 1100°F. respectively, and the largest capacity of the boiler is about 3,50,000 lb per hour consuming anywhere between 400 to 500 tons of coal per hour.

AB GUPTA

Associate Editor
The Coalfield Times, Dhanbad

Productivity Problems of Coal Industry

THE VITAL importance of coal in our present and future patterns of economic reconstruction can hardly be emphasised. Coal accounts even now for 75 per cent of the source of primary energy supplied to the Indian industries, and the position is not likely to undergo any appreciable change at least for another decade or so. That being the case, the pivotal role of coal in the country's industrial complex has to be recognised, and steps are to be taken to ensure that the productive tempo of the coal industry is not only maintained, but progressively accelerated, in keeping with increased overall demands.

Of late, the Government has adopted a business-like approach towards productivity problems of the coal industry. A Planning Group on Coal was formed some time back for preparing a working scheme for the coal mining industry. The Group estimated the total additional requirements of coal in 1970-71 as indicated in Table I.

TABLE I

(In million tons)

1.	Railways	16.00
2.	Iron and Steel	26.00
3.	Merchant Cokeries	2.50
4.	Cement	4.00
5.	Other consumers such as paper, brick burning, textiles, and jute	35.20
6.	Thermal Power	Nil (In case middlings are used)
	Total	83.70

As regards 'other consumers,' under item 5, the Group has computed its additional requirements of 35.20 million tons in the manner shown in Table II.

If the statistics given are accepted as the correct index of coal requirements of the different coal-based industries by

TABLE II

Consumer	Coal Council's Estimate for 1965-66	Projected for 1970-71
	(In million tons)	
1. Paper	2.00	4.00
2. Brickburning	4.50	12.50
3. Domestic coke	4.50	10.00
4. Bunker & Export	3.50	5.00
5. Refractories & Glass	2.50	5.00
6. Sugar & Chemicals	2.00	5.00
7. Textile & Jute	2.30	6.00
8. Colliery consumption	4.85	5.00
9. Small foundries	Nil	2.00
10. Other users	8.15	15.00
Total	34.30	69.50

1970-71, the coal output target by then should be fixed at the level of 180 million tons—on the basis of the Third Plan target of 97 million tons, **plus** 83.70 million tons additional requirements, as indicated in Table I.

These statistics show that the steel industry would require the largest quantum of coal. This quantity would have to be mostly either of the selected grades or of grade I, in order to ensure that ash in coke does not exceed 23 per cent to 23.50 per cent. In accordance with information received from the Union Ministry of Steel and Heavy Industries, the total requirements of washed dry coal, as fed into coke ovens of the six steel plants (two in the private and four in the public sectors) would be about 14.24 million tons by the end of the Third Plan period, which apppears to be equivalent to something like 24 million tons of raw unwashed coal. By 1970-71, the total requirements of by-product hard coke for steel-making would be 20 million tons, which, in terms of washed coal, would be 30 million tons, and, in terms of parent raw coal, something like 50 million tons. Since the requirement of raw coal for steel-making, at the end of the Third Plan, has been estimated at 24 million tons, the overall additional requirement of this variety of coal by the end of the Fourth Plan would hence be 50 million minus 24 million (i.e 26 million) tons.

Now, what would be the sources of the supply of this additional quantity of coking coal? The field-wise break-up figures in this regard have been estimated thus:

10.4 million tons of straight coking Jharia coal;

10.4 million tons of East Bokaro/Ramgarh coal; and

5.2 million tons of blendable coals from Dishergarh, Argada-Sirka, Ghordewa, Pench, and Jhilimili areas.

Blendable Coal

It is evident that blendable coal will play a very important part in steel-making. On the basis of the successful pilot plant experiments conducted by the Central Fuel Research Institute, Jealgora, it has been established, beyond doubt, that low-ash, weakly coking or medium coking coals can be blended in a much higher proportion than hitherto, and charged to coke ovens for manufacturing coke of the requisite standard. If that be so, much greater attention than hitherto should be paid on proper development, and increased output of blendable coals, particularly those of the Jharia coalfield, such as Zero and other seams. Such attention seems, till now, to be conspicuous by its absence.

Next in importance to the Steel industry are the Railways, which would require an approximate quantity of 37 million tons of coal at the end of the Fourth Plan period. The demand of the Railways during the Third Plan period being 21 million tons, the additional quantity required under the Fourth Plan would be 16 million tons. The entire quantity of this coal will have to be non-coking selected grades, non-coking grade I, and coking grade II. The point at issue is: how to maintain the requisite quality of the coal required for efficient steam traction. It is in this context that the Planning Group has estimated that of 37 million tons of their total Fourth Plan requirements, 25 million tons of coal required by the Railways will have to be of the washed variety, and the rest of at least Grade I quality. Establishing 25 million tons of washing capacity for the Railways alone will pose problems of a complicated nature, which will have to be tackled satisfactorily by the washeries to be set up.

The installation of a network of washeries, to be located in the most advantageous and strategic places, in proximity with thermal power stations, so that the middlings may be utilised for feeding the thermal plants, assumes, in this context, considerable importance. Unless the pace of the installation of these washeries is speeded up—the present pace being too slow, and rather disappointing—the tempo of the whole industrialisation programme is likely to be seriously affected.

Fourth Plan Target

As stated earlier, the Fourth Plan coal output target has been tentatively fixed at the level of 180 million tons. The sectorwise allocations of this target are indicated below:

	Million tons
NCDC Collieries	77.04
Singareni	12.00
TISCO	3.50
IISCO	2.00
Private sector collieries	85.46
Total	180.00

The Third Plan target for private collieries having been fixed at 62.00 million tons, an additional quantity of 85.46 million **minus** 62.00 million (i.e. 23.46 million) tons will have to be raised by them under the Fourth 5-Year Plan. The fieldwise break-up figures of this additional quantity of coal, to be raised by the private sector under the Fourth Plan, have been tentatively fixed as follows:

	Million tons
Jharia	4.00
Raniganj	15.50
Karanpura	0.50
Pench Kanhan	1.00
Korea/Rewa	1.00
Kamptee	0.50
Other fields	1.00
Total	23.50

The foregoing tables show that private sector collieries (excluding the TISCO and IISCO) will have to raise nearly 50 per cent of the total estimated coal output under the Fourth Plan. It is in this context that the creation of an atmosphere, congenial in all respects for the private sector of the coal industry, is indicated.

The Ministry of Mines and Fuel appears to have reoriented its policy in such a manner as to be conducive to the growth of the private sector. This reoriented policy should continue, and the lacunae still perceptible in it should be removed, in order that it may be possible for the private sector to shoulder its burdens successfully—not only to achieve its target, but also to exceed it. Neglect of the private sector, studied or otherwise, will be detrimental to the nation's interests as a whole.

How do trees transform themselves into coal

All around us we see Nature yielding her many-sided and colourful products for Man's benefit and happiness. Most of them are familiar to us, and yet we see neither the charm of novelty in things of everyday nor their usefulness until competent persons discover them for us. The following passage taken from the book "Marvels in Science and Industry", edited by John R Crossland, explains how trees transform themselves into coal.

"... Imagine this earth millions and millions of years ago. In various parts of the world great forests were forever thriving. As fresh trees took their place the old ones fell back into the water and the mud. and there — secure from the air — they underwent certain marvellous chemical changes. Often violent movements of the earth's crust would drown whole forests where they stood and seal them away beneath a coat of sand and heavy sediment.

"Perhaps a hundred thousand years later that area would again be raised above water and nourish another vast forest, which, in turn, would be sunk and preserved. The enormous pressure of the earth — along with certain chemical changes — slowly but surely altered the nature of these deep-buried trees. In countless millions of years they were transformed to the black diamonds we call coal.

"Between the wood from the trees and the hard black coal, however, there are several stages. The peat, for example, contains very little carbon — the chief element or ingredient of coal — but it is one important milestone on the road of development. Lignite is another stage nearer. And so on, through Brown and Cannel coals to ordinary household coal and the very hard type called anthracite, which contains as much as 90% of carbon ..."

JB SINGH

Formerly Director (Thermal Directorate)
CWPC, New Delhi

Avenues of Improvement in Thermal Power Stations

ONE OF the many things on which serious attention was focussed after Independence was the considerable margin available in improving fuel efficiency of thermal power stations. In the early post-Independence years, such attention mainly took the shape of installing power stations of modern design, fully in line with practices prevailing in advanced countries of Europe and the USA.

Prior to 1947, almost all power stations in India woefully lagged behind the then practices in technically advanced countries. The first major power station to be set up on modern lines was the Bokaro Thermal Power Station of the Damodar Valley Corporation. This was followed, in quick succession, by the Trombay Power Station of the Tata Power Company, the Coke Oven Power Plant of the West Bengal Government at Durgapur, and several others.

In 1958, the supply of coal, which, until then, had been reasonably easy, threatened to be outstripped by the demand, not only quantitatively, but, what was far more serious, qualitatively as well. Power stations, in common with other key industries, began to feel the pinch, and the pinch was the severest from the qualitative point of view. It soon became evident that a considerable amount of tightening of belt would have to be done by all concerned. In these circumstances, a Fuel Efficiency Committee was set up by the Government, in which all important coal-using industries were represented, besides the Central Fuel Research Institute. The Committee carried out its function of tightening of belts with commendable speed and energy, and in this process, power stations received enough attention.

It became evident in 1961 that really something more needed to be done. The Government of India asked the National Fuel Efficiency Service of the UK to assist, by sending a team of their experts to visit India, and to review the position against the standards and norms set up by the UK Committee in carrying out fuel efficiency work in their own country. This team made a careful study of the fuel efficiency conditions in a large number of fuel-burning industrial establishments of various types and sizes, and presented a report to the Government. This report has thrown light on a number of hidden weaknesses in the fuel efficiency of representative cross-sections of the chief coal-using industries in India. This led to the Planning Commission requesting the National Productivity Council to organise a nation-wide set-up for fuel efficiency in India.

The Central Water and Power Commission had been carrying out studies on fuel efficiency in thermal power stations all over India, even before the appointment of the Fuel Efficiency Committee in 1960. These studies took the shape of visits of inspection by expert engineers to power stations. Difficulties were studied at first hand, weaknesses in equipment and methods of operation and maintenance probed into, and, in almost all cases, it was found that substantial results could be and were in fact achieved.

The immediate occasion to take this work on hand was the need to adjust boiler plants to the qualitative downgrading of coal supplies to power stations. In the pre-Independence era, power stations, almost without exception, used the very highest grade of coal, known as 'selected grades'. It was no longer possible to allot such grades of coal to power stations with the same liberality, and in most of the power stations, downgrading in quality was enforced, although with all possible caution, and in gradual stages. Even this gradual and cautious process met with opposition in varying degrees; and many power stations warned that any downgrading in the quality of coal would result in disastrous consequences. It took us much patient and tactful effort, backed by actual demonstrations at power stations, to convince power station managers that the flexibility built into most power station boilers was sufficiently elastic, if carefully studied, and operation techniques modified in the light of modern approved practice, to cope with downgrading of coal quality, to a limited extent. The patience, tact, and perseverance shown in this regard were ultimately amply rewarded by the willing acceptance of power stations to the downgrading of coal supplies, which enabled selected grades of coal to be diverted to hard pressed industries like railways, steel, and metallurgical works.

The recounting of a few representative avenues of improvement found in power stations will be of interest.

1. **Cleanness of heat transfer surfaces in boiler plant:** Scale on the waterside, and soot and ash on the fireside, are deposits which have to be either prevented from occuring, or removed as fast as they accumulate. In many power stations, chiefly in the smaller size ranges with manual stoking and draft control, there is inadequate attention by the engineering staff, work being largely left to the tender mercies of the unskilled or semi-skilled workmen, leading to excessive accumulations of both scale and soot. All boilers are provided with soot blowers, in which the soot deposits are periodically blown off by jets of steam. In manually operated boilers, the soot-blowing is manually done—the most primitive, but still fairly common, method being a tubular soot blowing lance wielded by the boiler attendant by inserting it in holes provided in the boiler wall, through which he sweeps the lance across the tube banks. The steam supply to the lance is by means of a flexible steam pipe. This is an arduous and clumsy method, and, unless carefully done by a practised worker, results frequently in scalded hands and limbs. Most workers shun, and neglect this work. Malingering is easy where

supervision is lax. In most installations, such is the case. In a number of power stations visited by our engineers, the local staff affirmed that soot blowing is regularly carried out, but when asked to demonstrate, it was found that the equipment, through long disuse, was no longer in a workable condition.

2. **Gas Tightness of Flue Gas Passages:** In order to yield up their heat content, flue gases have to travel along a predestined course. In almost all water-tube boilers, baffles are provided to effect a multiplicity of flue gas passes across the tube banks. The baffles wear out quickly, due to continuous high temperatures as well as the abrasive action of ash and coal particles entrained in the flue gases. Access to the baffles in most boilers is far from easy, and it is quite common for portions of the baffles to have perished, leaving large gaps through which flue gases gain unauthorised entrance, short-circuiting the designed passes. In a number of cases, such deterioration of baffles is found to have remained undetected, and unattended to, for months, and even years.

Dilution Of Flue Gases

Gas tightness to external atmosphere is also found wanting in a number of cases. Most boilers, especially the manually operated ones, work under negative draft, and if gas passages are not air tight, air infiltrates through the cracks, and causes dilution of flue gases, resulting in poor heat transfer.

3. **Size Gradation of Coal:** In the pre-Independence era, rubble coal was used in all chain grate stoker fired boilers. This rubble coal was of a fairly uniform size, and, as a result, it was easy to ensure adequate passage of primary air through the fuel bed, as well as controlled combustion through the length of grate travel. In the present conditions, rubble coal availability for power stations has dwindled to well-nigh vanishing point, and practically all power stations get either slack, or run-of-mine. Slack coal, because of the much smaller-sized particles (a large proportion being coal dust) offers considerable resistance to passage of primary air. The position is made worse by the fact that screening arrangements at coal mines frequently leave much to be desired, and admixture of fairly large proportions of lump coal of a wide range of sizes is by no means uncommon. To cope with this difficulty, most power stations, which are in a position to do so, have installed mechanical crushers. Unfortunately, it is a common practice to pass the entire coal, compounded of slack and sized coal, through the crusher. While the sized coal component is reduced to the proper size, the slack coal component is further reduced in size, and generally comes out as dust. This considerably accentuates the difficulty in burning the crushed coal on the grate. The remedy is both obvious and simple, namely, to provide a screen before the crusher which will send only lump coal to the crusher, the slack being screened off and sent straight to the boilers. Perhaps because of the very obviousness, this was not done at a number of power stations until pointed out by CWPC.

4. **Boiler Instrumentation:** The common weaknesses fall into either of two extremes, too little dependence or too much depenence on boiler instruments. In the early days of power generation in India, where instrumentation was confined to a pressure gauge and a thermometer for the live steam only, combustion control was done by visual observation of the fire-bed, the flames in the combustion chamber, and the smoke issuing from the chimney. If done by a practised and competent boiler operator, such methods achieve generally a remarkable measure of success. Many veterans of the old school, who have a life-long practice of such methods, often tend to look down upon modern comprehensive boiler instrumentation as a new-fangled contraption,

whose purpose is to adorn the instrument board. There is also much to be said for this point of view, especially in respect of manually operated boilers, but with large mechanically fired boilers provided with mechanical draft, such rule-of-thumb methods, even when practised by a master in the art, are only partially successful. At the other end of the scale, boiler operators who swear by their instrumentation, very often tend to place much reliance on its infallibility. Boiler house instruments, like all other instruments, are fallible. Conditions in many boiler houses (heat, dust-laden atmosphere, etc) are not conducive to delicate instrument movements remaining unimpeded. In order to provide a safe guide, it is essential that all instruments be given periodical cleaning, lubrication, and calibration, according to a planned schedule. This is more often not done. Cleaning, if done at all, is confined to polishing the glass dial and metal body of the instruments. Small wonder that boiler instrumentation becomes erratic in working, and fails to provide a safe guide to quality control in boiler operation.

. . . Fuel efficiency is something more than a mere class-room exercise of chemical and physical principles of combustion and heat transfer and utilisation. Power plant set-ups, machines no less than men, can be extremely temperamental, and respond only to patient, well-directed, sympathetic, and really skilled approach . . .

5. **Adaptation of boiler plant to lower qualities of fuel than designed for:** As stated above, this has been the focal point of fuel efficiency work in the initial stages. Boilers are, by and large, flexible in operation, and, although rigidly tied down to design conditions for obtaining guaranteed efficiency, have generally sufficient built-in flexibility to permit satisfactory operation under conditions deviating from designed conditions, provided operating methods are suitably adjusted. Under such conditions of deviation within reasonable limits, efficiency is bound to be somewhat below guaranteed efficiency, but in other performance characteristics—output, reliability, ease of operation etc.—there is little or no ill effect. This generalisation, however, does not cover modern large central station boilers using pulverised fuel. Such boilers have much less built-in flexibility in this regard.

Operation Techniques

We have found that boiler operators at power stations have often to be initiated into the methods of adjustment of operation techniques. These have to be studied and determined for each particular boiler installation in the light of its design features, but the most common adjustments which have proved successful are:

(i) Adjustment of grate travel speed and fuel bed thickness.

(ii) Adjustment of proportion of primary to secondary air.

(iii) De-clinkering the fuel bed by steam or water jets under grate bars directed upwards to the fuel bed.

(iv) Overcoming "bird-nesting" troubles by air or water launching while boilers are under operation.

(v) Achieving uniformity of size of fuel in a particular boiler. In most cases it pays to sieve the coal, into two ranges of coal size, using these two ranges on separate boilers, thus achieving more uniformity of size and permitting closer and more effective adjustment of primary air.

6. **Special Cases:** Some cases, where adherence to designed operating methods, without adjusting for changed fuel quality, has led to severe operating problems, deserve special mention. Many boiler plants, chiefly those fitted with spreader stokers, are provided with what is called the "cinder refiring system". This may briefly be described as a refinement of fuel economy practice, where cinder particles entrained in the flue gases, which may consist of an appreciable proportion of unburnt carbon, are separated from the flue gases at an intermediate stage of travel through the gas passages, and reintroduced into the furnace. Such refinements can work satisfactorily only within a narrow range of coal quality variation.

It is obvious that with coal of increased ash content, this would result in heavy concentration of solid particles in flue gases. Such heavy concentration has been known to act as a sand-blast on boiler steel and refractory surfaces on which the flue gases impinge in the course of their travel, and erode such surfaces. The time, money, and effort spent in repairing such damage is usually several times the fuel economy achieved by cinder refiring. The obvious remedy

Do You Know...

In industry, there is inevitably a wastage of fuel due to the heat conductivity of scale which results in loss of production time due to periodical cleanings, not to mention the costs of replacing bulged and collapsed tubes due to overheating.

Natural water contains dissolved substances, both gaseous and mineral. In its natural state, water is, therefore, not at all satisfactory for use for industrial purposes because heat transforms dissolved salts into hard and adherent scales, while gases cause corrosion.

The quality of coal supplied to industries is so poor that boiler operators find great difficulty in burning the same not only efficiently, but effectively, with the result that consumption of coal goes up.

Effective fuel utilisation would not only reduce the cost of production, but would ease the pressure on the transport system which carried the fuel.

That judged by the per capita consumption of power, which is the modern yardstick of a country's progress, India occupies the 27th place. The per capita consumption will be 72 kWh at the end of the Third Plan. But this figure is far less than in the advanced countries — 11,000 kWh in Norway, 5,000 kWh in the USA, and over 2,000 kWh in most of the European countries.

is to discharge to waste the cinder separated at the intermediate stage.

These methods were evolved and introduced, over the years, to the extent the needs of each power station justified. The directive of the Planning Commission for the fuel economy in thermal power stations to be carried out by CWPC, on a regular planned basis, resulted in enlarged sphere of activities. A detailed programme of site inspection of power stations, covering not only probes into weaknesses in operation and maintenance, but also examination of operating and maintenance schedules, determination of optimum conditions of operating periods of different plant units, and other details of operation, maintenance, and inspection, was taken in hand. The charts attached will indicate, in broad outline, the *modus operandi* of such studies in a typical case study of one of the more important power stations recently carried out by CWPC. It will be seen that operation schedules over a two-year period have been analysed, and the results plotted on the charts. The chart of 'A' Station, which comprises seven sets of various sizes and ages, makes interesting study. It will be seen that while the load on the station could have been easily met by, at the most, four of the modern sets, all the seven sets have been regularly pressed into service practically throughout the two-year period, resulting in time not being available to devote to each set for thorough maintenance and upkeep. This has had the inevitable result of operating efficiency careering recklessly up and down.

In each set diagram, the full height shows the rated capacity, the shaded portion shows the reduced or derated capacity due to machines being in poor condition, and the white portion the extent of deration suffered by each machine. If the sets have been worked to a planned schedule, deration would not have taken place, and both operating efficiency and plant availability would have been much higher.

The chart for 'B' Station, although somewhat better, still shows substantial room for improvement. There are only two sets in this station, of the same size and age. Both have suffered derating by reason of inadequate time available for overhaul and maintenance. Had a planned operation and mainteance schedule been followed, deration of both sets would not have taken place, and both operation efficiency and plant availability would have been substantially better.

Automatic Control

I have deliberately omitted any reference, in this article, to fuel efficiency work in large modern thermal power stations. As indicated in the beginning, a number of such power stations have been installed during the last decade. Many more will be installed in the near future. These are all fully up to date power stations, replete with numerous refinements of heat economy, electrical economy, and economy of operating and maintenance personnel. It would be outside the scope of this paper to discuss problems relating to such power stations.

All major operation functions are performed under automatic control, the chief function of the operating personnel being to be on the alert to see that the automatic controls function properly.

What I have said before about instrumentation, applies with added force to automatic controls. An automatic control can only perform a mechanical operation which the operator's experience has proved desirable and profitable. It cannot *think*. The operator has to do the thinking first, profiting by his experience. He must then limit the task of the automatic controller to operations within that capacity. Failure to appreciate, and allow for, this limitation to automatic control has, in quite a few instances, led to unfortunate results.

It has to be emphasised that fuel efficiency is something more than a mere class-room exercise of chemical and physical principles of combustion and heat transfer and utilisation. Power plant set-ups, machines no less than men, can be extremely temperamental, and respond only to patient, well-directed, sympathetic, and really skilled approach. Any person who aspires to become a fuel efficiency adviser must have basically a thorough background, backed by years of experience, of the entire technical process of the industry whose fuel efficiency problems he aspires to solve—not merely the combustion, heat transfer, and heat utilisation part of it. Added to this, he must have the breadth and depth of vision necessary to grasp the problems in their entirety, and to separate the wheat from the chaff in selecting the relevant technical factors associated with the problem. The history of fuel efficiency work in India, sporadically carried out by various bodies, has had instances of a class-room approach being brought to bear upon this highly specialised work by investigators lacking in the above essential background and talents. Such instances have done more harm than good. Industrialists and factory owners are interested in getting results, not class-room lectures on the thermodynamics, and the chemistry of combustion.

Farm Productivity Rate Can be Raised Threefold, Says Desai

Enumerating the problems confronting India — poverty, social inequalities, unemployment, inequality of opportunity, dangers on our borders, etc. — Mr Morarji Desai, India's former Finance Minister, said in New Delhi, in a TV interview with Independent Television News of Britain, that "agricultural productivity rate can be increased three times."

He added: "We can also industrialise to an extent where we will become self-sufficient, ordinarily self-sufficient, not completely self-sufficient. Nobody in the modern world can become completely self-sufficient. We should not be dependent on other people all the time in order to go forward. We have also to meet foreign exchange requirements and try to have a surplus, which means we have to produce more..."

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Automatic Control of Boilers in Thermal Power Stations

MODERN requirements of temperature and pressure, being very much on the higher side, have had their impact on the magnification of boiler size, the sophistication of its design, etc. Any error in its operation, therefore, has a multiplier effect on fuel consumption, as also on the possibility and extent of risk to the plant. Besides, the layout of modern boilers makes imperative some sort of remote control on account of considerable distances between control points. It is well-nigh impossible for a human factor to keep a simultaneous and immediate check on the so many qualitative and quantitative variables involved in modern boiler functioning, the sudden and unpredictable changes in load, etc. This necessarily leads to automatic control of the boiler, and the feed cycle in a big power plant.

Automatic controls have been evolved for a wide variety of operational duties in respect of load, combustion, feed water, steam temperature etc. Besides freeing operators of repetitive tasks, automatic controls improve operational efficiency, effect considerable fuel economy, increase the life of the furnace and auxiliaries, and avoid smoke nuisance. The need for automatic control of boilers depends largely on the short-term variations in steam supply: the more variable the demand, the greater the need for automatic control. Automatic control has many advantages over manual firing: the required adjustments are made continuously and accurately, so that variations in steam pressure and temperature are reduced. The correct proportioning of fuel and air so very necessary for efficient combustion is more easily achieved with automatic control, and the boiler operator's time is saved and released for other work in the boiler house. The automatic control of a thermal power station may be divided into the following groups: Combustion control; Drum level control;

Superheat temperature control; Feed cycle control.

The object of automatic combustion control is to maintain the desired air-fuel ratio and the designed steam temperature and pressure, irrespective of load conditions. Automatic combustion control, if properly applied, effects considerable economy in fuel, increases the life of the furnace, reduces maintenance costs, etc. The boiler is a steady flow apparatus: the purpose of the automatic combustion control is to maintain balance between heat input and heat output at all times with the minimum loss of time, and to maintain proper combustion conditions.

Many types of automatic combustion controls have been developed, broadly classified as follows:

(1) Unified boiler control system
(2) Position control system
(3) Flow type control system

In the unified boiler control system, we have a battery of boilers supplying a single steam turbine. In this system, the speed of the D.C. motors, driving the auxiliaries supplied from a common source of variable D.C. voltage, is varied, depending upon the load coming on the boiler. In this system, the auxiliaries should be so designed that their speed/voltage characteristics are adapted to boiler requirements. The advantage of this method is its simplicity, but a human operator is required to carry out the trimming operations. Another distinct advantage of this method is the large saving in the auxiliary power at low loads. This is not however extensively used, because of increased cost of maintenance of the auxiliaries, and its needs must have a variable source of D.C. supply.

Change in Steam Pressure

In the positioning system of control (Fig. 1), normally adopted for small boilers, a change in the steam pressure is communicated to the master steam pressure controller which senses this change and sends out a proportionate signal. This signal actuates the damper of the induced draft fan, and alters the fuel supply. The forced draft fan is, in turn, positioned by the furnace pressure controller, which senses the change in the furnace draft as a result of the new position of the induced draft fan damper. It might be pointed out here that it is always preferable to send the signal from the master steam pressure controller to the induced draft fan first, because then, under no circumstances whatsoever, there will be a positive draft in the furnace which is very much desired. The disadvantage of this method is that load changes cannot be taken care of quickly, because the controls are actuated only when there is a change in steam pressure, i.e. after there has been a change in the load on the boiler. This might give rise to hunting of controls. This type of control is not suited for a battery of boilers operating in parallel. In the flow type control system, also known as metering

. . . Even though automatic combustion controls are a boon to the boiler operators, they can never be a substitute for the human brain . . .

type, the action of combustion control is initiated by a change in the steam flow, with the master steam pressure controller sending out a corrective signal. Here, the response of the system to changes in load is much more rapid. There are three main types of combustion controls in this system: control of combustion by steam flow-air flow ratio control, fuel flow-air flow ratio control, and oxygen analysis control.

Good Results

The steamflow-airflow ratio system has been used for many years, and with good results. In this method (Fig. 2), the fuel input is measured indirectly in terms of the rate of steam generation. By properly proportioning air flow to the steamflow conditions, proper combustion conditions could be obtained in the furnace. This is based on the assumption that the thermal efficiency of a boiler remains constant over the normal range of loads, and that it requires the same quantity of air in order to secure the same heat release for most of the common fuels used in boilers. This method of adjustment of combustion conditions will, however, not yield satisfactory results when using gaseous fuels containing considerable amounts of hydrogen and carbon monoxide, because the consumption of air for these two will be 15% and 28% below that of hydrocarbons. Also, the above system is unlikely to work satisfactorily, if more than one fuel were used in the boiler, the ratios of the two fuels used varying widely. Further, errors due to variation in boiler efficiency, air consumption, steam flow, and air flow measurement will cause errors in air supply, perhaps amplified several times. Another disadvantage of this system is its inherent time lag. It is very difficult in this system to make quick and fine adjustments to both demand and supply changes.

The fuelflow-airflow ratio method of combustion control (Fig. 3), has proved to be a good basis for combustion control. It is particularly well-suited for open hearth furnaces, and the like. The limitations of this system lies mainly in the possible accuracy of the fuel and air measurement.

In the oxygen analysis system of combustion control (Fig. 4), flue gases analysis is used as a basis for complete combustion control. This method is indeed a very good one, and can successfully be applied, provided the following points are borne in mind:

1. Since we are primarily relying on the analysis of the flue gases to make adjustments to combustion conditions, a representative sample of the gases should be obtained.
2. The sampling filter elements, which often get choked, should be kept in perfect condition.
3. Leakage of air into the sampling system should be prevented. If the oxygen percentage were to increase, say from 2% to 3%, due to inleakage of atmospheric air, etc., this leakage would be equivalent to a 50% error in the scale reading of the oxygen controller, which will be too large a variation for any controller to deal with. Therefore, extreme care has to be exercised in preventing inleakage of air through the boiler settings, if this method of combustion control is to work satisfactorily.

Automatic combustion control systems consist of the following parts, which can be combined in any way to suit a particular plant:

1. Master steam pressure controller
2. Furnace pressure controller
3. Selector station for remote-manual-automatic control
4. Fuel-air ratio controller
5. Power devices such as Piston operators or diaphragm motors for operating valves, dampers, etc.

There is no hard and fast rule to connect up these various devices, as the type of boiler, furnace, fuel burning equipment, arrangement of air and fuel supply systems, determine the type and elaborateness of the arrangement required. Any of the following four systems, however, can be used:

I Series Control

(a) Steam pressure adjusts the fuel supply. The fuel supply, in turn, establishes the air flow; or

(b) Steam pressure adjusts combustion air flow. Air flow, in turn, establishes the flow of fuel.

II Series Parallel Control

Steam pressure simultaneously adjusts the fuel rate and combustion air flow. Metering type fuel flow-air flow ratio controller readjusts either (a) the fuel flow or (b) the combustion air flow.

System I(b) and II have the advantage that the fuel supply is limited to the available supply of combustion air. For satisfactory operation with minimum of excess air at low loads, the leakage through the dampers and through the boiler settings should be the minimum, as otherwise there will be no regulation of air, which means that there will be no regulation of fuel. The maintenance of steam pressure at low loads, may, therefore, pose a problem. This could, however, be overcome by providing a stop or by-pass on the damper permitting a safe minimum air flow, and below this point, the master steam pressure controller regulates the fuel. In the flow type of control systems described above, it is the change in the steam flow which initiates all the controls and the master steam pressure controller sends out a corrective signal depending upon the change in steam pressure, as a consequence of the change in steam flow. This way, it is possible to reduce the time of response of the controls, and load changes can be taken care of, more effectively, without much hunting of controls. The time of response of the control system could be reduced further, by relying on the change in electrical supply frequency to initiate all the controls, instead of the change in the steam flow. However, this is possible only in the case of a frequency controlling power station connected to a power system.

Even though automatic combustion controls are a boon to the boiler operators, they can never be a substitute for the human brain. Combustion characteristics depend upon so many variables. As such, combustion control is seldom a simple and straightforward problem. Intelligent supervision of the boiler plant is necessary in spite of automatic controls.

Thermal Stresses

The maintenance of water level in a boiler drum is very important, particularly in the modern high pressure and high temperature boilers. The general trend in the boiler design has been to increase the ratio of evaporative to storage capacity of boiler. In fact, the amount of water stored in a modern water tube boiler will hardly suffice for a few seconds supply. Besides, for the proper operation of the drum internals, maintenance of correct water level in the boiler drum is important. Too high a water level in the boiler drum may submerge the drum internals, reduce the disengaging space available for steam separation from steam water mixture, and intensify priming and promote carry-over of dissolved solids. Too low a water level may cause circulation difficulties, and set up severe thermal stresses in the boiler drum. Unless the rate of feed water supply is in accordance with the rate of steam generation, there will be an alteration in the drum level. The drum level has, therefore, to be maintained at an optimum value irrespective of load conditions. The following three methods of feed water control are generally used to control water level in the boiler drum.

1. **Single Element Feed Water Control:** For small boilers, subjected to a steady load, single element feed water control system may be used. In this system, any change in boiler water level actuates a flow control valve which controls the feed water into the boiler drum. The flow control valve is actuated either by the expansion of an inclined tube connected to the steam and water side of the boiler drum. or by thermostatic bellows. The disadvantage of this method is that if there is a swelling in the water level, due to drop in steam pressure, the flow control valve begins to act even though the actual water level is different. This type of control also gives rise to hunting of water level, as it cannot anticipate the change in load demand, and will act only when there has been a change in the water level. In order to overcome this difficulty, two- or three-element feed water control system is employed.

2. **Two-Element Control:** Next, in the two-element control, the changes in water level and steam flow are both taken into account, being kept in balance by a system of controls and relays.

3. **Three-Element Control:** In the three-element feed water control, the steam flow, feed water flow, and drum level are taken into account (Fig. 5). The steam flow and feed water flow are balanced against each other in relay. Any imbalance sends out a signal to a computing relay, which receives a signal also from the drum level transmitter. The output signal of the computing relay which will be either the sum of the difference of the two signals, will be communicated to the control valve. If, however, there is a swelling in the water level due to flashing of steam on account of a sudden pressure drop in the boiler drum, the controls may respond to this change also. One way of preventing this will be to take into account the change in density of the boiler water. If a satisfactory method of detecting the change in the density of boiler water due to swelling could be devised, this system will work most satisfactorily. The three-element feed water control works satisfactorily on boilers which are subjected to sudden changes in load, and supresses the phenomenon of hunting to a great extent, if not completely.

The maintenance of the designed steam temperature is important not only from the point of view of efficiency of the steam cycle, but also from the point of view of the safety of the plant. It is possible to keep down the variation of steam temperature with load variations within reasonable limits, by a judicious proportioning of the radiant and convective heat transfer surface of the superheater. Even then, some form of automatic control is necessary, because ever so many variables influence the steam temperature. Many methods have been proposed to control the superheat temperature. They are:

1. Flue gas recirculation
2. Excess air supply
3. By-pass damper control
4. Tilting burners
5. Desuperheating or spraying of water or condensate.

In the flue gas recirculating method, a portion of the hot furnace gases are recirculated to increase the flue gas temperature which, in turn, increases the temperature of steam. This requires a special type of additional rotating machinery for recirculating hot gases. Also, because of the inherent time lag, there may be slight hunting of the controls. This method may be successfully applied at low loads.

The excess air supply may also be varied at low loads to keep the superheat steam temperature, at the cost of efficiency of the boiler plant, in a radiant boiler. When excess air over the optimum minimum value is supplied, it brings down the furnace temperature, reduces the amount of heat transmitted by radiation to water walls, and increases the flue gas temperature to inlet of convection superheater, which, in turn, increases the steam temperature. This method of superheat temperature control is not desirable unless and until the maintenance of steam temperature is extremely difficult at low loads. Normally, superheaters should be designed to maintain the desired degree of superheat at low loads, and the excess of superheat over and above the design value at higher loads should be removed by some other methods.

In the by-pass damper method, the quantity of hot gas passing over the superheater surface is varied to maintain the desired temperature. In this type of control, the superheater will normally be designed to give the desired steam temperature at low loads, and, therefore, one can expect the temperature to rise at full loads. The operation of the by pass

"Oh . . . Fuel consumption is almost nil in our make . . ."

damper will bring the temperature back to its design value. The disadvantage of this method is that there is an inherent time lag in the process as a result of which hunting of controls is likely to take place.

In the tilting burners method, the burners located in the furnace are tilted through 20° above or below the normal position, thus altering the effective furnace volume and shifting the maximum temperature zone. This alters the furnace exit temperature of the flue gases, and this, in turn, alters the superheat steam temperature.

In the desuperheating method (Fig. 6), the steam generator is designed for a given steam temperature at low loads; the excess steam temperature is reduced at high loads, by desuperheating. Desuperheaters are of two types: Direct and indirect contact. In the indirect contact type, boiler feed water is used in a heat exchanger to cool the steam flowing through it. The disadvantage of this method is that a heat exchanger capable of withstanding high temperatures and pressures is necessary. The advantage is that since there is no contact between steam and water the purity of steam is maintained. In the direct contact type, the feed water, normally taken from the discharge line of the boiler feed pump, is directly sprayed into the superheated steam by the nozzles located in the desuperheater. In this case, it is important to ensure that there are no impurities in water, and that chemicals are added to the feed water after the tapping point for desuperheater, as otherwise scales would be formed in the desuperheater sections, thus putting it out of action, frequently. In both the cases, it is desirable to locate the desuperheating element between two superheater stages, so that the last stages of superheater elements could be designed to withstand lower temperatures.

In addition to all these controls, certain safety devices and interlocks should be incorporated, such as prevention of relighting of burners to avoid furnace explosions when there is a fuel lockout.

Most of the actuating controls may be either electronic, hydraulic or pneumatic. Electronic controls reduce the time lag to a great extent. Pneumatic controls are preferred because of their simplicity. If pneumatic controls are employed, some safeguard should be provided against the failure of instrument air supply. This can be done by provision of locking arrangement for all controls, when there is failure of air supply.

The automatic control of feed cycle also is quite important. The factors to be controlled are water level in condenser, hot well feed water heater, the evaporator, and deaerater. Also, the conductivity and p.H. value of water should be maintained.

Three Important Aspects

Attention should be given to three important aspects in any fuel efficiency service programme. The first is to carry out sufficient propaganda and bring home to the industrialists and technical personnel the great need for fuel economy. Then comes direct technical survey and help. Thirdly, comes training and education of boiler attendants in fuel economy measures.

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Steps for Efficient Operation of Boilers

THERE was a time when the boiler house used to be considered as of secondary importance, occupying not quite a reputable place in the industrial establishment: out of favour, and a nuisance. It was even thought that not much technological knowledge or skill was necessary for operating boilers. As long as fuel was easily available—and there was no question of economy in those times—the boiler plants could and were in fact run by semi-skilled workers.

Times have changed. Boiler houses cost; their running also costs, and their stoppage is costlier. Modern managements, therefore, are aware of the value of fuel economy and the efficient running of boiler plants: and the two are interrelated.

Inefficient boiler operations are caused by bad combustion conditions, non-conformity of steam to the external load, haphazard way of cleaning fire, so that lots of combustibles go away with the ash, and dirty heat transferring surface, etc. For efficient operation, a skilled boiler operator will take the following measures in case of a mechanical stoker fired boiler.

(a) Adjustment of fuel thickness by the guillotine door, and regulating grate speed for supplying steam for a particular load. The same quantity of fuel can be burnt with a low speed of grate, and thick fire or high speed and thin fire. The boiler operator's own judgment and experience, along with such instruments, as pressure gauges, steam flow meter, CO_2 meter, draught gauges, steam flow-air flow meters will enable him to choose suitable grate speed and fuel thickness to have the best results.

(b) Introducing the required amount of air for combustion by the damper control in the forced and induced draught fan

Type of fuel	CO_2 %	
	Boiler Exit	Chimney Base
1. Pulverised fuel	13 to 14	12 to 13
2. Stoker firing (various coals)	12 to 13	11 to 12
3. Oil firing	12 to 13	11 to 12

ducting, or regulating the speed of the fans. The CO_2 meter gives an indication as to the amount of air to be introduced.

The table above gives an idea about the CO_2 percentage in the flue gas for several types of fuels, for efficient combustion. The boiler operator should try to keep proper percentage of CO_2 in flue gas by controlling fuel and air for combustion. Some boiler houses are equipped with steam/air flow meter, which is set initially by the combustion engineer; thereafter, the fireman adjusts the air supply by observing the indicator. Combustion can sometimes be improved by increasing the proportion of secondary air, as this increases the turbulence in the furnace. Boiler operators must adopt efficient methods of fuel firing. For hand firing, the fuel should be supplied regularly, and at short intervals, through alternate fire doors: a thin even fuel bed with all corners of the grate covered should be maintained. The thickness of the fire depends on the class of fuel and the demand for steam. Too thick a fire bed is uneconomical in fuel consumption. The best results are obtained by an even fire, and regulating the draught to give a very light-brown smoke. While firing, the fire doors should be kept open for as short a time as possible to minimise ingress of cold air into the furnace. When demand for steam increases, the draught should be increased. It is a bad practice to lower steam pressure by opening fire doors, and allowing cold air to enter furnace.

In mechanical firing also, fuel thickness and air pressure for any given steam output would depend on the class and size of coal. Again, the experience and judgment of the boiler operator are the best guide. The grate should be run at such a speed, and the fuel fed in such amounts, that the whole of it burns out completely on the grate, not more than three quarters down the length of the grate: because (a) a sudden call for more steam can be met only by increasing the grate speed without the unburnt coal reaching the dump bars; (b) otherwise, a short fire of less than $\frac{3}{4}$ length of the grate will cause intense heat under the front arch with consequent danger to the arch block; and (c) the length of fire affects superheats.

Clinker Formation

One of the most destructive factors in boiler economy is clinker formation. Burning of low-grade coal having ash of low fusion temperature leads to clinker formation, fuel wastage, inefficient running of boiler etc. Though the boiler operator may not be responsible for the procurement of inferior type of fuel, he should not allow incombustible ash to accumulate in the furnace. Fire should not be stirred as far as practicable, as ash gets raised in the fusion zone.

The boiler operator should also keep the heat-transferring surface as clean as possible by regularly operating soot blowing devices. The steam requirement in a power station, or a process plant, varies widely, and it is the duty of the boiler operator to take immediate steps to meet varying conditions, so that steam is not lost in blowing out through the safety valves, when the load is down, or the boiler is required to be forced, resulting in unburnt fuel going out with the ash when the load goes up. By watching carefully the pressure gauge, and the steam flow meter, the fireman can, to a great extent, reduce the losses. The installation of a critical pressure gauge in the boiler house is helpful in this respect. This instrument is used along with the normal pressure gauge, and is of magnified divisions operating between the limits of 10 lb/in^2 pressure on either side of the red mark, conforming to working pressure. With this pressure gauge, the boiler operator comes to know much earlier than the indications available from the less sensitive pressure gauges fitted on boilers, as to when to regulate his boiler.

Foaming and priming also stand in the way of efficient boiler operation, and cause wastage of fuel. These phenomena generally occur under the following circumstances: (a) high quantum of dissolved solids in boiler water; (b) going up of the water level in the boiler; and (c) the boiler being forced to meet sudden increase in steam demand. The salt concentration in the boiler can be kept at a desirable limit by blowing down a little amount of boiler water judiciously. The water level in the boiler can be kept at a desired level by controlling feed pump and feed check valve carefully. Forcing of boilers may be avoided by keeping a watchful eye on operating performance. Injurious scale formation also occurs in the superheater tubes, and the prime movers, with disastrous results. These are easily avoidable, if managements are really interested in Fuel Economy.

Discovery of Murdock

The year — 1792. A Scottish Engineer, William Murdock, one day, heated a quantity of common coal in a kettle, let the resulting gas to a tank, and there allowed it to escape through a small hole. By applying a match to the escaping gas, he discovered that he had a light by which he could read. Coal gas was first used for lighting purposes in the Soho Works under Boulton and Watt where Murdock distinguished himself by his inventive genius.

"A modern gasworks", says an essay on 'Modern Marvels in Science and Industry', "is really little more than a wonderful elaboration of Murdock's original plant. In giant brick ovens — each holding as much as 350 lb of fuel — the coal is heated to a high temperature by controlled furnaces, thus liberating the gas and leaving what we call coke behind. This raw gas, however, contains many impurities which have to be removed before it reaches our homes. In the first place it is passed through water, where a certain amount of tar and ammonia (which is later used in many ways) is removed, after which it is condensed and again scrubbed and washed to eliminate other traces of ammonia and tar. Whereupon a treatment by lime gets rid of sulphur impurities and the gas is ready for storing in those easily-distinguishable tanks we often call gasometers . . ."

Where SISUA Scores

South India is far away from coalfields, and the need for efficient use of fuel had been keenly felt by industries in the area for a long time, as fuel contributes a major cost factor in all manufacturing units using steam. Hence, in 1950, representatives of many industries got together in Madras, and formed the self-service organisation which was then called "The Madras Provincial Steam Users' Association." When the States were reorganised, the Association expanded the area of operation to cover the States of Andhra Pradesh, Kerala, Madras, and Mysore.

In an account of fuel efficiency service in South India, Mr AH Sargunar, Vice-President of South Indian Steam Users' Association (SISUA), says: "While most of the large steam users in the South have the required technical staff to deal with problems connected with efficient steam-raising and utilisation, most of the small steam users, like rice-mill owners and other small industries possessing small boilers, do not even have qualified boiler attendants." So, SISUA extended its services to such units by giving them technical advice and help, which they could not afford individually . . .

"One of the important works done at present by way of direct technical service is free analysis of boiler feed water and advise on feed water treatment. Minimising scale formation by suitable water treatment and blow-down control had led to the proper maintenance of boilers in many member-firms, leading to considerable saving in fuel. In addition, advice regarding lagging and steam trapping, air venting, condensate recovery, pre-heating of boiler feed water in economisers, avoiding steam leaks, using the available steam most efficiently, breaking of coal to proper-sized particles before use, etc., have been given and implemented which also have reduced fuel consumption. Special advice on the use of low-grade fuels, like rice-husk, groundnut husk, saw dust, wood waste, tapioca waste, coffee and cashew kernels, and bagasse have been given to small and big steam users, and we have given designs of step-grate furnaces, etc., to many members using such fuels. We have helped many member-firms in converting their coal-fired boilers to oil-firing."

RENE J BENDER

Associate Editor, POWER
New York

For High Efficiency . . .

Fuel and Boiler Must Go Well Together

IN MANY industrial plants the world over, the fuel used for steam generation constitutes one of the heaviest operating expenses. It is, therefore, essential that great care should be given to the selection of the most appropriate fuel and, at the same time, to the design of the equipment that will most effectively make use of it.

The first thought must be given to the possibility of not purchasing any fuel at all, or at least a minimum quantity of it. This is done more and more frequently in plants where some "exothermic" reaction takes place as part of the main process; a great deal of the heat thus generated can be recovered, through heat exchangers or some other means. Other plants where fuel purchases can be minimised are those where the process produces a cumbustible by-product, e.g., *bagasse* in the sugar industry, wood chips, saw dust, in the pulp and paper and the furniture industries; even coffee or cocoa hulls are good fuels. These special fuels can generally be fired efficiently in furnaces specially designed for that purpose, such as dutch-oven types; they can often be fired today on spreader stokers with some modifications. There may be enough of these by-products to supply all the steam needed; in other cases, some supplemental fuel may be required, normally or as a standby.

In the great majority of cases, however, fuel must be purchased. Which fuel will be selected depends, first of all, on the geographical location of the plant.

It is a well-known fact that the cost of transportation is a primary factor in the price of fuel. When the plant is located near a coalmine, a natural gas, or oilfield, there is no problem. Where the plant is located near the sea coast, a study needs to be made of the supply situation now, and projected into a reasonable future.

A source of fuel that looks highly advantageous today may dry out suddenly because of a change in the international outlook, a political upheaval, some evolution in the national economy; by the same token, another and, perhaps, more profitable source of some other fuel may open up. India happens to be in a particularly crucial portion of the world, with the proximity of Communist China, a powerful unknown quantity, and of vulnerable South-East Asia. It would, therefore, be advisable to be prepared for any economical change, and to select versatile equipment, capable of storing, handling and using a great variety of fuels, solid as well as liquid or even gaseous, as conditions may warrant. This is of particular importance if *large* steam generators are concerned, such as in a steel mill, a chemical complex, a paper mill, or a large food plant—not to mention a public utility generating station.

Relative Merits of Fuels

Let us, then, look at the various fuels, and talk about their relative merits.

There is a great deal of coal in India—but distances are long, from mines to utilisation points, and transportation generally difficult. It is, therefore, necessary to make use of the coal from the nearest possible mines—and the properties of these coals vary greatly. An analysis must be made to determine the essential characteristics of the coals available: volatile matter, moisture, carbon and ash content, expressed in percentages, calorific value, in B.t.u. per lb., grindability, expressed in index of grindability, and fusion temperature of the ash, in degrees F. These characteristics will be used to decide which sort of firing equipment must be selected.

Obviously the extent of the demand for high combustion efficiency will vary with the quantity of fuel burnt yearly—and its cost, delivered at the plant. When large tonnages of coal are involved, and/or when it is very costly, a much greater initial investment for efficient equipment is justified: even a small gain in efficiency, when multiplied by the tonnage, may mean many Rupees. On the other hand, if the tonnage is small, the tendency will be to use less expensive, even though less efficient, equipment.

One piece of firing equipment very popular in the USA is the spreader stoker. It actually makes use of a combination of two techniques: The "fines" in the coal are burned in suspension—like pulverised coal, but without any pulveriser—while the heavier portions fall upon a travelling grate, where they burn more slowly, and completely. These stokers are available from the smallest sizes—e.g., for a firetube or a watertube packaged boiler of 10,000 lb. per hour capacity, up to large capacities, say, for boilers delivering over $\frac{1}{2}$ million lb of steam per hour.

From about 1,20,000 lb. of steam per hour up, coal can be burnt with great efficiency in pulverised form. Its moisture content may be as high as 15% to 18%. It is dried with hot air while it is being pulverised. A broad range of coals can be burnt pulverised, even with a high ash content. When the fusion temperature of the ash is low, say, below 2,000°F, a "slag-tap" type of furnace is used, and molten ash is drawn out from the bottom, once or several times a day; when the fusion point of that ash is high, a dry-ash bottom, hopper-shaped, allows removal of the ash in clinker form. When the difference in cost between coal and other fuels is great, it may be entirely in order to install pulverised coal equipment for boilers producing well below the minimum mentioned above: equipment is available for boilers generating as little as 50,000 lb. per hour. This type of equipment was quite popular in America some 30 years ago, but today there is not enough price difference between the various fuels to justify its use for medium size boilers.

Another attractive way to burn coal—fines and crushed coal, **not** pulversied—is in a cyclonic type of furnace, especially when the ash fusion point of the coal is low. Here, coal and air enter tangentially into a cylindrical horizontal furnace, from 5 ft to 10 ft in diameter, and burn with great turbulence, and with a high release of heat. Under the high temperature, the ash melts and slag runs down into a tank. In India, where there are several cases where coal can be put into a slurry, with water, at the mine mouth, and brought to a boiler plant in a pipeline, the cyclone type of furnace is particularly adaptable, because it can burn, without any significant pre-drying, coal with an enormous quantity of water.

It may be stated that all installations where coal is burnt in suspension, partly or entirely, must have equipment available for the removal of cinders and fly-ash from the flue gases, especially in strongly populated areas: these may be mechanical, dry or wet, dust separators, or electrostatic precipitators.

Little needs to be said about natural gas as fuel; it is clean and efficient, although intrinsically not quite as efficient

"Our fuel transportation costs are frightful; but the Chairman of our Corporation loved life in a far away hill station."

... Versatility of equipment is a good insurance against surprise changes in the source of fuel supply ...

as an equivalent quantity of coal or oil, because of its higher stack loss due to the greater content of hydrogen in gas, which is transformed into water vapour.

When using gas, supplied either through a pipeline or through refrigerated methane-tankers, it is always prudent to have available a standby reserve of LP gas or fuel oil, and burners adaptable to these fuels, in case of interruptions of gas supply, for any reason whatever.

Whenever it is available, fuel oil is one of the best fuels: it has the advantage of perfect automaticity, just like gas, yet it is generally less costly. For small boilers, a distillate oil—often called furnace oil—must be used: it is clean, flows freely at low temperatures, has little or no tendency to clog strainers or nozzles. It is just one grade below what is called kerosene in America, and paraffin in Great Britain. For larger units, a heavy residual oil, called indifferently mazouth, No. 6 oil or Bunker C oil, is acceptable. It must, of course, be filtered, and preheated with steam or electric heaters in order to run freely in cold weather; when it is cold, the "viscosity" of the oil, that is its resistance to flow, is very high and it is quite unmanageable. For proper "atomisation", the temperature recommended is generally that which will bring its viscosity from 150 to 200 Saybolt Universal, which is about 4.5 to 6 degrees Engler, or 130 to 176 Redwood seconds.

Oil can be atomised mechanically under pressure followed by release through a fine-hole nozzle; by centrifugal force, in a burner shaped like a cup rotating rapidly around a horizontal axis; by compressed air; or, most frequently, by steam. Pressures and quantities of steam vary with every type of burner.

When burning heavy fuel oil having a high content of impurities in the ash, such as sulphur, sodium and vanadium, care must be taken to avoid condensation in the portion of the installation immediately preceding the stack, that portion which contains the tail-end of the boiler, the air heater, the induced draft fan and the breeching. If the temperature of the flue gases falls close to the "dew point", i.e., the temperature where condensation takes place, equipment gets rapidly corroded. That is because the water vapour in the gases condenses, combines with the sulphur products in these gases, and the result is sulphuric acid. This can be avoided, at least partly, in several ways. When the efficiency needs not to be very high, the flue gases can be made to leave the stack at a temperature high enough to avoid condensation; when, on the other hand, high efficiency is important, combustion carried out with a very low amount of excess air will generally minimise corrosion; present level accepted as advantageous: 5% to 6% of excess air. This method can be combined with the introduction into the gases of some magnesium compound such as dolomite, magnesium oxide, or even magnesium metal. It can be fed into the furnace, or sprayed upon the boiler tubes through the retractable soot blowers, several times a day.

Summingup, selection of a fuel and a steam generator is essentially a matter of good judgment, taking into account the location of the plant in relation to the source of most likely fuel, the cost and characteristics of the fuel, and the size of the boiler needed. Versatility of equipment is a good insurance against surprise changes in the source of fuel supply.

M SEN
and
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Utilisation of Fuel for Steam Generation

IN SPITE of the advent of atomic energy and increased emphasis on the development of hydel power and oil resources, it is certain that coal, our chief industrial fuel, will continue to hold its prime role in filling up the gap between the rising demand and supply of energy in the country for many years to come.

According to official estimates, the present production of coal is about 67 million tonnes. To meet its growing demand it was planned to increase production to about 97 million tonnes at the end of the Third Plan Period (1965-66), and to about 180 million tonnes at the end of the Fourth Plan Period (1970-71). To achieve scheduled targets, mechanical mining and handling, coupled with working of inferior seams, have to be introduced on a large scale than hitherto. This would mean higher concentration of dust, as also higher ash content in the coal mined. The demand of metallurgical coke conforming to stringent specifications of the steel industry has necessitated beneficiation of coal by washing techniques for which a number of washeries have already been set up. These washeries are designed to produce large quantities of high ash byproduct fuels, and it was anticipated that at the end of the Third Plan Period, the production of these fuels would amount to at least 6,500,000 tons a year. It was also estimated that at the end of the Third Plan, out of a total annual production of 97,000,000 tonnes, slack coal (below 1" size) would account for more than 30,000,000 tonnes. It is obvious that the bulk supply of fuel for steam-raising in future would have to be met from low-grade coals consisting of high ash non-coking coals, washery byproduct fuels, and non-coking slacks.

The availability of low-grade coals poses a number of problems in efficient fuel utilisation for steam-raising. The first and foremost thing is to make a suitable choice of boiler plant that will permit attainment of a high level of thermal efficiency, with minimum cost in boiler operation and maintenance. A recent survey of some existing boiler installations in the country by the Institute of Economic Growth (New Delhi) has revealed that improvement in efficiency to the extent of 15% to 20% can be attained, in many of the installations surveyed, by introducing appropriate fuel efficiency measures.

Major Problem

The major problem in the burning of low-grade fuels, in units not designed for the purpose, is the reduction in boiler availability and efficiency owing to poor combustion arising from excessive clinker formation, increased fuel bed resistance, and ignition difficulties. Considerable attention has been focussed, since many years, in developing suitable firing techniques to obviate the difficulties in low-grade coal combustion. The techniques developed may broadly be classified as: (1) Suspension firing, (2) Grate firing, and (3) Combined firing.

Suspension Firing: An important and well-recognised technique of burning low-grade coals lies in their use in powdered fuel-fired boilers. The efficiency of combustion in suitably designed pulverised fuel-fired furnaces can be as high as 90%. Pulverised fuel-fired boilers are classified as dry bottom and wet bottom types, depending on the methods used for ash disposal. The dry bottom type is suitable for coals with high ash fusion temperature (over 1400°C), whereas wet bottom furnaces operate under slagging condition, and are suitable for coals of medium to low ash fusion temperature.

The powdered coal, for efficient combustion in p.f.-fired furnaces, should have at least 70% of the material passing through 200 mesh (BSS). Extensive studies at CFRI have shown that the grindability for Indian coals is fairly independent of the ash content. Therefore, there would be no appreciable increase in power cost for grinding high ash coals. The power stations in Bokaro and Durgapur are examples of large p.f.-fired installations in this country: both, however, are of the dry bottom type.

The latest development in firing technique for low-grade coals is the introduction of the slag tap cyclone furnace. Cyclone firing can handle a wide range of coals with ash varying from 3% to 50%, moisture from 3% to 61%, and volatile matter even as low as 7%. The cyclone furnace essentially consists of a fully water-cooled cylindrical chamber into which the fuel/primary air mixture and secondary air are fed, so that the streams whirl a few times before the gaseous combustion products leave the chamber through a re-entrant throat at the back end. Depending on the location of the coal/air mixture nozzle, the cyclone may be classified as axial or tangential fired. In axial firing, the coal/air mixture is introduced helically through a scroll at the cyclone axis, and preheated secondary air is admitted tangentially along the periphery of the burner. In tangential firing, on the other hand, both the coal/air and secondary streams are introduced tangentially at the cyclone periphery.

Cyclone Furnace

Besides decreased dust entrainment problems, and other related merits, the cyclone system of firing offers the greatest advantage over p.f. firing in its reduced power cost for fuel preparation as it takes only coarse fuel in the size range of ¼"—0", even wet.

The smooth operation of cyclone furnace, however, warrants that the hemispherical temperature of the coal ash should not exceed 1350°C, and the viscosity of the fused ash at 1430°C should be below 250 poise. In this context it might

TABLE I

An estimate of sectorwise consumption of coal in India for the period 1961 to 1971 (in million tons)

	Sector	1961	1965-66	1970-71
1.	Railways	15.32	21.00	35.00
2.	Iron & Steel	8.90	16.10	27.00
3.	Electricity Generate	6.10	17.00	39.00
4.	Merchant Cokeries	1.04	2.00	4.50
5.	Cement & Brick	3.94	8.50	21.00
6.	Paper & Paper Board	1.00	2.00	3.50
7.	Textiles (Cotton & Jute)	2.16	2.30	3.20
8.	Sugar & Chemicals	1.12	2.00	4.50
9.	Engineering & Foundries	0.50	1.88	2.00
10.	Domestic	2.00	4.50	10.00
		42.08	77.28	149.70
11.	Others including Colliery Consumption	10.92	17.72	25.30

be apprehended that the large-scale adoption of this technique may not be practicable, as the ash of a large majority of Indian coals is refractory in nature. This refractory character of coal ash and its flow property, however, can be suitably modified by a technique known as "doping." Doping studies carried out at CFRI have shown that by addition of doping agents, like haematite or limestone, in small but adequate quantities, or by blending with washery rejects and middlings having large iron content in suitable proportions, the fusion characteristics of the coal ash can be suitably controlled for cyclone firing.

Restricted Adoption

For obtaining detailed information on the basic design data and operating characteristics of cyclone firing, with particular reference to Indian coals, an 18" diameter slag tap cyclone furnace has been installed at CFRI. Although the p.f. and cyclone firing systems are highly conducive to efficient combustion and heat generation, yet their adoption, on a large scale, is restricted by the relatively higher capacities for which the units have to be commissioned. Techno-economic considerations make it imperative that normally for such installations the steam generation capacity of the boiler plant should not be less than 100,000 lb of steam per hour.

The technique of fluidised firing developed in France provides combustion of coal fines virtually in boiling fluid bed. The process claims to be able to handle any coal (up to 3/8" size), with high ash and moisture content: it has, however, found little commercial application so far.

Grate Firing: The most important class of boilers next to p.f. and cyclone fired ones for burning low-grade fuels are stoker fired units. Mentioned below are some of the important stokers with their fuel specifications:

(a) *The compartmental stoker:* The compartmental stoker is a modified design of travelling grate stoker in which the distribution of air is properly zoned along the grate length so as to permit burning of $1\frac{1}{4}$"−0"-sized coals with ash content up to 35%.

(b) *Sprinkler or spreader stoker:* This type of stoker is adoptable to variation in fuel quality, fuel sizing, etc., and $1\frac{1}{4}$"-0" coals having ash up to 30% and fines (1/8") as high as 40% can be burnt.

(c) *Martin Stoker:* A number of different types of overfeed stokers have been developed specifically for burning low-grade coals, including washery byproduct fuels such as middlings and slurries. The Martin Stoker is an important instance of such stokers. This is a sloped stoker with reciprocating grate surface, and can handle coals with ash up to 40% and moisture up to 40%.

Combined Firing System: A number of techniques incorporating both grate firing and p.f. firing have been developed for burning low-grade coals, and the H-K system developed in Hungary is one of them. In brief, the principle of its operation consists in passing the raw coal to a vertical classifier, where particles below ⅛" are separated by hot flue gas elutriation and the oversize collecting at the classifier tube bottom is fed by a rotary feeder to a grate hopper whence it is drawn by a roto grate of a conventional design. The fine dust entrained in the hot flue gas is sucked by a closed circuit grinding mill which delivers the pulverised coal through suitable burners into the rear, or sides, of the boiler furnace.

In view of the deteriorating fuel quality, the new installations in the country should be encouraged to adopt suitable designs of firing mechanism as described above to burn increasing quantities of low-grade fuels.

For the existing boiler furnaces, and particularly those which are designed for better grade coals, it would be necessary to incorporate suitable changes in the firing mechanism in order to operate with inferior quality fuel. This change, in many cases, particularly in stoker-fired boilers, can be effected either by the introduction of simple and inexpensive modifications, and/or additions in the boilers, or by suitable treatment of fuel prior to changing.

When a good quality of fuel is available, mixed firing with low-grade coal, either by blending the two prior to charging, or by firing them in two separate layers over the grate, with the better coal at the top, as practised in the sandwitch system, has proved to be helpful in many instances.

In places where the supply of solid fuel is of a lower grade, lower than for which the stoker was designed, either Oil Assisted Ignition or Steam Jet Ignition system can be adopted to help in the ignition and better combustion of low-grade coals. In the Oil Assisted Ignition system, a few oil burners are installed at the top of the fuel bed in front of the stoker, so that the flame impinges on the coal bed to help its burning. In the Steam Jet Ignition system, the equipment consists of a number of steam nozzles arranged in such a way that the jets cause a reduction of pressure in the ignition zone of the combustion chamber, as a result of which the hot gases and flames flow back towards the front side of the grate, and assist combustion of the incoming green fuel.

Boiler Rating

To study the operational characteristics and possibilities of using high ash coals in existing installations, tests with washery middlings were conducted by the CFRI on a water tube boiler of 140,000 lb per hour evaporation capacity, and fitted with a spreader stoker. It was possible to run the plant at nearly 90 per cent of the rated load, without any operational difficulty. The fuel used was of 1½"–¼" size, and it was expected that by increasing the fines it might have been possible to raise the boiler rating without attendant difficulties.

The scope for utilisation of low-grade coals in hand-fired boilers is limited, but by proper conditioning of fuels with moisture, or by humidifying the under grate air with adequate steam, these types of boilers can accommodate, a larger amount of fines in the fuel without any serious trouble. For large installations, it is preferable to change over from hand-firing to mechanical stoking, and this changeover will not only permit the use of inferior types of fuel, but also improve the thermal efficiency of the plant by eliminating the usual losses inherent in hand-firing. Under certain economic conditions, some of the small hand-fired boilers may profitably be modified to p.f. firing. The CFRI has carried out considerable developmental work in this field, and have worked out details for such changeover.

Combustion Problems

In the designing of new boiler plants, or modifying an existing one for burning inferior grades of coal, the following points are to be considered carefully:

First, since the ash residues to be handled and disposed off will be considerably large, the capacity of ash handling plant and facilities for dumping the refuse are factors which require particular consideration in general plant layout, and site selection.

Secondly, not only the quantity of coal ash, but also its composition and other characteristics, that are liable to cause deposit and corosion troubles, have to be considered in designing the boiler furnace, and its ancillary equipment.

Thirdly, it may be necessary also to provide dust collectors and suitable refiring mechanism, so that the dust burden and the combustible content of the dust at the stack may be comparatively reduced.

The choice and design of a suitable burning appliance, though of vital consideration, is not, however, the only answer to the question of efficient fuel utilisation for steam generation. The scope of the subject is quite wide, as within its jurisdiction lie the problem of suitable choice of steam-generating equipment; all the steps beginning from proper storage and handling of fuel up to the disposal of the refuse; and the mainteance and operation of the boiler plant, auxiliaries, and instruments.

Where a new industrial boiler plant is contemplated, the advantage of high steam pressure in relation to the generation of back pressure power should be considered. Process steam pressures, on the other hand, should be reduced to the lowest practicable limits in the interest of both efficient steam utilisation and back pressure turbine. Mention may be made here that boilers of the Trombay Power Station, and those of the Durgapur Thermal Power Station and the Rourkela Steel Plant have all been designed to operate at pressures of 1,000 lb/sq. in. or above.

The operation and maintenance of a boiler plant are as much a specialised job as its design or construction. Boiler operators should be educated to a standard

Aid to Increase Yield from Farms

Solar energy can be profitably utilised not only for generating power, but also as an aid to increasing yields from the farms.

Speaking on some problems in utilisation of solar energy, at a meeting of the Institution of Electrical Engineers in New Delhi, on Jan. 17, Prof. U. Arifov, academician of the Uzbekistan Academy of Sciences, said, solar enery must be utilised to the maximum as some sources of energy were fast dwindling. Very little research, he added, was being done in the field of conversion of solar energy into mechanical and electrical energy. The problems involved in this conversion were great, and needed a thorough study and research.

in keeping with the needs of their job. The proper maintenance of safety valves, or adequate treatment of boiler feed water, is as important as vigilance on the rate of firing or water feed.

Unfortunately, the need for adequate insulation of the boiler plant is not often realised fully. The surface heat losses from an uninsulated boiler can, however, easily exceed 10 times that of a similar, but properly insulated, one. Proper insulation of boiler plant should thus be practised rigidly to restrict surface heat losses to the lowest practicable limit.

A provision, to the appropriate extent, for waste heat recovery has to be introduced in all boiler plants by installation of suitable boiler auxiliaries, such as air preheaters, economisers, and steam superheaters. To illustrate the importance and economic justification of these heat recovery units, it may be mentioned that the installation of a simple economiser even in a small boiler house is apt to raise the thermal efficiency of the boiler plant by 6% to 8%, and the cost involved in the new installation can be well recovered in less than two years' time from the savings to be incurred in reduced coal consumption. Another important aspect of waste heat recovery is the use of return condensate in boiler, which, if adopted properly, will not only recover heat otherwise going as waste, but also will help to keep the boiler free from scale deposits, thereby maintaining the heat transfer rate at a high level, and ultimately extending the life of the unit.

Mechanical handling of coal and ash should be employed, wherever possible, as a means of reducing cost on boiler house.

Pulse of Boiler Plant

Boiler house instruments are the pulse of a boiler plant, and, without the aid of adequate instruments, it is neither possible to run the boiler efficiently nor to assess its performance. Minimum requirements of instruments in boiler practice include suitable devices for the measurement or recording of steam flow, steam pressure, draught, flue gas temperatures, pH of feed water, and combustion efficiency in furnace. By far the most important instrument from the point of view of efficient boiler operation is, however, the device that records combustion efficiency in terms of air used per lb. of coal consumed, whether this takes the form of a CO_2 meter, a residual oxygen meter, or a simple laboratory gas analyser. The smokeless combustion of coal is not only vital from the point of boiler effi-

...Scientific and efficient utilisation of coal for steam-raising is vital for the conservation of fuel resources, as also for minimising the steam bill of consuming industries...

ciency, but is equally important, if not more, from the point of health and sanitation of the surroundings.

Boiler performance tests should be conducted periodically, and the test data utilised in introducing suitable measures to effect fuel economy.

The automatic control of boiler plant is not only more certain than manual control, but is also sure to effect improvement in thermal economy.

With the growth of industrialisation visualised in the successive Five-Year Plans, the use of coal for steam generation will assume an increasingly important role. Scientific and efficient utilisation of coal for steam-raising is thus vital for the conservation of fuel resources, as also for minimising the steam bill of consuming industries. The country's fuel position warrants that for the future steam raising, low grade coals have to be utilised in increasing proportions with the march of time. Efficient utilisation of these low-grade coals will necessitate, on the one hand, increased adoption of modern techniques for burning inferior grade coals in proposed installations, and, on the other, introduction of suitable modifications in the firing techniques of existing installations to facilitate accepting inferior types of fuels.

Apart from selecting the right type of boiler plant with its accessories, attention is also called for proper supervision of its operation, and maintenance. Economy in fuel consumption is an important aspect of efficient fuel utilisation. A survey of some boiler plants in the country has revealed that a good deal of economy in fuel consumption can be effected in many of the units surveyed by the introduction of appropriate fuel efficiency measures. Hence it is imperative that efficiency tests should be conducted in all boiler plants periodically, and test findings implemented properly, for not only attaining the rated efficiency of the plant, but also for effecting economy in fuel at all steps of its usage.

The Loss

The loss in human lives in coal mining is pretty high. "Every day", says an essay on Marvels in Science and Industry, "men in cages descend deep into the interior of the earth. There, often lying for hours on their backs, hacking away at the coal seam above, they defy the peril of lurking gases, crumbling walls and frightful explosions so that we may mend our fires and feed our hungry machines. Often terrible pit disasters occur. Every year the price of coal is paid in scores of lost lives and mutilated limbs. . . ."

HS DWARAKANATH

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Cause, Effect & Cure of Fluctuating Steam Loads

FLUCTUATING steam loads, with pronounced peaks and valleys, occur in many industrial undertakings. Very obviously, they have an adverse effect on fuel efficiency, and, therefore, upon fuel costs. Not only does the fuel account get inflated, but production is also affected in quantity or quality—or both. There have been many cases in which the management, because of the incidence of peak loads, has decided to install new boilers as extensions to the existing plant, and even to scrap the existing boiler plant, though it involves large capital expenditure, considerable disturbance within the works, and sometimes temporary shut-down with consequent loss in output. In the great majority of these cases, alternative methods were available, at much less capital expense. This paper tries to explore the basic causes of these fluctuations, noting alongside some possible cures. Each case, however, has to be treated on its merits, separately diagnosed, individually treated: there is no easy solution to every case.

Two main types of fluctuation may be broadly differentiated on time basis: long and short duration peaks, or valleys. Typical examples of short-term peaks, inevitably followed by valleys, are the colliery winding engine, or in a steel works, those loads caused by steam hammers and the drives of rools and presses. Figure 1 shows the steam loading on a steel works. Long-term peaks and valleys are found in textile works and in sugar refineries, and in any chemical plant where batch processes are carried out. Figure 2 shows a typical uncorrected steam loading from the dye works section of a textile mill.

Figure 3 (from a paper by EG Ritchie) shows the fluctuation in steam load in a colliery over a period of only three minutes: during this short time the load varied from 5,000 lb to 2,25,000 lb per hour. No boiler plant, uncorrected, can meet this variation in load with both efficiency and safety, certainly not without some reduction in steam pressure. An attempt is made to meet the situation by dropping the pressure in the boiler when the water level is high, thus permitting some flashing off of steam from the surface, but this may involve carry-over.

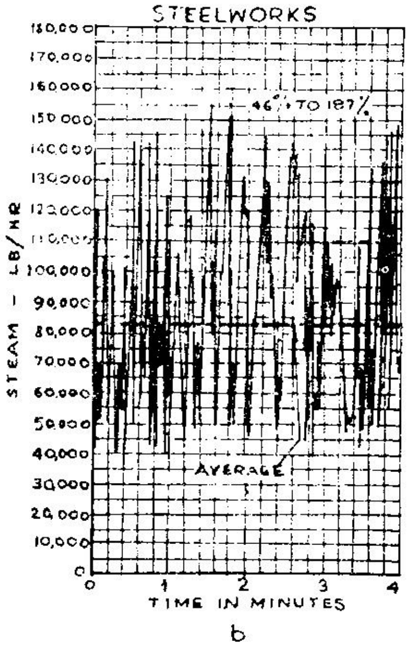
Figure 4 shows a decimal-reading steam chart from a textile mill, the mill including sizing, dyeing, bleaching, scouring, drying, mercerising, and stentering. The full-scale deflection of this steam meter was 47,000 lb of steam per hour. Considering the period between 8 p.m. and 11 p.m., the load was only about 10,000 lb per hour at 8 p.m., rising in steps to 37,600 lb at 8-30 p.m. and falling to 24,000 lb at 9-30 p.m. At 9-45 p.m., it rose sharply to 42,000 falling again to 18,800 at 11 p.m., followed by a fairly steady loading until 1 a.m.

Figure 5 shows, on a direct-reading chart, the steam load in a starch and glucose factory, having two converters, one for glucose and the other for dextrose: these are the items of steam-using plant which, in this factory, exert the greatest influence. At 3 p.m. the load was about 19,000 lb per hour, and steady, but at 3.35 p.m. a convertor was put on causing a sharp peak up to 33,000 falling rapidly to 25,000 at 3-45 p.m. when a second convertor was put on, pushing the peak to 35,000 at 4-0 p.m. Similar peaks and valleys occurred at 4-45 p.m. and at 5 p.m. Although the corresponding pressure curves are not shown, it is apparent that these must have occurred in inverse ratio, peak demand being chased by falling pressure, whilst shortly afterwards the rising pressure must be damped down, driving the boiler fireman crazy and preventing him from giving sufficient time to correct boiler operation, for maintaining high efficiency level.

The examples quoted so far show the effect of the starting up, or the shutting down, of one or two major users of steam, due to the apparent needs of production, though the boiler fireman might not agree.

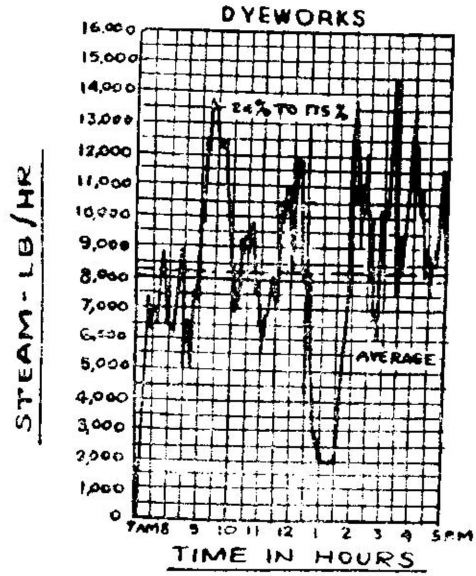
Let us now consider the effects of fluctuation in steam load. Figure 6 is Ritchie's diagram, and it shows the rate of steam demand, not the actual flow, in a factory equipped with a small boiler house. The rate of demand is shown by the solid line, rate of production by the broken line, and the steam pressure by line C. Between 2.0 and 2.45 it is assumed that conditions were steady, and that a rate of firing had been established corresponding to the steam demand, so that the pressure was reasonably well-maintained. At 2.5 a peak develops causing the boiler steam pressure to drop: with this indication that he was short of steam, the fireman increased his rate of firing and opened up his dampers. The boiler was slow to respond, and the pressure continued to fall, while the steam demand reached the maximum at 2.55 and then began to fall off. At 3.05 the safety valves lifted, and with this indication that he was making more steam than was required, the fireman reduced the rate of firing and closed down the dampers. Again the effect was not immediate; and the steam demand was still falling; hence the safety valves remained open until about 3.20 when the rate of steam production was again equal to the demand. At this time another peak demand occurred, and the chase started all over again. The white areas in the figure represent steam demands that were not met; they could be missing altogether on a steam meter chart, except for the amount of flash steam produced from the boiler water by the drop in pressure due to the peak demand. The horizontally hatched areas show the amount of steam blown off by the safety valves. Vertically hatched areas show the steam demand which was actually met.

Unless a boiler is operated with proper care and attention as regards the fuel supply and the necessary air for correct combustion of a given amount of fuel, it is not possible to maintain high



TYPICAL SHORT TERM PEAKS

Fig. 1



TYPICAL LONG TERM PEAKS

Fig: 2

thermal efficiency. But when wide fluctuations of load are present, the fireman cannot give continuous attention to proper boiler operation; he has not got the time, being hard-pressed either in meeting a peak load with falling pressure, or in damping down a rising pressure, and avoiding expensive blow off through the safety valves. Because of the slow response of many boiler plants, when a peak starts it gets aggravated, and the subsequent valley gets deepened; there are also other adverse effects. For example, since a fall in steam pressure affects the specific volume of steam, more energy is lost in transferring increased volumes through the pipework with even lower pressures at the point of usage. Where exact temperatures are critical, as in the rubber and chemical industries, peaks and valleys in steam demand are very likely to affect the quality of the product.

A question is naturally asked: "Need these fluctuations ever occur?" How about the timing of operations which cause the peaks and valleys? This is not a question for the engineer alone, nor for the head of any particular section: it has to be worked out and decided by mutual consultation in which every member of the production team must take part, and each must approach the question with an open mind, and not with a narrow approach. Frequently it would be possible to arrange schedules, slightly differently, without loss of production, but rarely is this done, generally because the various sections of the mill or factory are too parochial, and top management does not take sufficient interest, or perhaps does not stand sufficiently far back to see the overall problem. Assuming that re-scheduling has been examined and proved to be impracticable, other means must be considered.

If thermal energy can be stored in

readiness to meet peak demands, then the boiler plant can be fired at a more or less steady rate with resultant higher thermal efficiency. Storage of thermal energy is possible, in the boiler, as live steam, as preheated feed water, or as preheated hot process water.

Developments in boiler design, over the last few years, have resulted in the production of the Thermal Storage Boiler, generally a high performance economic boiler, increased in dimensions, and capable of operating at very high overload evaporations whilst under steady firing, this being done by starting with high water levels and working down to much lower levels than are permissible in conventional boilers. Such units can produce steam at extremely high rates for periods of 20 minutes or slightly more. Though they are costly, they may not yet be available in India, and, in any case, they are going to require many alterations within the works for an installation.

In any plant, where steam is generated at both high and low pressures, or where it is generated at high pressure only, but is used at both high and low pressures, storage of live steam is possible, and probably helpful, this storage being in the form of a steam accumulator. The accumulator will smooth out both peaks and valleys to a considerable extent, and by permitting the boiler plant to work at reasonably steady rates of production, will materially improve the efficiency of that unit. If, however, the steam is used only at high pressures, an unusual but possible condition, the use of a steam accumulator is not a suitable choice, and other methods must be considered, such as the storage of hot boiler feed water. Even where steam storage is possible, there is no ready rule; each case must be evaluated separately on its merits, and the sizing of the accumulator fixed by the load pattern.

This will prove of advantage where the steam demand is mainly at boiler

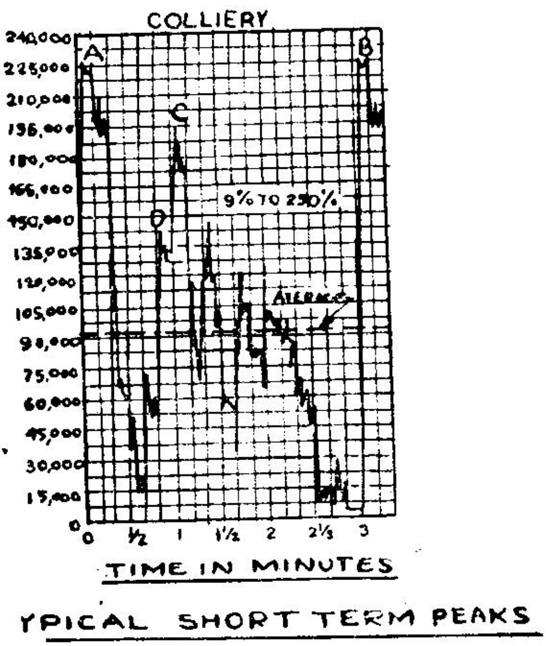


Fig. 3

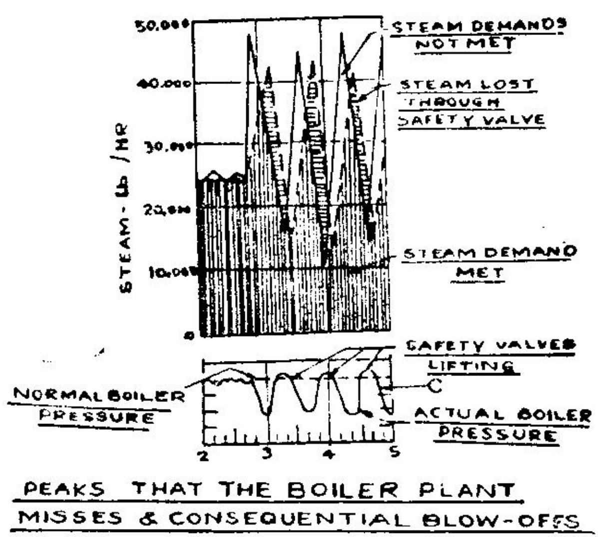


Fig. 6

pressure. The system calls for a nearly constant rate of boiler firing, with a uniform rate of feed supply to the boiler at full steaming temperature, and a constant rate of evaporation, pressure, and superheat. During valleys in demand, excess steam is used for heating feed water. The full value of this arrangement is only possible where the normal feed water temperature is low, and where ample economiser capacity is installed. Up to 30% above the average, the demand can be met without undue drop in steam pressure.

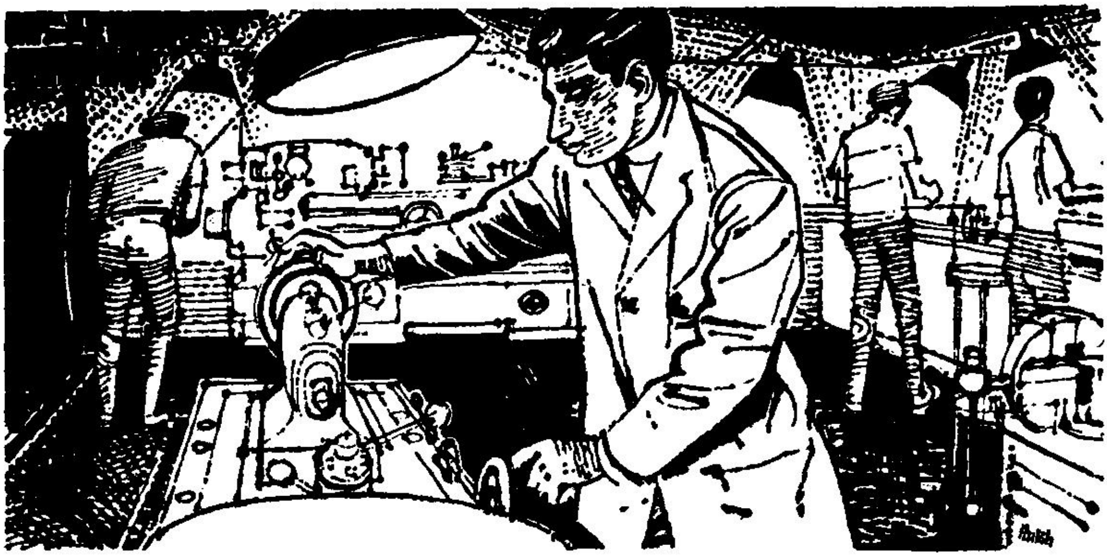
Boiler Peaks

In a great many processes, particularly in the textile industry, water for process usage is raised from cold to, or near to, boiling point, by the use of steam. Instead of this, if hot water is stored and used for the process, it will avoid, or at least reduce, boiler peaks, and may also improve output, because its use will accelerate the process and perhaps reduce dilution due to condensation of steam.

The preceding analysis shows that while it may be impracticable completely to eliminate peaks and valleys, it is still possible to smoothen them considerably. Especially long-term peaks can be smoothened away in a majority of cases. In some cases, the cure may be technical; in others, it may be managerial or both. However, it is sufficient to say that smoothening of peaks would effect considerable economies in fuel consumption, increase production, and improve the quality of the product.

Correlation between Wage and Productivity

Writing on correlation between wage and productivity in USSR, N. Charuikov (Planned Economy) says that USSR has planned to increase productivity in industry 4 to 4½ times, in the coming 20 years, and real income per habitant 3½ times. "Productivity increase should be superior to wage increase. This, being accepted as a basic principle of socialistic economy, means that a certain correlation must be established between wage and productivity to expand production continuously on the one hand, and to elevate living standard progressively on the other hand."

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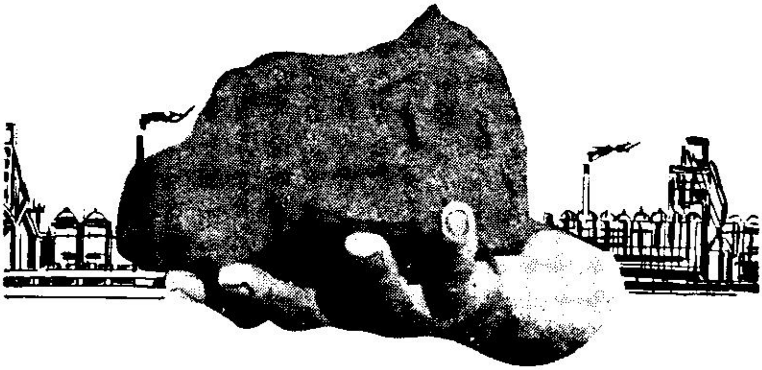
INDIAN IRON ORE PROVIDES THE MUSCLES AND SINEWS OF INDUSTRY ALL OVER THE WORLD



India's hard-lumpy ore has a high iron content ranging from 62% to 69% FE, with impurities of Sillica and aluminium in a proportion that facilitates slag-making. This iron ore is in universal demand for blast-furnaces. The quantity of India's quality ore bought by various countries in 1964 is shown below.

Country	Lakh Tonnes
Japan	66.26
WESTERN EUROPE	
Italy	2.68
Germany	7.47
Others	3.42
EASTERN EUROPE	
Czechoslovakia	7.51
Rumania	5.25
Poland	2.70
Yugoslavia	3.53
Hungary	0.60
East Germany	0.40
Grand Total	99.82

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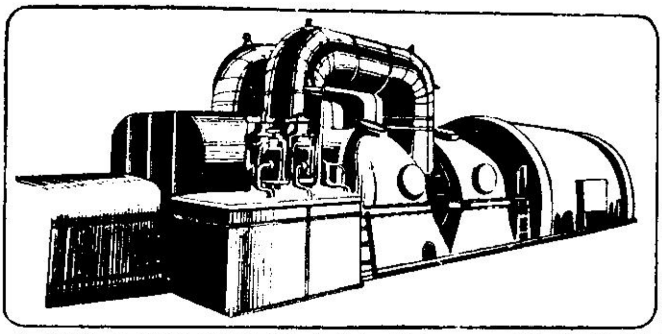
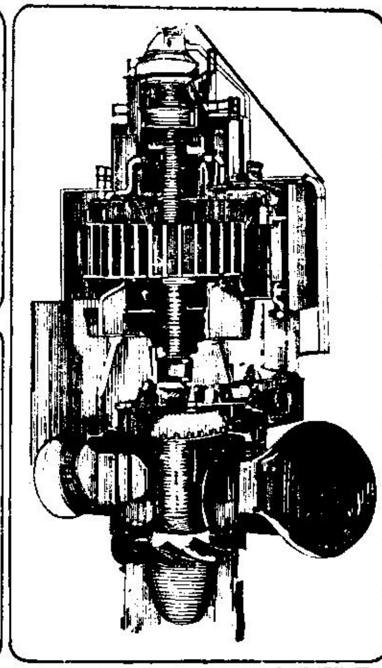
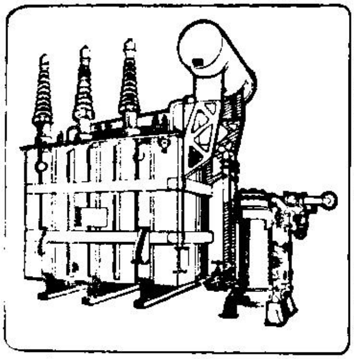
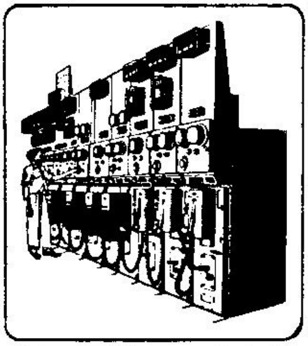
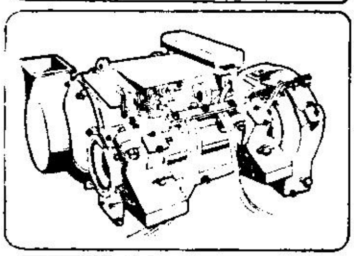
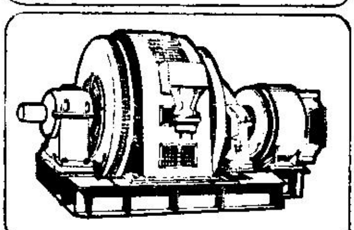
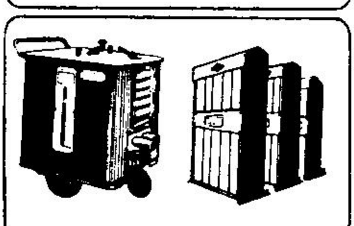








H SAHAI

Chief Fuel Engineer
Bhilai Steel Plant, Bhilai

Fuel Factor in Steel Production

In the making and shaping of steel, fuel and refractories play an important role. In India, where the steel industry is based on coal, and metallurgical coal is not available in abundance, it has become increasingly desirable to concentrate fully on the techniques which lead to fuel economy. The true functions of a fuel economy organisation is not only to reduce fuel consumption per unit of product produced or treated; it has also to control the quality and distribution of fuel, and resultant processes of combustion.

IN A COMPOSITE, integrated steel works, like the one at Bhilai, the problems relating to the efficient use of fuels in all their varied forms are really complex. The work in regard to co-ordination of fuel supply and utilisation has to be directed so as to ensure that heat and power are not only produced, but also used to the best advantage throughout the plant. Hence routine control has to go alongside experimental work, technical investigations, improvement in work processes—all designed to gain increased heat economy, and lower conversion cost.

Coal, coke, coke oven and blast furnace gases, and coal tar oils are the fuels used at Bhilai. Coal in a blended form is carbonised to produce coke which is a raw material in the manufacture of iron. It serves as a reducing agent, and helps to support the burden in the blast furnaces, and also, in small quantities, in foundry cupolas. The smaller fractions find their use in the sintering plant, soaking pits, refractory materials plant, and in the preparation of tap hole mass.

Coke oven gas is a direct by-product of coal carbonised in the coke oven batteries. The coke oven and blast furnace gases are used for industrial heating, either separately or mixed in desired proportions, to meet the calorific value requirements. Blast furnace gas is produced in large quantities by partial combustion of coke in the blast furnaces. Roughly 28% to 30% of this is utilised for stove heating, and the rest is free for utilisation as a low calorific value fuel.

The pitch creosote mixture (liquid fuel) is obtained during the processing and distilling of tar, and is used in the open hearth furnaces primarily for purposes of carburation. The coal tar oils could be gainfully utilised in boilers for fuel injection in the blast furnaces and for spraying the charge to be carbonised at the coke ovens so as to increase its bulk density and yield of coke per oven.

The fuel component in steel making and shaping varies from 16% to 25% in the total cost of production of the finished products. The design, layout, and operating conditions at the Bhilai Steel Plant offer scope, as in fact any other modern plant would, for taking proper measures in the interests of fuel economy.

At the coke ovens, the specifications of metallurgical coke preferred for making basic pig iron are:

Ash	approx.	20%
Volatile matter	between	1.0% and 1.5%
Phosphorus	below	0.2%
Sulphur	below	0.69%
Drum value	above	320 kgs
Porosity	between	42% and 45%

To produce the specified coke, the ash in coking coal has to be *around* 15%. Our resources of low ash coking coal are limited and declining, and the production of coke cannot be kept up to those specifications. Attempts have therefore been made to use better washed coal, along with other measures, such as optimum blending, optimum crushing, and minimum handling.

Optimum Blending

About 40 blends of coal of various sources were tried for carbonisation, paying special attention to bulk density, pushing schedule, flue temperature, moisture control, crushing and screening, in order to achieve consistency in the quality of coke supplied to the blast furnaces. The results were closely followed in respect of its chemical and physical properties, so as to determine the most optimum blend, keeping in view the supply position.

The ash content in the unwashed Jharia coal, besides being high, varies widely whereas in the washed coal it is comparatively low with less variations. By judicious blending and increased usage of washed coal, it has become possible to keep the fluctuations within the limits, thereby producing comparatively low ash coke. It may be of interest to note that the percentage use of washed coal in the blend has gone up to 78.8 in 1963-64 from a figure of 36 per cent in the year 1961-62. Unwashed coal in the blend was correspondingly 64 per cent in 1961-62, and 21.2 per cent in 1963-64.

The economies of various blends with respect to its performance and cost are being given weightage. It may be mentioned that 1% increase of ash in the mixture of coking coal causes an increase of 42 kgs of coke, an addition of 39.5 kgs of flux per tonne of iron, an increase of 46 kgs of steam consumed by blowers which again would mean an increase of about 10 kgs of coal required for production of that steam. Besides, it will cause loss in tonnage of pig iron, and increase in phosphorus content of the iron. The importance of the right type of blended charge need be hardly stressed.

Increased and consistent fineness of the crushed charge, under more or less uniform conditions, increases the coke strength, a vital factor for the operation of larger blast furnaces. It is known that by recycling 2% to 3% coke breeze, it is possible to make coke of higher mechanical strength, provided crushing facilities are available. The use of selective crushing, it's economics and usefulness, is under careful examination, and so is the addition of oil in the charge to increase its bulk density and yield of coke, per oven.

Coke disintegrates to finer fractions when subjected to handling. It also disintegrates if stored for a longer time, and the disintegrated small fractions cannot be gainfully used in the blast furnaces.

Under normal conditions coke production is regulated at the coke ovens to meet the requirement of blast furnaces; it is fed directly to blast furnace bunkers by conveyor belts, thereby keeping the breakage and handling losses to the minimum.

Coke performs three functions in the blast furnace: it serves as a fuel and as a reducing agent for the iron ore, and it helps to support the burden in the blast furnace shaft. The chemical reactions involved in the reduction of iron ore by carbon and carbon monoxide are, in general, well understood, but the significance of the physical properties in the reduction process is largely conjectural. It is generally accepted that the resistance of coke to impact, abrasion, and crushing is important, though in an imprecisely defined way. Also, the size range, bulk density, apparent specific gravity, and porosity of coke are all believed to be of some importance in blast furnaces. In attempts to assess the influence of coke quality on iron making, each of these coke properties has at some time been suggested as a suitable control function. It is nowadays generally accepted that improved burden preparation, including the use of more uniformly sized coke, is an essential requirement for improved furnace performance.

Coke, however, forms only one, though an important, part of the blast furnace burden. Coke properties, which are sometimes suggested as important for blast furnace purposes, are true specific gravity and porosity. Provided, however, the coke is of sufficient strength to support the furnace burden, the principal factors affecting blast furnace working are gas-solid contact, and gas flow. In other words, voidage and bed configuration are the factors which largely influence the coke behaviour in the blast furnace. It is, therefore, necessary to have coke of the proper quality and strength. Stress has also to be placed on the consistently uniform quality of coke, so that coke behaviour in the blast furnace is of a predictable nature.

Oil injection, which has proved to be relatively simple and effective both in increased output and reduced coke consumption, is under consideration. The extent to which oil can replace coke is very important in the iron and fuel-using industries. To achieve this, some rethinking would be necessary on the point of injection, the burner design, whether to atomise, and where to add oxygen at the blower or through the oil burner.

Rise in Daily Output

A 10 per cent gain in output was reported in one of the big steel plants abroad, without measurably increasing either the oxygen content or the blast rate. At 25 per cent oxygen, the daily output has been reported to have increased by over 40 per cent.

Blast furnaces built under the one million tonne plant at Bhilai are designed for a useful volume of 1,033 M^3 each. The fuel rate in these furnaces were progressively brought down during the past years by the introduction of:

1. Self-fluxing sinter in the burden
2. Burden preparation
3. High top pressure
4. High blast temperature
5. Moistening of blast by steam

It has, as a result, meant more iron input, and, therefore, increased production, besides conservation of the metallurgical coal.

For the first time in India, self-fluxed sinter was successfully utilised at Bhilai. Self-fluxing sinter means that instead of feeding limestone directly with the burden, it is introduced along with other materials for the production of sinter. This saves the heat required to counter the endothermic reaction of dissociation of limestone into lime and carbon dioxide, thereby lowering the fuel rate at the blast furnace.

The details of the achievements for the last three years are given on page 616.

Particulars	Unit	1961-62	1962-63	1963-64
Sinter in burden	%	10.6	32.9	39.7
Specific consumption per tonne of hot metal:				
(a) limestóne	kg	580	392	246
(b) coke	kg	945	904	832
Production in terms of rated capacity	%	91.3	106.5	116.7

The raw materials are being subjected to the process of averaging both at the mines as well as at the plant in order to feed the blast furnaces to the extent possible with a uniform quality of iron ore. Careful burden preparation techniques, such as optimum crushing, sizing, screening, and averaging have their own advantages for smooth and economic operation of the furnaces. Iron with low silicon for good open hearth practice is considered very desirable.

To achieve optimum productivity, the furnaces have to be driven faster, but this increases the velocity of the ascending gases, and results in increased flue dust losses and decreased time to transfer the heat to the burden. To counteract these adverse effects, the high top pressure technique is usually employed. At high top pressure, the velocity and volume of gas decrease, and the hot gases stay for a longer time. The heat transfer to the burden is thus better, and the fuel rate decreases as the furnace productivity increases. The table below gives the details for the last three years:

Particulars	Unit	1961-62	1962-63	1963-64
Top pressure	atm.	.31	.44	.51
Air blast per tonne of hot metal	1,000 M^3	4.1	2.8	2.5
Flue dust per tonne of hot metal	kg.	24.7	23.3	.23
Coefficient of utilisation of useful volume of the furnace	M^3/tonne	1.08	0.89	0.78
Average production/day	Tonne	2,777	3,239	3,540
Fuel rate per tonne of hot metal (wet)	kg.	945	904	832

It is a well established fact that any increase in the temperature of hot blast results in saving of coke, on account of increased feed rates. An increase of air blast temperature by 100°C has been noted to lower the coke rate by 20 kgs to 30 kgs per tonne of hot metal. Introduction of insulated blow pipes has made it possible to sustain higher blast temperatures in the region of 900/950°C.

Moistening of Blast by Steam

The thermal condition in the hearth is controlled effectively by adjusting the amount of steam in the blast. Humidity control and humidification of air blast have led to smooth operation without scaffolds, hanging or slips, particularly when employing high blast temperature.

The dissociation of steam into hydrogen and oxygen is an endothermic reaction. It decreases the velocity of burning of coke; lower coke rate is made possible on account of smoother operation of the furnaces. It has been established that 10 gm NM^3 increase in blast humidity results in about 3% increase in pig iron production, and 10 kgs per tonne in reduction of coke rate.

In this one million tonne plant, there are six open hearth furnaces of 250 tonnes capacity each, of which five have been converted to basic, to increase furnace availability, and to take increased thermal loads.

Scrap-ore process is used for making steel, and the charge generally consists of about 770 kgs of hot metal, 220 kgs of steel scrap and 26 kgs of cast iron scrap per tonne of hot metal. Coke oven and blast furnace gases mixed in various proportions during different periods having a calorific value ranging between 2,300 and 2,600 Kcals/NM^3 are used as fuel. Coal tar fuel, CTF 200, is used for carburisation. The mixed gas and the air for combustion are preheated in the regenerators before they enter the furnace. The gaseous fuel is admitted into the water cooled gas port towards bath. The combustion air is enriched with oxygen introduced through the sides of the gas port for the intensification of the flame.

The reduction in the fuel consumption rates at the open hearth furnaces has been achieved by introducing:

1. Proper thermal regime of the furnaces—correct combustion and furnace pressure,
2. Utilisation of waste heat,
3. Increased productivity and decreased duration of heat,
4. Increased furnace availability by reducing the down time of the furnaces, and
5. Oxygen lancing and enrichment through ports.

Thermal Regimes

The life of the furnace and its production capability is increased by strict adherence to the prescribed thermal regimes. The thermal characteristics of the heats are studied from time to time, and the data obtained and analysed for different periods of the campaign. The standards prescribed for basic and silica roof given elsewhere are indicative of the action that is being systematically taken.

Combustion control is effected by analysing the flue gas samples from the gas uptakes during different periods of heats, and the fuel loss is thus minimised. These data also help in formulating the air and oxygen quantities in the thermal regimes. The furnace pressure is maintained at optimum level to minimise infiltration of air into the furnace.

The fuel consumption rates for the last four years are given below from which it could be seen that there has been a gradual decline in the rates:

Fuel consumption per tonne of ingot steel in 100 kilo calories

1960-61	1,357
1961-62	1,258
1962-63	1,019
1963 64	882

For utilisation of waste heat, the following facilities are provided:

Regenerators: Each open hearth furnace is provided with two pairs of regenerators. By suitable reversal system, the incoming gas and air get preheated alternatively in the right or the left side checker.

Waste Heat Boilers: The waste gases from the open hearth furnaces, after they leave the regenerators, are passed through waste heat boilers which raise steam at 18 atm. and is utilised for running the coke oven steam exhausters and also as process steam at various places, thereby leading to considerable economy.

Evaporation and Cooling System: An evaporation and cooling system has been installed at each open hearth furnace for the skew back beams along the front wall and gas ports which increases the life of these cooling elements. Besides, steam to the extent of 30 tonnes per hour, as evaporated, is utilised for process work, deaeration of feed water to waste heat boilers and the chilled water and ventilation system. The particulars of steam raised by the waste heat boilers is given hereunder:

Steam raised by waste heat boilers

1961-62	223,090 tons
1962-63	300,561 tons
1963-64	285,590 tons

Proper setting up of thermal regimes, lower duration of heat (by application of oxygen in increased quantities), and use of basic refractories in lining of the roof of the open hearth furnaces that allow greater thermal loads have been responsible for the increase in productivity.

The details are given here:

Particulars	Unit	1961-62	1962-63	1963-64
Production in terms of rated capacity	%	78.9	106.0	114.3
Ingot steel production per M^2 of furnace bottom per day	Tonne	6.4	7.9	8.4
Oxygen consumed per tonne of ingot steel	M^3	23.5	30.2	31.5

THERMAL REGIMES OF OPEN HEARTH FURNACES
(Basic Roof)

Oxygen consumption:	27 NM^3 per tonne	Duration	8 hours
Liquid fuel	5.5 kg per toone	Specific consumption	0.71–0.78 x 10 K cals

Period	Duration Hrs. Mts	Coke oven gas flow in M^3/hour	B.F. gas flow in M^3/hr	Liquid fuel in L/hr	Heat load per hour 10^6 Kcals	Air flow 10 M^3/hr	Oxygen in M^3/ hour
Fettling	0.30	3,500—4,000	4,500	Nil	19—21	21—23	Nil
Charging	1.30	5,000—5,500	4,500	150	27—29	25—27	1,000
Sill making and hearing	1.00	4,500—5,000	4,500	100	24—27	22—25	1,000
H.M. pouring	0.30	3,000—3,500	4,500	100	18—20	22—25	900
Melting	2.30	3,500—4,000	4,500	200	21—23	26—29	900
Refining and tapping	2.00	3.500—4,000	4,500	150	21—23	25—28	800

Air check temperature	Max 1350°C Min 1100°C
Gas checker temperature	Max 1300°C Min 1100°C
Waste gas temperature	Max 700°C
Furnace pressure	2—2.5 mm W.G.

A number of steps have been taken at Bhilai to increase furnace availability and thereby achieve increased production. Special attention has been paid to cutting down delays and repair period.

A new process for open hearth furnace bottom-making has been developed wherein bottoms are made by burning in magnesite in three layers instead of 10 layers, as per the previous practice. This has reduced the bottom-making time from 125 hours to about 19 hours.

A new technique has also been introduced by which bottom can be repaired after 75 heats, instead of the old practice of 25 heats, and thus increasing the furnace production.

The practice of charging ore on the bottom of the furnaces has helped to keep the bottom clean, prevent building up of the bottom, and consequent reduction in capacity. This has also been responsible for reducing the bottom repair time.

Planned efforts in regard to the timely availability of fettling and charging materials, hot metal, scrap, ferro alloys as well as placement of slag thimbles teeming ladles, and mould train have led to the minimisation of the heat duration, and, therefore, the fuel rate.

The details of furnace availability for three years is given below:

	Furnace availability	Duration of heat
1961-62	73.30%	12.26 Hrs.
1962-63	79.70%	10.04 Hrs.
1963-64	81.00%	9.32 Hrs.

In the Rolling Mills, there are three major consumers of gas: the Soaking Pits, the Reheating Furnaces of the Rail and Structural Mill, and the Merchant Mill.

Incoming coke oven gas and blast furnace gas at 750 mm wg pressure is mixed to give a calorific value of 1,550 Kcal/M^3. This mixed gas is boosted to 1,600 mm wg, and supplied to the reheating furnaces of the Rail and Structural Mill and the Merchant Mill. Unboosted mixed gas goes straight to the Soaking Pits.

The Soaking Pits function as a reservoir of hot ingots, and they supply, constantly, hot ingots to the Mill at the proper rolling temperature. Heat consumption per tonne for heating six to seven tonne ingots works out to 400,000 Kcal/tonne for cold ingots and 150,000 Kcal/tonne for ingots charted at 800°C. The overall fuel economy and the high productivity of the Soaking Pits depend, to a large extent, on the track time. It is defined as the time taken between the end of teeming at the open hearth bay and

AVERAGE HOURLY GAS BALANCE

Particulars	Blast Furnace Gas: Quantity in 10^3 M^3	Blast Furnace Gas: Heat value in 10^6 Kcals	Blast Furnace Gas: Per-cent	Coke Oven Gas: Quantity in 10^3 M^3	Coke Oven Gas: Heat value in 10^6 Kcals	Coke Oven Gas: Per cent
TOTAL MAKE	373.7	322.9	100	54.1	237.1	100
CONSUMPTION AT:						
(a) Coke Ovens and By-Product Plant	93.6	80.9	25.1	9.0	39.4	16.7
(b) Sintering Plant	4.6	4.0	1.2	0.5	2.2	0.9
(c) Blast Furnaces	111.4	96.2	29.8	0.6	2.6	1.1
(d) Steel Melting Shop and Mixer	26.1	22.6	7.0	19.1	83.7	35.3
(e) **Rolling Mills:**						
Soaking Pit	20.7	17.9	5.5	4.7	20.6	8.7
Rail & Strl. Mill	22.2	19.2	5.9	5.1	22.4	9.4
Merchant Mill	13.1	11.3	3.5	3.0	13.2	5.5
(f) Foundry Shop	—	—	—	0.7	3.1	1.3
(g) Forge Shop				0.3	1.3	0.6
(h) Refractory Materials Plant				0.3	1.3	0.6
(i) Machine Shop				0.1	0.4	0.2
(j) Boiler House	44.4	38.3	11.9	7.0	30.7	12.9
TOTAL:	336.1	290.4	89.9	50.4	220.9	93.2
LOSSES	37.6	32.5	10.1	3.7	16.2	6.8

Why Oil Productivity Is Higher In USSR

The NPC-sponsored Indian Productivity Team on Oil Industry has pointed out that the main factors responsible for the high level of productivity in the oil industry of USSR, Czechoslovakia, and Rumania are: 1. Rapid strike towards automation and mechanisation of the production process; 2. the incentives offered to workers; 3. the application of new techniques and technological development; and 4. the system of planning and organisation of production.

the placement of heat at the soaking pits. The influence of surface temperature on matters relating to fuel economy is enumerated below:

Ingot surface temperature at charging in °C	Number of ingots charged per pit	Gas consumption in 10^3 M	Heating time in Hrs. Mts.
800	18	22.5	4–35
750	18	25.0	4–55
700	18	27.5	5–30
650	18	30.0	5–50
Cold Ingots	15	50.0	9–50

The problems attendant on the efficient utilisation of the gases from coke oven and blast furnaces are peculiar to the iron and steel industry. Co-ordination of fuel supply and fuel utilisation has assumed increasing importance in view of the development of integrated works. The layout has to be so designed, and the basic system of gas distribution so planned, that every fuel is used to the greatest advantage. At Bhilai, the pattern of gas distribution is as illustrated elsewhere.

The normal working pressure of blast furnace and coke oven gases is around 700 mm wg. To the extent possible, high pressure system has been avoided in the plant design to keep the losses due to leakages to the minimum.

It may be mentioned that gas line networks have been so laid as to keep the line of communication to the minimum length. This minimises the pressure drop across the lines. Repairs to the gas supply system are carried out on 'live' gas mains.

Fuel is the basic raw material, the cost of which enters into the cost of nearly everything we see around us. In one way or other, fuel and its derivative power enter into practically every material element in our lives. The cost of fuel has an important influence on the cost of nearly everything else. Even those industries which directly use

THERMAL REGIMES OF OPEN HEARTH FURNACES
(Silica Roof)

Oxygen:	21 NM³ /tonne	Duration:	9.00 Hrs.
Liquid fuel:	7 kg/tonne	Specific consumption:	0.7-0.76 x

Period	Duration Hrs. Mts	Coke oven gas flow in M ³/hour	B.F. gas flow in M³hr	Liquid fuel in L/hr	Heat load per hour 10^6 Kcals	Air flow in 10M³/hr	Oxygen ³/hr
Fettling	0.30	2,500—3,000	5,000	Nil	15—17	16—19	Nil
Charging	1.30	4,000—4,500	5,000	150	23—26	22—25	700
Sill making and heating	1.00	3,500—4,000	5,000	100	20—23	19—22	600
H.M. pouring	0.30	2,500—3,000	5,000	100	16—18	20—23	500
Melting	3.00	3,000—3,200	5,000	200	19—20	24—26	700
Refining and tapping	2.30	3,000—3,200	5,000	200	19—20	23—25	500

Air checker temperature:	Max 1300°C
	Min 1100°C
Gas checker temperature:	Max 1300°C
	Min 1100°C
Waste gas temperature:	Max 700°C
Furnace pressure:	1.5—20.0 mm W.G.

little fuel, require other materials into which the cost of fuel enters largely. Industries in which fuel cost is an appreciable proportion of the total cost may be expected to seek the most efficient ways of using fuel.

Our supplies of metallurgical fuel are growing less. Carbonising industries are already concerned about the reserves of coking coal. Economy in the use of coal, particularly that of coking grade, is of national importance.

Fuel economy means saving fuel, doing with less; whereas fuel efficiency means getting the most out of our supplies; the ultimate impossible is 100%. Fuel efficiency contributes to fuel economy by the simple process of using less fuel, and that more efficiently. In a developing industry, like steel, it is desirable that by the ordered application of existing knowledge and technology, inefficient utilisation of fuels should be minimised.

Scientific and economical utilisation of fuel is a good and desirable thing. In this matter, as in so many others, values are not absolute, but relative; and fuel appears to be in that class of "consumer goods" where high consumption is to the advantage of the producer, whilst the utmost efficiency in utilisation benefits the consumer, and thereby the community.

New Method for Determination of Ash Content in Fuel Oils

A new speedy method for determination of the ash content in fuel and other petroleum oils has been developed at the Ecole Polytechnique in Montreal (Canada).

It is a modification of the standard method (under ASTM designation D 874-63), and requires only eight to nine minutes for the evaporation of oil, as against 1½ hours in the earlier one.

In this method, a uniform temperature is maintained over the whole surface of the crucible containing the oil placed well inside a muffle furnace. The escaping oil vapours are drawn rapidly away by placing an inverted funnel over the furnace, and applying a slight water pump suction to the bent tube of the funnel, so that only oil vapours and as little outside air as possible are drawn. In this way, the evaporation of oil is accelerated. Overflowing and foaming are eliminated, and the possibilities of oil kindling, which causes mechanical losses, are also removed.

This method can also be applied to the preparation of sulphurated residue from lubricating oils.

H SAHAI

Chief Fuel Engineer
Bhilai Steel Plant, Bhilai

Bhilai Steel Plant:

Work Organisation of Energy & Economy Department

THE FUNCTION of an Energy and Economy Department is to ensure that heat and power are produced and used to the best advantage throughout the works. It also includes consideration not only of fuel efficiency, but also of work productivity, quality of products, and manufacturing cost.

At Bhilai, the department of energy and economy was constituted early in 1960.

In other steel plants, such a department acts only in an advisory capacity. From the experience that we have gained, it is but reasonable that the units which contribute towards the efficient use of fuel and works productivity should be under the control of the department as is the case in Bhilai, as otherwise the danger is that the department loses its utility, and, therefore, its importance in respect of providing service to all the works department.

The proper use of fuel in the iron and steel industry is a subject the importance of which has only recently been begun to be recognised. It was, of course, earlier recognised that the commercial success of metallurgical processes depended on, among other factors, the weight of fuel used per ton of product; but the complexity of the fuel problem was not appreciated; and those who were concerned with the costs of production had only the idea of reducing fuel consumption to the minimum. It is a crude idea in the light of present-day experience, but, doubtless, it meant originally a step in the right direction. Fuel economy implies fuel reduction, but it also means wider conception of the art of fuel control. The true function of this branch of engineering is not only to reduce the fuel consumption per unit of product produced and treated, but it also amounts to the control of quantity, quality, and distribution of fuel and the resultant processes of combustion, so that overall cost of production is minimum, while the quality of product is unimpaired.

The post of fuel technologist in a large steel works, like Bhilai, is no sinecure, and it is very true that the outstanding fuel engineer, like the outstanding metallurgists, do not grow on every bush. As to their technical qualifications, they must be engineers in the widest sense of the term.

It can be said that the work of the department at Bhilai at present falls into:

1. Experimental and New Development;
2. Routine Control;
3. Planning and Production Control;

1. **Experimental and New Development:** The experimental work consists of making technical investigations on fuel-using plants of works processes with the object of introducing improvements which will give increased heat economy, plant productivity, and lower conversion costs. With that in view, at Bhilai a thermo-technical unit has just started collecting data on performance of furnaces, fuel, and material consumption, and preparing critical analysis which will show the variations of the heat and energy consumption in the works, and give reasons for fluctuations. This work, when fully organised, will arrange to prepare daily reports on information about soaking pits, reheating furnaces, thermo-technical data, shift production, consumption of heat per ton of production, temperature of metal heating, and temperature of recuperators, and give recommendations for increasing productivity.

With all the data that would thus be available, it will be possible to maintain a record of the thermal regimes of the furnaces at the steel melting shop, soaking pits, boilers, and heating furnaces at the forge and foundry shop. Comparison would enable the working out of standards which, in turn, would enable us to ensure that the fuel is used in the most advantageous manner in respect to heat efficiency, works productivity, and therefore, the final manufacturing cost. Comparison even otherwise is always helpful, for in a work of this nature, it will mean introducing thermal dimensions which are so important in a modern plant like ours.

It has, therefore, become imperative to introduce in the works a pattern, so that we are able to achieve a real measure of success so far as it relates to the efficient use of fuel in all its forms.

2. **Routine Control:** This is the day-to-day control which is concerned with keeping the plant operating at maximum efficiency. Its field is very wide, and it should cover the following, viz.,

(a) Supply of fuel, including the policy in regard to the purchase of fuel;
(b) Distribution of internal fuel supplies;
(c) Reporting and tabulation of data;
(d) Energy utilisation.

The purchase of coal from outside suppliers affords a fruitful field for the fuel engineer's activities. It is becoming more genuinely recognised that coal which can be bought at the lowest price per ton, delivered at the works, is by no means necessarily the coal which will result in the lowest fuel cost. It is desirable that the department of energy and economy should be taken into full confidence in matters relating to fuel purchase.

Fruitful Field

The problems attendant on the efficient utilisation of the surplus gases from coke ovens and blast furnaces are peculiar to the iron and steel industry, and afford another valuable field for the fuel engineer's skill. It has been seen that, as a result of the effective utilisation, even in a country like ours, we have witnessed a remarkable reduction in the overall fuel consumption per ton of rolled steel from the ore.

It will be realised, however, that the interdependence of the various stages of the complete steel-making processes on account of the inter-linking of gas supplies and requirements, introduces its own problems of gas distribution. In fact the really effective system of control of gas distribution has its own importance in the integrated operation of a steel plant. In a modern steel plant, the byproduct fuels supplemented by the imported fuels meet the thermal load of the works. Gaseous fuel is the lifeline for a number of production shops and gas facilities constitute an important link in production. The gas facilities at Bhilai Steel Works comprise the following units:

1. Gas Cleaning Plant for Blast furnaces 1, 2, and 3;
2. Excess blast furnace gas burner;
3. Inter-shop gas mains;
4. Gas-mixing and booster station;
5. Gas control room;
6. Gas safety station, and gas supply maintenance;
7. Liquid Fuel Station.

The operation and maintenance of the above units are the responsibility of the department.

Gaseous Fuels

The blast furnaces and coke-ovens are the sources of gaseous fuels in the works. The blast furnace and coke-oven gases are utilised separately, or in mixtures of required calorific value. The purity of gas is an important factor. The blast furnace gas is received in the Gas Cleaning Plant after the dust catchers, with a solid content of about 5 grammes per cu. m., and it is cleaned to contain less than 10 mgms per cu.m. The blast furnace gas output is about 3,000 cu.m. per ton of pig iron. The coke-oven gas is freed from impurities in the byproduct plant, and would have the concentration of harmful constituents as the tar fog, naphthalene, hydrogen sulphide, cyanogen and ammonia within the limits. With the present blended use in coke-ovens, the average production is 300 cu.m. per ton of dry coal charged.

The inter-shop gas mains include 4,200 metres of gas lines mounted on columns pipe lines less than 350 mm. diameter, seamless pipes, and pipes larger than 400 mm. of welded sheets. The normal gas pressure in the line is about 750 mm. water gauge. The excess blast furnace gas burner acts as a relief valve, and maintains pressure at the desired level. The pressure in the coke-oven gas line is maintained at an upper limit set by the water seal at the coke-ovens. The major consumers are provided with pressure regulating throttles before their shop, and receive gas at a pressure of 350/400 mm. water gauge.

The reheating furnaces at the Merchant Mill and the Rail and Structural Mills require maximum gas at a pressure of 1500 mm. water gauge, and this supply pressure is maintained by the gas booster station. The gas main pressure is regulated above 400 mm. water gauge to maintain proper supply at the consuming ends. In order to facilitate removal of condensate from the gas mains, water drainers have been provided at an interval of 180 metres.

At the gas-mixing and booster station, the coke oven and blast furnace gases are mixed in a fixed proportion. The proportionating arrangement comprises of four regulating throttles actuated by mixed gas pressure and pressure differential across the throttle. These then provide automatic control over gas volume ratio, and hence over calorific value of mixed gas. Four gas boosters operated by 350 kW squirrel cage motors are installed to raise the pressure of mixed gas. Each can normally deliver 40,000 cu.m. gas at a heightened pressure of 1750 mm water gauge.

The gas control unit provides steady and economic gas supply to the principal consumers by proper co-ordination, and takes steps to eliminate performance troubles in gas pipe lines. The gas distribution engineer regularly checks up the gas balance of the works from the flow meter readings, and requires the consumers to regulate their consumption according to gas supply position. The main consumers of gaseous fuel are the blast furnaces, the rolling mill, the sintering plant, the power and blowing station, and the steel melting shop.

Gas Distribution

Though the department has the responsibility in respect of gas distribution, it should be appreciated that this responsibility is shared by the consumers, for it is only then that proper understanding and co-ordination can lead to less delays as a result of shortage of gas. Within the limitation of the priorities that are drawn up by the department it is also the task of the gas distribution engineers to make the control flexible and responsive to varying demands. It is true that certain natural obstacles can limit the fuel stability. However, the coordination of fuel supply and fuel utilisation in the integrated works, where the whole series of physical, thermal, metallurgical and mechanical operation necessary to produce finished steel from the ore, coke, and limestone are carried on, there is no denying that a wide field of the work has to be met in a manner so that the weight of the heat input is within the prescribed limits.

The Gas Safety Station renders useful service in carrying out inspection of gas mains and gas aggregates, executing gas hazardous jobs, assisting personnel working on gas mains and in 'gaseous atmosphere', and in arranging a course of instruction in gas safety methods.

The use of gaseous fuels, particularly blast furnace gas, is attended by the twin hazards of explosion and gas poisoning. The Gas Safety Station checks up for gas leakages at the consuming ends where gas hazards are likely to be there; and besides, as a matter of routine, samples of air are drawn from control rooms and gas affected areas which are analysed systematically in the laboratory for the carbon monoxide content. Carbon monoxide concentration up to 0.03 mgms. per litre is considered physiologically safe for normal work. Whenever higher concentrations are detected, warning cards are issued, and the shift-in-charge in the shop advised about the conditions.

The establishment of records for every unit of plant is of the first importance in order to provide a continuous check of operating efficiency, and to be able to assess the progress made; and it is equally important to establish standards of performance for the consuming units of the iron and steel works, for it is desirable to know how different units are maintaining their efficiency and to have this knowledge continually available.

Compilation of Data

It will be realised that a considerable amount of operating and test data is collected, and in order that it may be available to all concerned, it is essential that it be recorded and circulated. It is also important that these data be properly recorded for compilation purposes. The statistical section thus deals with the aforesaid aspect and carries out the following work:

a) Calculate, tabulate, and plot where-ever necessary, the data in regard to the consumption rates of materials;

b) Prepare comparisons, showing reasons for variations;

c) Take out gas, water and steam consumptions, and flow loads from meter readings, and prepare a balance showing production and usage;

d) Record plant operating data;

e) Abstract plant operating data from recorded charts, prepare summaries; and

f) Circulate data and reports to the various works departments concerned.

It has been possible to introduce in the Works:

a) Daily production planning and fulfilment data;

b) Weekly summary and operation report for discussions;

c) Monthly operational reports, giving the characteristics of production;

d) Data for costs as it relates to the plant;

e) Cost analysis giving reasons for variation in costs elementwise;

f) Information in regard to the breakdowns, including the details of the damages;

and

g) Yearly works data.

3. **Planning and Production Control:** This wing of the department was started in December 1960. Its main functions are:

a) to plan work load and repair schedule of main units of the plant in conformity with this work order, and then prepare daily, weekly, and monthly production programmes of the various units.

b) Exercise control over the production in conformity with the schedule of production as well as repairs, and render all timely help to ensure fulfilment of the schedules.

c) Take steps for timely provision of raw materials and semi-finished products, spares for various equipment, refractory materials, rail transport arrangements, power and fuel requirements, etc.

d) Carry out systematic analysis of the work of the various shops.

e) Calculation of technological indices.

f) Fixing up norms of material and energy consumptions for every main shop, and prepare technological measures for realisation of the above.

It may be incidentally mentioned that with all the major units of the works having been commissioned, and initial teething troubles got over, the need for such a control was felt urgent to ensure proper co-ordination of various shops for smooth and streamlined production, and to keep the management posted with hour-to-hour working of all the departments. In the beginning, the work of the Central Production Control post was confined to collections of operating data, hourly in case of important shops like coke-ovens, blast furnace, steel melting shop, rolling mills, gas distribution networks and power generation, etc., as a consequence of which it had become possible to discuss production problems in the morning conference, and that undoubtedly has helped in achieving the targets planned.

Distribution of Costs

The production control posts at the blast furnaces, steel melting shop, rolling mills, besides rail transport, gas distiribution, and power generation are functioning. It is expected that work at the other control posts would also be soon introduced.

Not An Easy Task

Probing for oil is not an easy task. Though India's efforts in the last few years have been praiseworthy, the task demands a great undertaking, calling for imaginative and determined effort, and large capital investment.

"With the rising tempo of industrial progress", says the report of the NPC-sponsored Indian Productivity Team on Oil Industry, "it is of paramount importance that India should develop its own oil resources, failing which there will be an ever-increasing drain on the country's foreign exchange resources. Attainment of self-sufficiency in crude oil production is thus the keynote of the problem, which calls for intense geophysical and geological surveys and exploratory drilling. In fact, only a fringe of the country's 400,000 square miles of sedimentary basins has been probed for oil...Apart from finding huge capital, suitably trained technical men, particularly geologists and geophysicists, are most essential in achieving the desired objective."

The other equally important function, which deals with the planning of production, has also been taken up successfully. It is hoped that in time to come, it would be also possible to deal with the maintenance planned, for the objective of all maintenance work is to ensure that the availability, i.e. the services factor, and the efficiency of different units in the steel plant, is such that the total manufacturing costs are minimised.

It is interesting to mention that the distribution of costs in making steel in the USA, UK, and India has been approximately as follows:

	USA	UK	India
Works Labour	17	17	28
Fuel (coal)	16	21	23
Raw Materials	32	32	27
Balance	35	30	32
Total:	100	100	100

Fuels and raw materials, therefore, form an important element in the cost of production. Fuel, as could be seen, constitutes 23% of the total cost, and compared to the other countries, there seems to be a possibility that, with the introduction of more modern techniques, reduction in fuel cost is likely to occur. In modern blast furnaces, the production of one ton of pig iron requires roughly about one ton of coal.

. . . Idle running of electrical equipment, unnecessary plugging of meters, excessive friction load, overtight friction drags, overtight break bands—all these result in wasteful consumption of electricity and thereby in reduction of fuel and energy . . .

In this connection, it may be interesting to mention that, under Indian conditions, coking coal, with about 15% of ash, would be an ideal solution, with the quality of the iron ores that India possesses.

As ash percentage increases, the following effects are felt:

One per cent increase of ash in the mixture of coking coal causes an increase of 42 kgs. of coke per tonne of iron; an addition of 39.5 kgs. of flux per tonne of iron; an increase of 46 kgs. of slag per tonne of iron produced; an increase of 46 kgs. of steam consumed by blowers which again would mean an increase of about 10 kgs. of coal required for production of that steam; besides, it will cause loss in tonnage of pig iron, and increase in phosphorous content of the iron.

That being so, it goes without saying that the right type of coal would lead to the right type of coke, and ultimately to lower cost in production.

Coming somewhat nearer to the field of fuel technology, a survey that was made

Material Consumption per Tonne of Pig Iron

Particulars	Unit	1961-62	1960-61	Foundry	Projected Basic	Overall
RAW MATERIALS :						
Coke	Kgms.	959	941	1120	890	953
Iron Ore	Kgms.	1443	1317	646	890	821
Manganese Ore	Kgms.	49	56	28	30	29.4
Sinter	Kgms.	170	NIL	1080	825	897
Limestone	Kgms.	589	598	374	232	272
Scrap	Kgms.	0.26	4.20	10	10	10
Quartzite	Kgms.	32	36	50	50	14
Sand	Kgms.	5.2	6.1	—	—	—
SERVICES :						
Steam	Kgms.	116.7	137.0	—	—	150
Water	M^3	30	41	—	—	30
Electricity:						
i) at furnaces	KWH	9.56	0.15	—	—	9.2
ii) at P.C.M.	KWH	1.44	1.83	—	—	—
Compressed Air	M^3	5.50	4.20	—	—	2.25
Air Blast	10^3M^3	4.16	4.23	—	—	3.12

NOTE: As per 1961-62 consumption rate, for every ton of pig iron, a 1% reduction of coke leads to a saving of Rs. 7.3 lakhs; of Iron ore, Rs. 2.3 lakhs.

Material Consumption per Tonne of Ingot Steel

Particulars	Unit	1961-62	1960-61	Projected
MATERIALS :				
Pig Iron	Kgm.	749	803	776
Scrap	Kgm.	264	242	241
Iron Ore	Kgm.	166	164	200
Scale	Kgm.	4.6	7.8	—
Lime	Kgm.	10.6	11.6	20
Limestone	Kgm.	78.5	79.0	65
Fluorspar	Kgm.	0.28	0.22	—
Bauxite	Kgm.	0.73	2.89	10
Raw dolomite	Kgm.	40.5	47.0	10
Burnt dolomite	Kgm.	25.9	24.1	25
Magnesite	Kgm.	6.2	6.5	10
Ferro-manganese	Kgm.	16.2	13.8	—
Ferro-silicon	Kgm.	0.92	1.12	—
Aluminium	Kgm.	43	54	—
SERVICES :				
Electricity	KWH	12.8	19.39	17.4
De-aerated water (for evaporation and cooling)	M^3	0.41	0.53	—
Water	M^3	15.60	15.94	11.26
Compressed Air	M^3	60.30	56.30	23
Oxygen	M^3	23.50	0.12	31
Steam	Kgm.	1.27	1.36	0.60
Total heat	10^3 K.cal	1298	1357	1100

NOTE : Based on 1961-62 rate, a 1% reduction in metallic input can save about 12 lakhs of rupees per year.

Average Hourly Gas Balance

Particulars	BLAST FURNACE GAS Quantity in 1000 M^3	BLAST FURNACE GAS Per cent	COKE OVEN GAS Quantity in 1000 M^3	COKE OVEN GAS Per cent
TOTAL MAKE	400.0	100.0	53.0	100.0
CONSUMPTION AT:				
a) Coke-ovens & Byproducts Plant	43.0	10.8	16.8	31.7
b) Sintering Plant	2.5	0.6	0.3	0.6
c) Blast Furnaces	116.0	30.5	0.7	1.2
d) Steel-Melting Shop and Mixer	30.0	7.5	19.6	37.7
e) **Rolling Mills:**				
i) Soaking Pit	30.0	7.5	3.8	7.1
ii) Rail & Strl. Mill	24.0	6.0	3.5	6.9
iii) Merchant Mill	18.0	3.0	2.6	3.0
f) Foundry Shop	—	—	0.6	1.1
g) Forge Shop	—	—	0.3	0.6
h) Refractory Materials Plant	—	—	0.3	0.6
i) Boiler House	106.5	26.6	4.1	7.7
TOTAL:	370.0	92.5	52.0	98.2
LOSSES:	30.0	7.5	1.0	1.8

Fuel Rates (in terms of heat)

Particulars	Unit	1960-61	1961-62	Projected
1. Per ton of charge carbonised	10^3K.Cals	656	626	630
2. Per ton of coke produced	10^3K.Cals	846	808	850
3. Per ton of Ingot Steel	10^3K.Cals	1357	1298	1100
4. Per ton of Ingot soaked	10^3K.Cals	539.6	392.9	350
5. Per ton of Blooms charged in reheating furnaces of Rail & Structural Mill	10^3K.Cals	—	1124	749
6. Per ton of Billets charged in reheating furnaces of Merchant Mill	10^3K.Cals	2274	781	801
7. Per ton of Rails & Strls.	10^3K.Cals	3526	1334	835
8. Per ton of Merchant Products	10^3K.Cals	2595	829	871
9. Per kg of Steam raised	K.Cals	692	749	745

Energy Rates

Particulars	Unit	1960-61	1961-62	Projected
ELECTRICITY CONSUMPTION :				
1. Per tonne of charge carbonised	KWH	13.5	13.5	15.99
2. Per tonne of Coke produced	KWH	17.4	17.4	21.59
3. Per tonne of Pig Iron:				
i) at furnaces	KWH	9.15	9.56	9.2
ii) at P.C.M.	KWH	1.83	1.44	—
4. Per tonne of Ingot Steel	KWH	19.39	12.8	17.4
5. Per tonne of Blooms	KWH	—	33.2	27.9
6. Per tonne of Billets	KWH	—	33.4	28.3
7. Per tonne of Rail & Strls.	KWH	—	98.7	57.5
8. Per tonne of Merchant products	KWH	—	97.3	66.7

ORGANISATIONAL AND FUNCTIONAL CHART

Department of Energy and Economy

(Responsible for the efficient use of fuel, operation and maintenance of gas net-works, collection and compilation of technical data and the work of production control.)

Gas Cleaning Plants: (Deals with the efficient operation of gas cleaning plant and its light maintenance)

Gas Facilities: (For gas distribution, gas safety operation of boosters and fuel storage equipment and the net-work light maintenance)

Energy Section: (For economic utilisation of electrical energy, steam, compressed air, oxygen, water etc.)

Statistical Section: (Deals with collection and compilation of statistics on production and operation of the plant, cost analysis, evaluation of energy charts etc.)

Planning and Production Control

(Responsible for planning of and preparation for production and the work of the production control posts)

in the iron and steel industries in regard to the energy requirements, process by process, shows that the highest proportion was required in the finishing processes, roughly 34% followed closely by iron-making 32%; steel-making requires only about 15%; and general services and transport, about 9.5%. These figures indicate the potential benefit of any development in the finishing processes which might lead to reduction in energy demands. Incidentally, it may be stated that the recent alterations carried out at the Power and Blowing Station at Bhilai have resulted in the reduction of steam consumption in the blowers, which, in turn, has led to considerable economies.

There is information available that fuel and power represent roughly 11.5% of the cost of iron, 7% of the cost of ignot steel, and only 2% of the cost of finished products, transport and general services taken together.

It, therefore, seems that any improvement in the reduction of the consumption data, as given above, could be further reduced by the application of progressive techniques as has been gradually done at Bhilai.

There are certain other aspects — minor as they might appear to be — but they have their contribution to make in the reduction of fuel and energy, such as wasteful consumption of electricity in the works due to idle running of electrical equipments, unnecessary plugging of meters, excessive friction load, and over-tight friction drags or over-tight brake bands. Sometimes, due to neglect, great quantities of electricity might be lost through grounds in the conductor wires.

It has been noticed that on the lifting magnets operators leave the current turned on, resulting in wanton wastage of current, and damaging the equipment unnecessarily.

A 200 Watt bulb, if kept on for 24 hours, would in terms of the coal equivalent alone, consume roughly a ton of coal per year.

A 13 mm diameter pipe of compressed air, at a pressure of 4 Kgs/sq. cm., if kept open, would lead to wastage of 3,200 cu.m. of air, which roughly is Rs. 3,000 per month.

A 13 mm diameter pipe of steam, at a pressure of about 12 kgs per sq. cm., if kept open, would lead to wastage of 550,000 kgs of steam, which is equivalent to approximately 80 tonnes of coal or Rs. 3,000 per month.

Similarly, a 13 mm diameter pipe of water at a pressure of 4 kgs per sq. cm., if kept open, would lead to a wastage 7,000 cu.m. of water per month.

These figures show that considerable economies could be effected by everyone in the plant, if one would appreciate that wastage helps none, but, on the contrary, creates operating problems.

Information given elsewhere provides data in respect of the consumption rates and also gas balances, which if examined, would certainly arouse interest in measures that would lead to economy.

Summing up, it could be said that a proper organisation of the pattern that has been introduced in the Bhilai Steel Works, coupled with the production volume that is getting stabilised, would contribute still further to higher productivity, and the efficient utilisation of materials that go to make a ton of steel, resulting in the gradual reduction of manufacting costs.

The Cost of Smoke

The report on fuel conservation issued by the Anglo-American Council on Productivity has an interesting passage on the cost of smoke which is reproduced below:

"When coal was cheap and plentiful in Great Britain the apologists, with full knowledge of its wasteful use, were fond of quoting the Yorkshire saying: 'Where tha's muck tha's money'. Today, wiser men know that 'where there's smoke there's waste, and that smoke abatement and fuel efficiency go hand in hand. Much smoke is simply unburnt fuel—that is, lost heat. It is estimated that in Great Britain the entire output of 10,000 miners is wasted each year in the form of unnecessary smoke, apart from which the dirt and damage caused by smoke ties down a great deal of manpower on non-productive work."

PD SUNAVALA

Assistant Professor of Furnace Design,
Indian Institute of Technology, Bombay

Fuel Economy as Affected by Steel-making Processes

STEEL-MAKING and steam-making mark out the nation's progress, and the fuel technologist has a significant role to play in both these industries in chalking out the productivity and the fuel economy drives. Strange and inexplicable as it may seem, the petroleum refiner is following closely on the heels of the steel smelter and the boilerman, thus completing a valuable hand-in-hand trio of the indices of progress of industrialisation.

Table I shows the progress of the fuel technologist in India during the First, Second, and the Third Five-year Plans. Table II indicates the production of crude steel in India as compared with advanced countries like the UK, the USA, and the USSR, from 1939 to 1960, and the vast gap that India has as yet to catch up. Table III gives our estimated steel requirements for the future based on an assumption of 4% rise per annum. It will be shocking to note that even by planned targets, India's crude steel production at the end of the 20th century will not be able to equal the present production in the USA. It is, therefore, high time that productivity and fuel economy drives in steel manufacture be carried out at full speed.

The Bessemer Process: The invention of the pneumatic process, in its two forms, was announced by Henry Bessemer in a paper entitled 'The Manufacture of Malleable Iron and Steel without Fuel', read at the British Association at Cheltenham on Aug. 11, 1856. It was Bessemer's genious which conceived the idea of the foreign elements in molten pig-iron (silicon, carbon, sulphur, phosphorus, etc.), these being sufficiently combustible to enable their elimination being effected in a few minutes, without human labour, by a simple process of air blowing, the heat generated thereby more than sufficing to keep the bath molten throughout the process. This epoch-making discovery must be ranked among the world's greatest achievements in metallurgical fuel economy, for it at once eliminated

TABLE I

Production of Crude Steel, Electrical Power, and petroleum products in India during First, Second, and Third Five-year Plans

Year	Crude Steel Production (In mill. tons)	Thermal Power Generation (In mill. kW.)	Petroleum Refining Capacity (in mill. tons.)
1955	3	3	3
1960	6	6	6
1965	12	12	12

TABLE II

Production of Crude Steel in India, UK, USA, USSR, and World Total from 1939 to 1960

Crude steel production (In million tons)

Year	India	UK	USA	USSR	World Total
1939	1.07	13.4	47.9	17.6	136.0
1953	1.53	17.9	101.3	38.0	234.5
1956	1.8	21.6	116.5	49.5	295.4
1960	6.0	26.0	134.5	68.3	372.7

TABLE III

Estimated Steel Requirements

	Year	Population (millions)	Per Capita Consumption (kgs)	Ingot Steel (mill. tons)
End of 1st plan	1955	390	8	3
End of 2nd plan	1960	430	14	6
End of 3rd plan	1965	480	25	12
End of 4th plan	1970	525	36	19
End of 5th plan	1975	570	50	28
End of 20th century	2000	840	130	110

from iron-to-steel conversion any combustion of fuel other than the impurities in the metal itself. It has been estimated that the heat requirments in the Bessemer process for steam-raising for the blowing engine is 125,000 kcals per ton ingots, as against 800,000 kcals per ton ingots for the open-hearth process. A heat balance of the process has shown an efficiency of nearly 40%, with losses of about 56% in the gases, and of about 4% by radiation.

The possibility of fuel economy by replacing the open hearth process by the Bessemer process can be judged by comparing two cases typifying the average American and German conditions before the war respectively. Nevertheless, it should be mentioned, at the outset, that the choice between the two processes is dependent solely upon the quality of iron ore and coal available, and the degree to which the finishing operations are carried out. Fuel economy plays a second fiddle to steel quality control. The first is a plant in which cent per cent of the steel is made by the basic Bessemer process, and probably somewhat representative of the German plants which have already established themselves on a heat recovery basis. The second is a plant, more nearly representative of average American conditions, which enables 20% ingot-production by the Acid Bessemer process, and 80% by the basic open-hearth process.

It is assumed that in the Bessemer process, 1.25 tons of iron is required per ton of ingots produced, and that in the open-hearth operation, 0.60 tons of iron is required per ton of ingots. It is obvious, therefore, that in a plant making all of its steel by the Bessemer process, considerably more iron will be required per ton of ingots produced, and that, to produce a greater quantity of iron, additional coke will have to be produced. Hence, the surplus gases from the coke oven and blast furnace operations will be substantially higher per ton of ingots produced in the 100% Bessemer plant than in the 80% open-hearth plant. The heat in the blast furnace gas per ton of iron produced has been taken as 3,315,000 kcals, assuming 3,960 nm³ blast furnace gas of 836 kcals/nm³ per ton of pig iron. The complete figures for these two conditions are tabulated in Tables IV, V, and VI.

Hence it is seen that for the given set of conditions—

(1) Steel made by the Bessemer process consumes 70% more coal per ton of salable steel than the open-hearth process (Table IV).

(2) The overall heat requirements for steel-making are from 28.4% to 33.5% less in the Bessemer process

TABLE IV

Comparison of Fuel Economy in Bessemer with Open-Hearth Furnace, Surplus Heat from Blast Furnaces and Coke Ovens per ton Ingots.

Blast Furnaces	**100% Bessemer**	**80% Open-hearth and 20% Bessemer**
Tons iron/ton ingot	1.25	0.73
kcals in total gas/ton iron	3,315,000	3,315,000
% gas consumed by stoves	25	25
% gas consumed in blowing gas blown	15	15
Turbo blown	25	25
% Surplus gas/ton Iron		
gas blown	60	60
Turbo blown	50	50
kcals surplus gas/ton iron		
Gas blown	1,990,000	1,999,000
Turbo blown	1,660,000	1,660,000
kcals surplus gas/ton ingots		
Gas blown	2,500,000	1,450,000
Turbo blown	2,080,000	1,210,000

Coke Ovens	**100% Bessemer**	**80% Open-Hearth and 20% Bessemer**
Tons coal/ton coke nm3	1.33	1.33
Surplus gas/ton coal carbonised	198	198
Tons coke/ton iron	0.90	0.90
Tons coal/ton ingot		
nm^3 surplus gas/ton iron	238	238
Net kcals/nm^3 coke oven gas	4230	4230
Net kcals surplus gas/ton iron—	1,000,000	1,000,000
Litres tar/ton coal carbonised	40.8	40.8
Litres tar/ton iron	49.0	49.0
Litres tar/ton ingots	524,000	302,000
Tons breeze and domestic coke Ton coal carbonised	0.04	0.04
kcals breeze and domestic coke Ton ingots	405,000	237,000

TABLE V

Comparison of Fuel Economy in Bessemer with Open-hearth Furnace—kcals Total Surplus Heat per ton Ingots

kcals/ton ingots from	**100% Bessemer**		**80% Open-Hearth and 20% Bessemer**	
	Gas blown	**Bessemer**	**Gas blown**	**Turbo blown**
Blast furnace gas	2,495,000	2,080,000	1,450,000	1,210,000
Coke oven gas	1,260,000	1,260,000	730,000	730,000
Tar	524,000	524,000	302,000	302,000
Breeze and Domestic coke	405,000	405,000	237,000	237,000
Open-Hearth waste gas	—	—	270,000	270,000
Total	4,684,000	4,269,000	2,989,000	2,749,000

TABLE VI

Comparison of Fuel Economy in Bessemer with Open-hearth Furnace—kcals Heat Requirements per ton Ingots

kcals/ton ingots For	100% Bessemer	80% Open-Hearth and 20% Bessemer
Open-Hearth Furnace	—	806,000
Bessemer blowing	126,000	25,200
Soaking pits (Heating ingots)	252,000	252,000
Reheating furnaces:		
Hot blooms	252,000	252,000
Cold blooms	630,000	630,000
Billets	302,000	302,000
Total:—Blooms charged hot	932,000	1,637,200
Blooms charged cold	1,310,000	2,015,200
Electric power 110 KWH / ton finished bars	471,000	471,000
Total: Blooms charged hot	1.403,000	2,108,200
Blooms charged cold	1,781,000	2,486,200

than in the open-hearth process (Table VI).

(3) The total surplus heat available are from 55.3% to 56.6% more in the Bessemer process than in the open-hearth process (Table V).

Therefore, it follows that an integrated iron and steel industry, based on the Bessemer process, will consume 70% more coking coal on the blast furnace to make available about 55% more surplus heat than that based on the open-hearth process. Accordingly, in countries like Germany, where the reserves of coking coal are large, the adoption of the Bessemer process would be a fruitful proposition since it would do away with the purchase of any other form of fuel or energy, and make the plant a balanced works. In countries like India, where the reserves of coking coal are meagre, and those of non-coking coal large, the Bessemer process has no place, since any additional fuel or energy requirements can be met at the expense of non-coking coal, thereby conserving coking coal.

As the percentage of hot metal in the charge increases initially, the fuel consumption decreases due to the added sensible heat from the hot metal. However, if the hot metal percentage increases beyond about 35% (depending upon the percentage of metalloid impurities in the hot metal), the fuel consumption increases again. This is because the time required for removing these impurities increases considerably as the percentage of metalloid impurities increases beyond this limit (Fig. 1.)

Fuel Economy in Open Hearth Furnace

Effect of Nature of Fuel: The open-hearth furnace is the largest consumer for process heat in a steel plant. Hence the

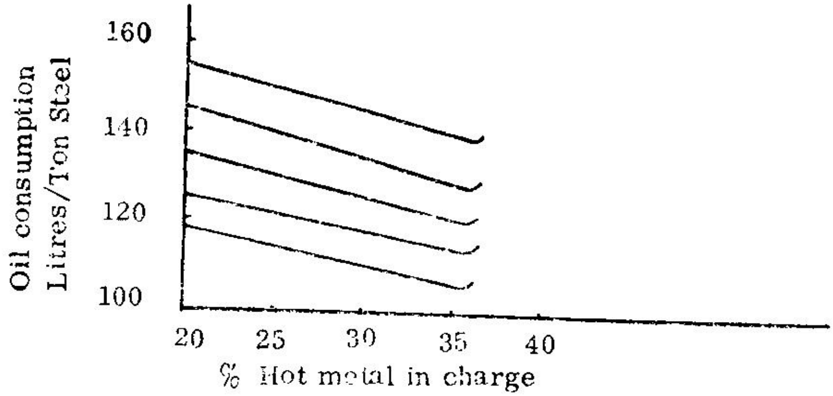


Fig. 1 Effect of Hot-metal ratio on fuel consumption per ton for open-hearth furnace.

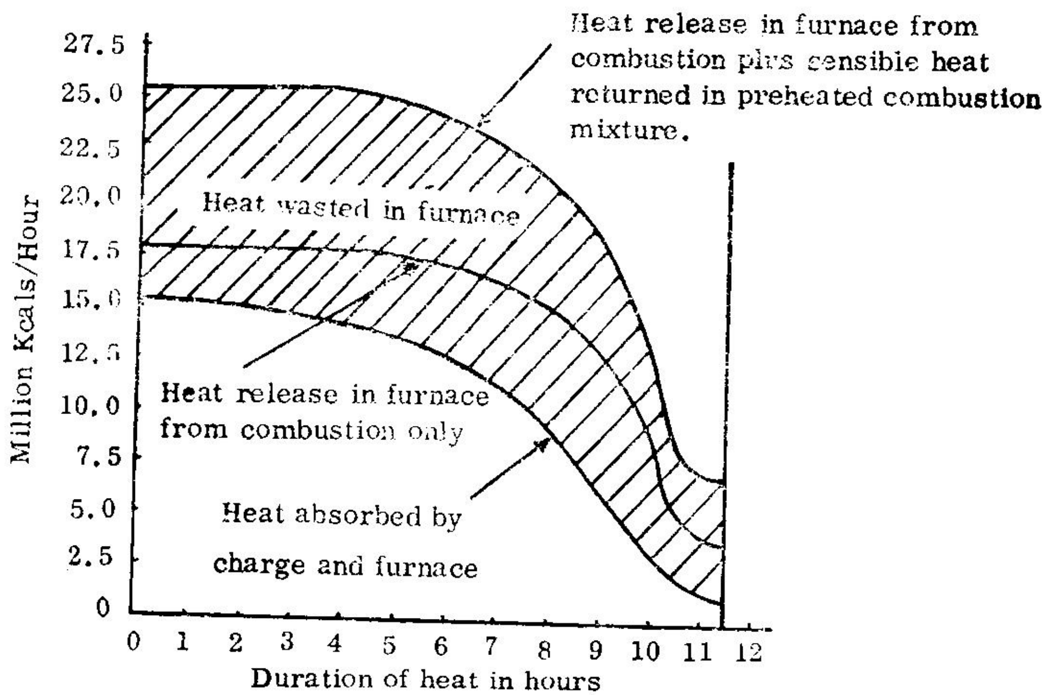


Fig. 2 Variation of Heat Input throughout the process for open-hearth furnace operation

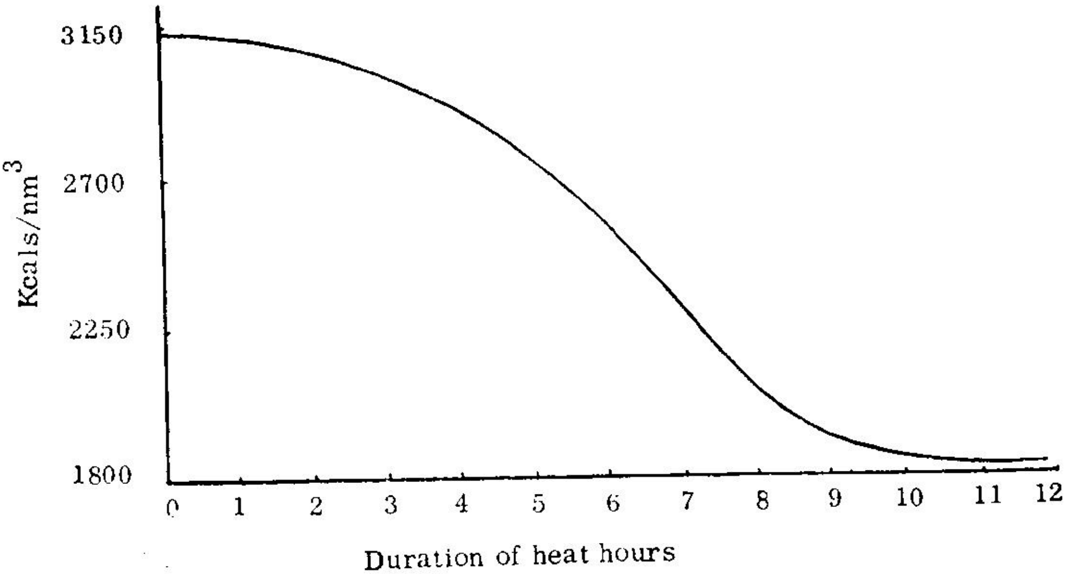


Fig. 3. Variation in calorific value of mixed-gas throughout the process for open-hearth furnace operation.

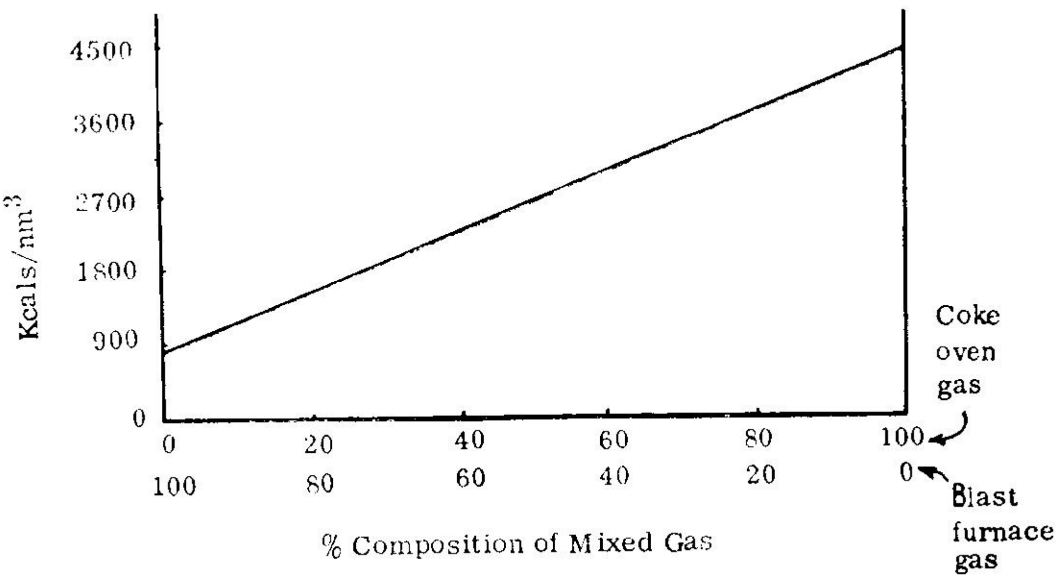


Fig. 4 - Effect of composition of mixed gas on its calorific value

right selection of the fuel to be employed is important. The three main characteristics that are required for a good fuel in the open-hearth practice are: (1) high calorific value, (2) high flame luminosity and (3) low sulphur content.

Coal tar is the best liquid fuel. Its high calorific value of about 8,100 kcals/kg gives a very high flame temperature, while its flame is exceedingly luminous on account of its free carbon content. This expedites the rate of heat transfer to the hearth, and cuts down the time of operation leading to increased output, and hence low overall fuel consumption. However, coal tar being a valuable raw material for almost the whole organic industry, and for manufacture of road tars, it is usually economised in national interests.

. . . If the moisture content of the gases, or the temperature of preheat, exceeds limits, the result would be a complete lack of luminosity. It should, however, be mentioned that a greater moisture content in the gas is sometimes desirable in order to eliminate the bulk of the carbon deposited in the checker work . . .

Furnace Oil comes next in view of its high calorific value of about 10,700 kcals/kg, but its flame is not as luminous as that of coal tar, while its sulphur content is also higher.

Blast furnace gas contains about 50% of the heat value of the coke charged into the blast furnace. It is too lean a fuel to produce such high temperature as 16,00°C required in a steel-melting furnace. Besides, its flame is absolutely non-luminous. These properties make its use as such impossible in the open-hearth practice. However, its sulphur content is almost nil, it gives a soft flame, and its specific gravity is almost that of air (sp. gr. 1.035), so that its flame spreads uniformly over the charge. Hence, by admixture with coke oven gas it can confer to the mixture these beneficial properties which the other lacks.

Coke-oven gas contains about 25% of the heat value in the coal from which it its produced, besides 50% or more of hydrogen, and hence is much lighter than air (sp. gr. 0.44). It gives a sharp, i.e. a short and very intense flame which tends to travel up causing overheating of the roof, while lesser heat is given to the charge. Consequently, it has to be directed close to the charge, and at considerable pressure, up to 3.5 kg/cm^2 gauge. The minimum gas velocity for coke oven gas is 80 m/sec., corresponding to a pressure of 3000–5000 mm wg. The minimum gas pressure requirements for other fuel gases are given in Table VII.

TABLE VII

Specific Gravities and the Minimum Gas Pressure requirements for various fuel gases

Gas	Sp. gr. (Air-1)	Cal. Value kcal s/nm^3	Minimum gas pressure mm.wg.
Blast furnace	1.035	890	750/1000
Producer	0.957	1330	1000/1500
Mixed	—	2040	2000
Coke oven	0.44	4100	3000/5000

The luminosity of coke oven gas flame is poor. It is more than that of blast furnace gas, but much lesser than that of producer gas. It burns with a transparent, but rather white, flame. During the charging and melting operations, the heat transfer to the charge is mainly by direct conduction and convection from the furnace atmosphere, and a great deal of heating is necessary. Hence coke oven gas or mixed gas (a mixture of coke oven and blast furnace gas containing 30%-40% of the former) can be used.

But during the shaping and refining periods, an insulating layer of molten slag forms on the surface, and the heat transfer to the metal below has to be mainly by direct radiation. For this purpose, luminosity of the flame is essential. During this period the use of straight coke oven gas becomes prohibitive. However, this can be overcome by adding an illuminant to these gases, such as oil or tar, to the extent of 10%-25% of total heat input, or, instead, straight producer gas or coke oven gas-cum-producer gas mixtures can be used. Alternatively, the coke oven gas can be preheated. The preheated mixture tends to a lower flame temperature than straight coke oven gas, but the effective heat transfer is increased. If coke oven gas is used totally during the shaping and refining period, then due to the poor radiating power of their flames, the slag tends to cool down, and becomes viscous. This prevents the free escape of carbon monoxide and carbon dioxide during the slag forming period, and the slag starts 'foaming' or 'frothing', and voids are produced in the mass. Besides, in the molten condition, the iron absorbs a lot of impurities from the furnace atmosphere. Coke oven gas contains a high percentage of sulphur (0.54%), and hence its use during the refining stage is not desirable.

The effect of foaming slag can be disastrous to the brick work, particularly the roof, and once it has started, there appears to be little that can be done to suppress it. The only remedy is to cut down the gas immediately in order to preserve the brick work, and keep on feeding oxide gently. The charge will however gradually lose heat, and the refining time will be considerably prolonged, thus increasing the fuel consumption. In addition, the furnace will probably be damaged. Hence, it is clear that it is not practicable to work on coke oven gas throughout the process without either carbon enrichment by fuel oil or by preheating.

Mixed Gas Operation: Mixed gas is a mixture of coke oven gas and blast furnace gas in the ratio of about 1:2. Its usual calorific value ranges from 2000-2400 kcals/nm^3. The same principles of partial fuel oil additions or preheating apply for mixed gas practice as in the case of coke oven gas. In the open-hearth furnace, during melting, the heat input may be increased substantially above the average rate; during refining only enough heat may be applied to maintain the temperature restricting the input to as low as 15% of the average rate. Fig. 2 shows how the normal fuel input, and normal heat requirements in an open-hearth furnace vary throughout the heating operation. This variation in heat requirements throughout the process can be very easily varied by varying the calorific value of mixed gas as shown in Fig. 3. The composition of mixed gas corresponding to these calorific values is shown in Fig. 4.

In spite of this advantage in flexibility of mixed gas application to open-hearth, the drawback due to lower luminosity of the flame will still remain. To counteract this, the gas mixture is preheated to a temperature (1,200°C) high enough to cause some cracking of hydrocarbons, thus resulting in a luminous flame.

Producer Gas: Although this is a low calorific value fuel (1330 kcals/nm^3), the presence of tar fog in the gas gives a great luminosity to its flame on regeneration of the gas in the checker work. Hence, although the efficiency of producer gas generation is only about 80%, it is the best gaseous fuel (apart from natural gas) for open-hearth furnace. In steel-making units, where coal tar or furnace oil is not employed, producer gas is desirable in order to give the fuel the desired luminosity. Hence, steel smelters habituated to open-hearth operation on producer gas are reluctant to switching over to coke oven gas, or mixed gas operation, on account of difficulties sometimes arising in refining with coke oven gas or mixed gas.

Comparing producer gas with fuel oil, on an equal heat release basis of 1 million kcals, we get the following values:

755 nm^3 producer gas+976 nm^3 air =1570 nm^3 waste gases
0.1125 nm^3 fuel oil+1105 nm^3 air =1165 nm^3 waste gases.

On account of the larger volume of the waste gases, it is necessary that open-hearth furnaces, run on producer gas, be equipped with waste heat boilers. The fuel consumption is equivalent to 1.74 million kcals per ton of ingot in terms of coal fed to producers. Allowing a producer efficiency of 80%, the amount of heat in the gas at the furnace is 1.38 million kcals per ton of ingot.

In such cases of coke oven gas, mixed gas and producer gas application, where cracking of hydrocarbons takes place, the moisture of the gases plays a very important role. Cantelo has pointed out that dissociation of methane takes place at temperatures as low as 500°C, as shown in Table VIII.

TABLE VIII

Effect of Temperature on Dissociation of Methane

Temperature	Composition of equilibrium mixture	
°C	CH_4%	H_2%
500	63.9	36.1
600	37.9	62.1
700	16.3	83.7
800	13.0	87.0
850	7.5	92.5
900	3.6	96.1
1000	2.0	98.0
1100	0.8	99.2

However, it is certain that there is no luminosity in the flame below 950°C, which indicates that these amounts of carbon deposited up to this temperature are completely absorbed by the water-gas reaction $C+H_2O=CO+H_2$ taking place simultaneously because of the moisture present in the gases. While the carbon is apparently precipitated at 950°C–1150°C the water gas reaction reaches its maximum intensity at 1200°C–1250°, but proceeds also at lower temperatures. The products of the water-gas reaction, carbon monoxide and hydrogen do not contribute anything to the flame luminosity; hence to suppress this reaction, the optimum temperature of preheat should be within the apparent carbon deposition range, but lower than the temperature of maximum water-gas reaction rate, i.e., it should be 1000°C–1150°C.

If the moisture content of the gases, or the temperature or preheat, exceeds limits, the result would be a complete lack of luminosity. It should, however, be mentioned that a greater moisture content in the gas is sometimes desirable in order to eliminate the bulk of the carbon deposited in the checker work.

Effect of Operational Controls: The optimum operating controls in the case of an open-hearth furnace on fuel oil are reported by Marshall and White as:

1) The oil and the steam pressures should be as given below:

Period	Oil pressure kg/cm² gauge	Steam pressure kg/cm² gauge
Charging	5.4—5.8	6.8—8.1
Melting	4.1—4.4	4.7—5.1
Refining	3.7—4.4	4.4—5.1

The steam pressure should not exceed 10.9 kg/cm² maximum.

2) The steam pipe orifice should be 3.18 mm. diameter.

3) The steam oil ratios required

Do you know . . .

India still remains the largest market in the world for kerosene as an illuminant.

The total consumption of energy in India is equivalent to slightly over 1,300 billion kilowatt hours per annum (nearly 185.6 million tons coal equivalent).

India is the sixth ranking country in the world so far as total energy consumption is concerned. Her requirements are exceeded by those of the USA, USSR, China, UK, and West Germany.

Eighty per cent of the energy available to Indian economy is dissipated in the form of waste heat — only 20% is converted to work.

Efficiency of use of fuel is particularly low in the domestic sector — mainly because of the widespread use of low-grade, non-commercial fuels for cooking in inefficient appliances — "chulahs", "sigris", or open fires.

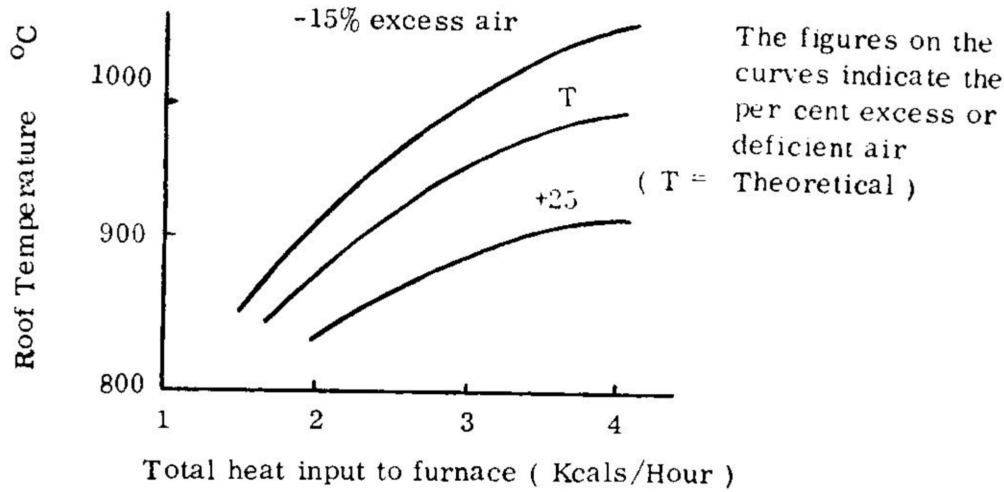


Fig. 5 Vairation of Roof Temperature with Heat Input rate for open-hearth furnace

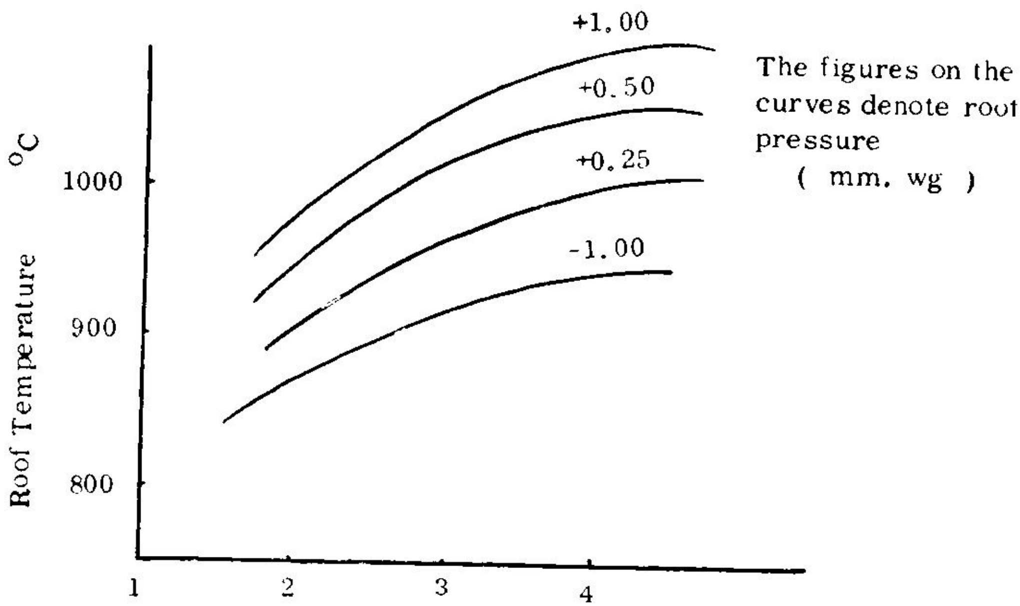


Fig. 6 Total heat input to furnace (Kcals/Hour)

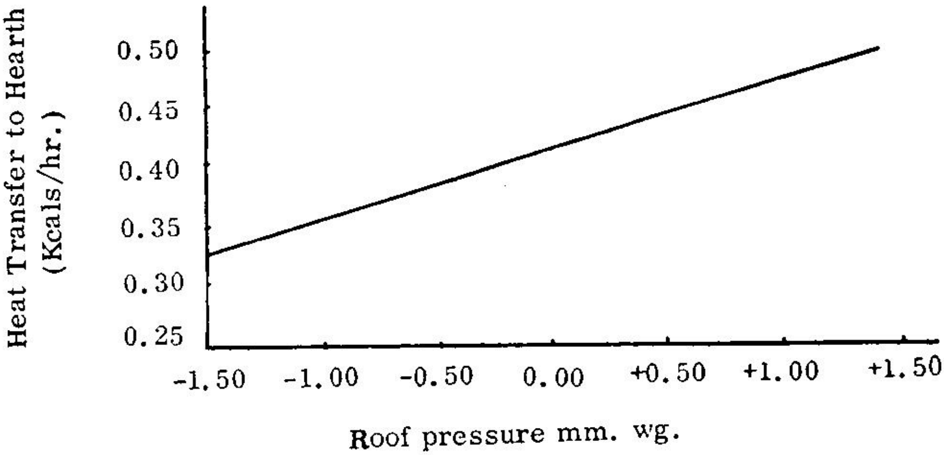


Fig. 7 Variation of Heat Transfer rate with roof pressure for open-hearth furnace with no flame escape from doors.

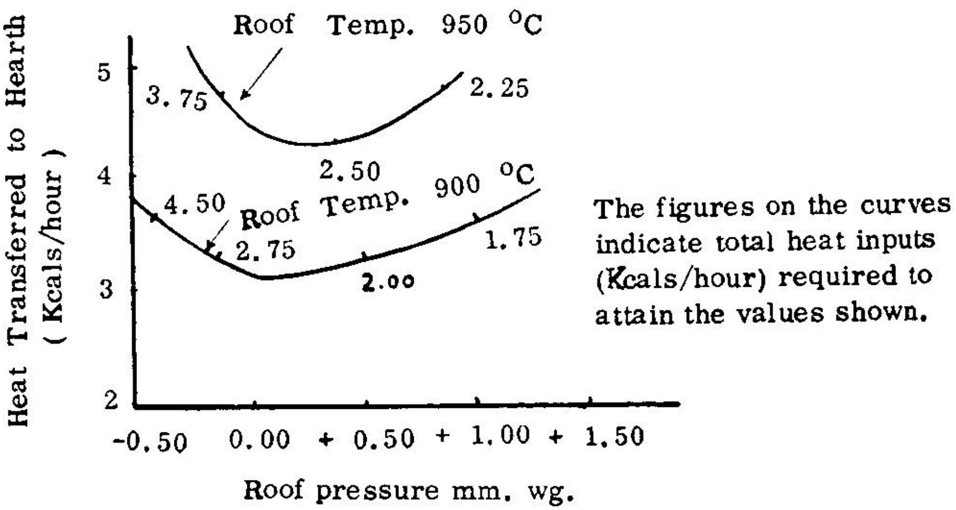


Fig. 8 Variation of heat transfer rate with roof pressure and roof temrerature for open-hearth furnace.

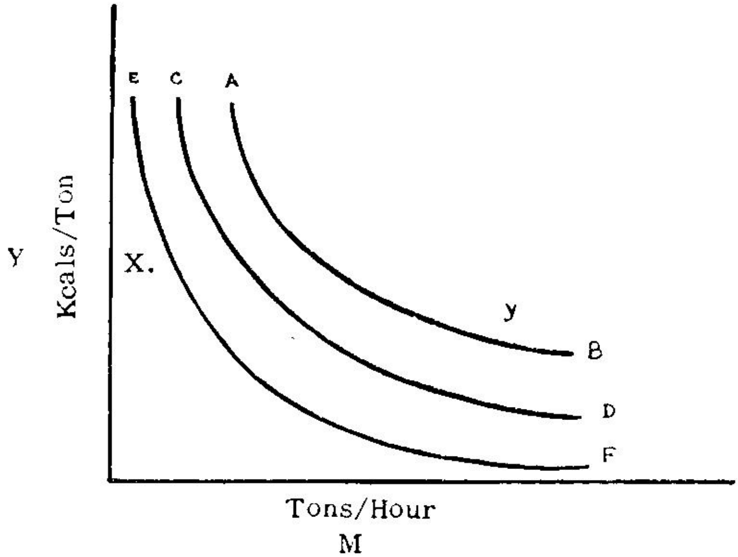


Fig. 9 Variation of fuel consumption per ton with production rate for open-hearth furnace.

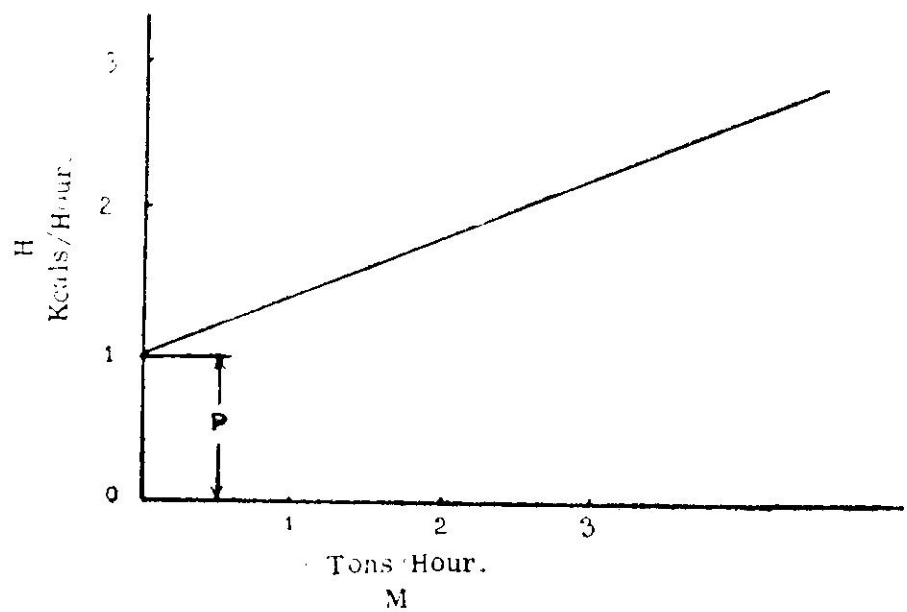


Fig. 10 Vairation of Heat Input rate with production rate for open-hearth furnace.

should be as follows:

Kg steam per litre of oil

Period	Total	Atomising Steam Only
Charging	10.8	9.7
Melting	8.5	7.4
Refining	7.0	6.0

4) It has been found that the fuel consumption is minimum when the length/breadth ratio is within 2.8–3.0. This is known as McCance's classification.

5) The furnace pressure should be maintained constant at 1.27 mm wg. In the case of oil-fired furnace, this can be done by maintaining a constant air flow. As indicated previously, the theoretical air requirements of oil fuel are almost equal to the waste gas volume produced. If the air volume is kept constant, then variations in fuel flow will not produce any wide variations in waste gas flow due to negligible volume of oil fuel. It follows that very little variation in furnace pressure, or in air infiltration, will take place, since furnace pressure may be considered to be the combined effect of fuel, air, and waste gas flow. However, producer gas requires 1.3 volumes of air for 1.0 volumes of gas giving 2.1 volumes of waste gas for theoretical combustion. Consequently, even with constant air flow, variations in fuel flow produce marked changes in the waste gas volumes, furnace pressure, and air infiltration.

Use of Excess Air

The heat transfer to the hearth increases as the roof temperature increases. However, the maximum safe roof temperature is fixed by the quality and nature of the brick. The roof temperature before commencing to charge must be 1450°C, while a temperature of 1630°C must not be exceeded during any period of the charging stage. The use of excess air may bring about this increase in heat transfer to a slight extent for a given roof temperature, but the fuel consumption is substantially increased thereby. It would be of little practical interest if a high heat transfer to the hearth was made possible by artificial cooling of the roof, since this would lead to excessive fuel consumption. The roof temperature can be increased either by an increase in the heat input, or by increasing the roof pressure, or by decreasing the excess air as indicated in Figs. 5 and 6.

The furnace pressure is increased and there is a progressive increase in heat transferred to the hearth, as shown in Fig 7. The variation of heat transfer to hearth with roof pressure is shown in Fig. 8. This curve is very important.

From the above it follows that:

(1) The heat transfer to the hearth increases as the roof temperature increases, at a given roof pressure.

(2) The heat transfer to the hearth for a given roof temperature can be increased either by working at a very high roof pressure with marked economy in fuel consumption, or at very low roof pressure (excessive draft) involving high fuel consumption.

(3) The heat transfer to the hearth may be increased by the use of appreciable excess air, but also at the cost of a greatly increased fuel consumption.

It should be noted that until relatively high roof pressures are attained, the advantages of increased roof pressure are more marked as regards fuel economy, rather than increased rate of heat transfer, though both these requirements stand to benefit. Besides, the furnace pressure has a great effect on the degree of combustion of the gases inside the furnace, and will be apparent from Table IX.

Clearly the most effective furnace pressure in this case is 2.03 mm. wg. In practice, it is difficult to determine the furnace pressure directly by a straight gas tapping from the furnace in view of the very high temperature and danger of impingent flame. For this reason Kistner's formula for the pressure drop in regenerators is used.

TABLE IX

Variation of Waste Gas Analysis by Adjustment of Furnace Pressure

Oil flow litres/hr.	Air flow nm^3/hr.	Roof pressure mm. wg.	Waste gas analysis % CO_2	% O_2	% CO
1,180	14,000	1.35	12.0	6.6	Nil
1,180	14,000	1.52	12.8	5.0	Nil
1,180	14,000	1.88	13.8	3.9	Nil
1,180	14,000	2.03	14.0	2.3	Nil
1,180	14,000	2.29	14.8	0.7	0.7

The formula is given below:

$$P = 2.4 \times 10^{-4}\ K\ S\ V^2\ T \quad \text{mm } H_2O$$

Where P=Pressure drop in regenerator, mm H_2O

K=constant equal to 0.3 per course of bricks in regenerator.

V=mean theoretical velocity of gas in passages, m/sec.

T=Mean temperature of regenerator °K

Hard Coking Coal

The Central Fuel Research Institute has been experimenting on making hard coking coal out of low-grade non-coking coal by adopting a technique of low temperature carbonisation in two stages. About 50 tons of such coke have been made in their pilot plant. If this process is further developed, and becomes a technical and economic success, it will create a revolution in the coal industry.

Knowing the inlet gas, air and chimney waste gas pressures, the pressures at inlet and outlets of the furnace can be calculated, their mean giving the furnace pressure.

Through a series of reports, the work of the International Flame Radiation Research Foundation at Ijmuiden has primarily tried to emphasise the importance of burner thrust in the heat transfer to the hearth by convection and radiation in the open-hearth furnace, and is due to more rapid mixing leading to more rapid combustion of the soot, and a rapid increase in gas temperature. At the same time, however, the emissivity decreases.

When the variables like steam/oil ratio and steam pressure are compared for the same burner thrust, there was not much to choose from.

The addition of carbon black to gas oils leads to higher heat transfer rates due to increase in luminosity. The relation between average flame emissivity, carbon-hydrogen ratio of the liquid fuel, and the average boiling point of the liquid fuel (T°C) was given as

$$E_{T_{avg}} = 0.282 \ln\left(\frac{R-1.5}{7.5}\right) + 0.0005\,(T-200) + 0.774$$

It has also been shown that the emissivity at any point is a function of the soot concentration C in mg/ml as follows:

$$E_T = 1 - e^{-0.275\,C}$$

Effect of Geometry of Furnace: The factors deciding the area and depth of the bath for a given furnace capacity are the capital costs and the production rate. Thus, if for a given furnace capacity the bath is made very deep, thereby decreasing the hearth area and the capital costs of the furnace, the result will be longer melting periods due to decreased heat transfer surface, and longer refining periods due to decreased oxidation rate of the bath, eventually decreasing the production rate. On the other hand, if for a given furnace capacity, the hearth area is increased causing shallow baths, then although the production rates will be increased, the capital costs of the furnace will be large.

The problem, therefore, lies in striking the balance, such that the following cost is a minimum—

$$\frac{\text{Capital costs Rs.}}{\text{Life of furnace in years}} + \text{production rate} \left(\frac{\text{tons}}{\text{year}}\right) \times \text{Cost of steel} \left(\frac{\text{Rs}}{\text{ton}}\right)$$

and thus for any given capacity of the furnace there will exist a certain optimum depth of hearth which will be most economic. Table X represents economic British practice.

TABLE X

Furnace capacity Tons	Optimum Depth of Metal Bath m.
50	0.28
100	0.375
150	0.405
200	0.53
250	0.57
300	0.63
350	0.68

According to a statistical study made by Nickols and Thring, the production rate of furnaces in the range 7 to 20 tons/hr can be expressed by the following dimensionless regression equation

$$\left(\frac{i}{\bar{i}}-1\right) = 0.337\left(\frac{a}{\bar{a}}-1\right)+0.568\left(\frac{b}{\bar{b}}-1\right)+0.152\left(\frac{c}{\bar{c}}-1\right)-0.091\left(\frac{d}{\bar{d}}-1\right)+0.252\left(\frac{e}{\bar{e}}-1\right)$$

where: a = furnace capacity
b = hearth area
c = percentage of total output in non-alloy steels
d = mean percentage of tap carbon in carbon steel expressed as a percentage of total output
e = hearth shape (max. length/max. width)
f = percentage hot metal in metallic charge
g = air uptake area
h = fuel input rate
i = production rate (with a bar denoting a mean value).

In view of the paramount importance of capacity and area in determining the output, the regression of output on these variables was calculated:

$$\left(\frac{i}{\bar{i}}-1\right) = 0.447\left(\frac{a}{\bar{a}}-1\right)+0.521\left(\frac{b}{\bar{b}}-1\right)$$

Effect of Furnace Capacity, Output, and Performance Standards: Marshall has stated that an increase in furnace capacity from 100 tons to 200 tons leads to a decrease in fuel consumption by as much as 0.5 million kcal/ton, with a productivity increase of about 10 tons/hr. His further observations are as follows:

a) If the furnace capacity is increased by increasing the depth of the furnace, a 10% increase in capacity causes a 3% increase in output.

b) If the furnace capacity is increased by increasing the hearth area, but the average depth kept constant, then a 10% increase in capacity would give a 9% increase in output.

Orrok has given an empirical formula expressing the thermal efficiency of a furnace as a function of the fuel input rate. Orrok's formula was

$$\eta=\frac{1}{1+\frac{G\sqrt{C_r}}{60}}$$

where G=kg air/kg. fuel
and C_r=kg. fuel burnt/hr.m^2 heating surface.

A similar empirical formula was put forward by Hammond and Sargant, and was as follows:

$$\eta=\frac{1}{1+\frac{G5/3\sqrt{C_r}}{355}}$$

Thring, on the basis of his theoretical studies put forward the following formula expressing thermal efficiency of a furnace in terms of dimensionless parameters, as in terms of dimensionless parameters.

(α This sign used in the following pages represents 'alpha')

$$\eta=\left\{1-b\,(1-a)\right\}\left[1-e^{-1/z}\right]-\frac{ab}{z}$$

where a= 'wall loss paramater'

$$=\frac{\alpha_w}{\alpha_u}\frac{A_w}{A_u}$$

b= 'heat availability parameter'

$$=\frac{t_u}{\beta\;t_a}$$

z= 'heat input variable'

$$=\frac{C_r}{\alpha_u}\frac{G}{\beta}\;'C_p$$

where: α_u = effective mean heat transfer coefficient between the gases and the charge expressed in terms of the temperature difference between the gas temperature t_g and the temperature of the charge t_u Kcals/hr. m^2 °C.

α_w = effective mean heat transfer coefficient through the walls expressed in terms of the temperature difference between the charge and the atmosphere kcals/hr. m^2 °C.

A_w = area of wall through which heat is lost, m^2

A_u = heating surface of charge, m^2

t_a = adiabatic flame temperature °C

$$C_r=\frac{\text{kg. fuel burnt}}{\text{hr m}^2\text{ of heating surface}}$$

$$G=\frac{\text{nm}^3\text{ wet flue gases}}{\text{kg. fuel}}\quad\text{or}\quad\frac{\text{kg. wet flue gases}}{\text{kg. fuel}}$$

C_p = mean specific heat of wet flue gases

$$\frac{\text{Kcals}}{\text{nm}^3\ ^\circ\text{C}}\quad\text{or}\quad\frac{\text{Kcals}}{\text{Kg. }^\circ\text{C}}$$

β = dimensionsless parameter representing the effect of delayed combustion (varies from 0.5 for long laminar flames to 1.0 for short highly turbulent flames).

It would follow from Thring's equation that the thermal efficiency of a furnace would be zero up to the value of the heat input variable Z corresponding to the heat input sufficient to bring the system up to the working temperature t_u and would then rise almost linearly up to values of Z corresponding to the peak thermal efficiency. After the maximum is reached, the thermal efficiency would fall as the heat input increases due to increase in heat losses in the waste gases, because of the heat transfer bottleneck between the heating gases and the charge. Experiment has shown that generally high temperature furnaces, like open-hearth and reheating furnaces, operate in the initial linear part of the curve, where the efficiency increases with increase in heat input, whereas boilers owing to the limitation of the heat transfer surface is operated in the region where the efficiency decreases with increase in heat input. In short, the important point brought out in Thring's treatment is the possibility of designing a furnace, so that the average heat input will occur at about the value corresponding to peak thermal efficiency, and where this is not practicable—e.g., because this would imply too large a heating surface, and hence too high a capital cost the desirability of installing waste heat equipment to take account of the necessarily enlarged stack losses would be clear.

Solving Thring's equation for obtaining the fuel input corresponding to peak thermal efficiency the following equation is obtained.

$$Z = \frac{C_r \ G' \ C_p}{a_u \ \beta} = \frac{1}{2.303 \ \log \left[\frac{1-b\,(1-a)}{ab}\right]}$$

Thus

$$C_r = \frac{a_u \beta}{2.303 \ G' \ C_p \ \log \left(\frac{1-b(1-a)}{ab}\right)} \quad \text{kg./h}_r \ \text{m}^2$$

The values of 'a' and 'b' for low and high temperature furnaces are generally represented thus:

For low temperature furnace
a=0.003 for good insulation
a=0.10 for bad insulation
b=0.1
For high temperature furnace
a=0.011 for good insulation
a=0.033 for bad insulation
b=0.7

Importance of Setting Performance Standards: Fig. 9 shows the relation between the output and heat consumption. The curve A B has been drawn for normal operating conditions. The curve E F has been drawn for the heat conditions when the furnace was run on test under strict supervision. The curve C D has been drawn as a mean between these two operating conditions, which represnts the standard of performance to be attained. In the Figure, the operator X has more than fulfilled the standard imposed upon him, while Y has failed in this attainment although he has consumed less heat per ton of production than X.

In Fig. 10 the slope of the characteristic (kcals/hour) curve is slight, i.e., the effect/of furnace loading is so little that the heat required (kcals/hours) is almost independent of the amount of material heated (tons/hour). The kcals/hour increases by only 27% when the output is trebled. This curve is almost a straight line, and can be represented by the equation.

$$H = F + \alpha M$$

where: H = heat consumed per hour (kcals/hour)

F = furnace constant, or amount of fuel required to keep the furnace up to the temperature when empty (kcals)

M = Weight of material heated per hour (tons/hour)

α = heat required per unit weight of material, irrespective of the furnace constant (kcals/ton).

The value H gives a useful indication of the efficiency of the furnace operators.

Once the line is plotted under standard conditions, the object of control is to lower the curve below this basis, since any improved result will show as a reduced fuel per hour H.

Effect of Lagging & Waste Heat Recovery: All furnace walls not specially protected are permeable to gas. If the difference in pressure between the furnace chamber and the external atmosphere is appreciable, there is a tendency either for hot gas to flow outwards, or for an inleakage of cold air from the atmosphere: both effects may result in a lowered thermal efficiency.

Heat Losses

For an insulating porous brick of permeability and a mean thermal conductivity of 8.2 kcals/hr. m². °c over the range of 1000°C (inside)—80°C (outside) and a pressure difference of 5.1 mm w.g. across the wall and for a 23 cm. thick wall, the heat losses amount to 836 kcals/hr. m² for non-permeable conditions and 1160 kcals/hr m² for outward flow. The difference in heat losses amounts to an increase of 30% due to permeable flow. These facts point to the need for close joints and external plating, and indicate the existence of a problem not solved by the makers of porous bricks. An interesting new construction in which the products of combustion are exhausted through the walls of the furnace (these walls being made of a permeable material) has been described by Anderson, Gunn, and Roberts. The advantage of this construction over the orthodox design is that it results in the sensible heat of the waste products of combustion being used to apply the heat storage of the furnace wall. At the same time a more rapid attainment, and a more even distribution of the furnace temperature, are practicable. But it has not yet been tested how would the heat balance of such a furnace, fitted with a permeable lining, would compare with one without it (each being equipped with an efficient heat-recovery unit—recuperators, regenerators, or any other mechanism for heat recovery).

It has been estimated that the percentage saving by the installation of a permeable lining over a nonpermeable one are:

$$P = \left(1 - \frac{Q - 1{\cdot}76\ T_0}{Q - 1{\cdot}76\ T_2}\right) \times 100 \text{ percent}$$

where T_0 = temperature of gases inside the furance, °C.

T_2 = temperature of gases in the annulus outside the permeable wall where the waste gases are exhausted, °C

and Q = gross calorific value of the gas, kcals/nm³.

Throughout the steel industry every effort is being made to increase plant efficiency, and to effect savings which will tend towards lesser production costs. Not the least important step in this direction is the general application of waste-heat boilers to open-hearth furnaces, notoriously low in thermal efficiency. The steam thus generated is usually used for fuel atomisation, gas producers, or process work, and in some cases for power generation. Waste gases leaving the checker-work of well-designed open-hearth furnaces carry from 45% to 55% of the heat of combustion of the fuel fired, depending on furnace size, operation and practice, volume of checker work, and kind of fuel used. With good design and operation of waste-heat boilers, approximately 55%—65% of the heat in these gases is recovered and converted into steam, representing 20%—35% of the heat of combustion of the fuel fired in the furnace. The temperature of gases entering the boiler usually runs from 540° to 700°C depending on practice, checker-work, and size of furnace. Well-designed waste heat boilers will cool the gases to give an outgoing temperature of 240°C to 260°C.

Table XI gives the boiler horse power to be expected for different fuels, on the assumption of 1.5 million kcals in fuel per ton of steel, burned with 100% excess air. The temperatures of the gas at inlet and outlet of boiler are assumed to be 590°C and 250°C respectively. Specific heat of gases used are 0.24 for dry gases, and 0.48 for moisture in the gases. The steam generated was calculated at 95% of the heat extracted from the gas in the boiler, thus allowing 5% for radiation.

It will be noticed that the heat recovery from producer gas stands considerably above that from the other fuels, due to the lean nature of the fuel, with its accompanying high stack loss. This was already pointed out previously.

TABLE XI

Heat Recoverable from Open-hearth Furnace Waste Gases When Operated on Different Fuels

Fuel	Kg. gas from furnace per ton of steel	Total kcals to boiler per ton of steel	Boiler H.P. generated per ton of steel
Natural Gas	5,200	496,000	55.8
Coke oven gas	4,380	428,000	48.3
Producer gas	6,680	624,000	70.0
Oil	4,810	455,000	51.3
Tar	5,050	467,000	52.5

In any type of waste-heat boiler, the velocity of gases through the boiler should be considerably higher than in direct-fired practice, due to the small amount of radiation taking place in waste-heat practice, heat transfer being affected principally by convection which is dependent largely upon velocity. The high gas velocity required in waste-heat boilers, with the accompanying high draft loss, necessitates the use of induced-draft fans. Such fans should have efficient capacity to handle all gas which might come from the furnace under any operating conditions. In no case should the waste-heat installation be allowed to interfere with the primary furnace, but, on the contrary, the fan should result in even better furnace conditions. For this reason, the fan-drive is preferably variable speed. Either motor or turbine drive can be used. The turbine has good economy, provided the exhaust steam can be used for feed water heating or some such use. Tables XII and XIII give the results of various types of waste heat boilers. The fire-tube boilers show the smallest amount of heating surface per ton of furnace capacity and per Brake Horse Power, indicating a higher rate of heat transfer. On the whole, there appears little to favour either type over the other.

Just prior to World War I, one or two plants making use of the Vautin system of generating steam while granulating blast furnace slag in enclosed plants were installed at the clearance works of Messrs. Bell Bros. Ltd., in the Middesborough area. The method consisted in quenching and granulating the molten slag in water. The dirty steam so generated at 100°C was collected at a very low pressure of about 0.07 kg/cm^2 gauge, and used to evaporate clean water in Kestner single-effect climbing-film evaporator (heating surface 51 m^2) under a pressure of about 224 mm. of mercury (at which water boils at 90° to 91°C). In this way 41.5 kgs of dirty steam were generated by quenching the slag, and experiments showed that 389 kgs of clean steam could be obtained per ton of slag quenched. And, inasmuch as a modern exhaust turbine working with a full load, and under a vacuum of 724 mm mercury, used no more than 12.3 kg. of steam per h.p. under the said conditions, the available h.p. when used for power generation would be 31.6 per ton of slag per hour. Other results give the power produced variously from 30 h.p. to 60 h.p.

TABLE XII

Data Indicating Effectiveness of Fire-tube Boilers as a Means of Waste Heat Recovery from Open-hearth Furnace

Gas temperature before boiler °C	567	668	642	731	727
Gas temperature after boiler °C	257	241	255	252	255
Boiler H.P. developed	363	307	285	258	261
Litres oil per hour	1705	1048	930	690	704
kg. waste gases per hour	—	24300	24800	17500	18100
Heating surface, m^2	465	284	284	218	218
Draft load mm H_2O	—	46.2	47.5	65.3	64.8
$\frac{m^2 \text{ heating surface}}{\text{ton furnace capacity}}$	5.11	5.58	5.58	6.23	6.23
$\frac{m^2 \text{ heating surface}}{\text{Boiler H.P. developed}}$	—		about 1.12		

TABLE XIII

Data Indicating Effectiveness of Waster-tube Boilers as a Means of Waste Heat Recovery from Open-hearth Furnace

Gas temperature before boiler °C	630	673	584	607	622
Gas temperature after boiler °C	276	291	268	243	252
Boiler H.P. developed	258	308	218	392	472
Litres oil per hour	952	cal	1180	coke, gas	tar
kg. waste gases per hour	2500	31700	22400	37400	44500
Heating surface, m^2	383	472	472	485	647
Draft loss mm. H_2O	—	—	—	52.8	73.5
$\frac{m^2 \text{ heating surface}}{\text{ton furnace capacity}}$	7.64	7.81	7.81	6.51	6.51
$\frac{m^2 \text{ heating surface}}{\text{Boiler H.P. developed}}$	—	about 1.67		about 1.30	

per ton of slag per hour—for instance, the plant attached to one small furnace produced 500 kW. This is of course a very low power, and there is no evidence that these plants were kept in operation for more than a few years, no doubt because upkeep and capital costs were not justified by the power produced. Another serious difficulty was that the addition of water to molten slag produced quantities of sulphurous gases which had a strongly corrosive action on metal plant. Since then little has been heard of attempts to use heat.

Effect of using gaseous oxygen: The use of oxygen for steel-making can take any of the following forms: (1) oxygen lancing in ladles, (2) Bessemer Blast Enrichment, (3) L. D. Process, (4) oxygen lancing in the open-hearth furnace. The introduction of oxygen through lances or jets into the metal for desiliconisation of blast furnace metal in ladles, removes a proportion of the silicon before the metal enters the open-hearth (about 2% lime or limestone is added to make a slag), thereby reducing the slag bulk during the later stages of refining which means faster refining, and reduced fuel consumption. Apart from the removal of silicon the other advantage arises from the fact that during desiliconisation it is possible to melt quantities of awkwardly sized scrap, such as ladle skulls, and still finsih with the iron some 50°–100°C hotter than at the start. Roughly speaking, oxygen is consumed in desiliconisation at a rate of about 1.7 m^3 per 0.1% silicon removed per ton of metal, and it has been found very useful for the removal of silicon, say from the region of 1% down to 0.4% or thereabout. Oxygen is consumed at a rate of about 10 m^3/ton. and to desiliconise 20 tons of metal using a 1-2 cm lance will take about ½ hour, the lance delivering about 55 nm^3 / min at a pressure of 10 kg/cm^2. Having regard to the slopping and foaming difficulty, the introduction of oxygen is generally limited to a speed of about 55 nm^3/min.

The other forms of oxygen enrichment, viz., the Bessemer Blast Enrichment and the L.D. process, also lead to an increase in overall fuel economy due to the increase in production owing to shorter refining times. Each process has its limitations as outlined below:

Experiments have shown that oxygen enrichment of the flame, either by lancing through the roof, or by injection in checkers, have little effect on the melting rate. Short-term increases in melting rate, and in production, have certainly been recorded, but in practically every case, the gains achieved have been offset by increased refractory consumption, and shortened furnace life. The verdict has generally been of 'No. Proven'. Even during the refining periods the use of oxygen by jets spaced 15 cm above the metal surface has been restricted to the final phase of refining, viz. decarburisation, when the metal has lost all its silicon and probably its phosphorus, and contains not more than 0.30%–0.40% carbon. Lancing of oxygen during the initial refining period when the silicon, phosphorus, and carbon in the metal are high causes violent 'slopping' and agitation inside the furnace, together with foaming of the slag, and the generation of clouds of thick brown fumes. These three effects of slopping, foaming and fuming during early oxygen injection can make life almost impossible for melters on the stage, and just about equally unpleasant for the refractories inside the

Process	Nature of pig iron	Time of blow (min.)	Oxygen consumption
(1) Oxygen lancing in ladles from top (dipping into metal)	Si > 0.4%	60	1.7 nm^3 / 0.1% Si. ton pig iron @ 5.5 nm^3/min
(2) Bessemer oxygen enrichment (up to 30 per cent O_2) Blow from botton of converter	P > 1.6% Si preferably low	18	Maximum 60 nm^3/ton steel
(3) L.D process Oxygen lance from top (but not dipping in metal)	P < 1.6% Si < 0.4%	25	Maximum 60 nm^3/ton steel @ 85 nm /min

furnace. When oxygen is used for decarburisation during the final phase of refining in the open-hearth the mean rate of refining is notaly accelerated which, according to the degree to which refining is necessary, may lead to substantial economies in both time and fuel. The refining action when oxygen is used is an exothermic one, unlike the reaction when oxidation is carried out with iron ore or mill scale; hence the fuel supply during blowing may be substantially reduced, or even cut off altogether, but, of course, there is a slight loss of recovery as ore and mill scale contain iron, but oxygen does not.

A further advantage which accrues when oxygen lancing is used for the production of refining steels is that it enables the finally desired carbon figure to be obtained with a greater degree of certainty. Experience has shown that the specific oxygen consumption, which amounts to an average of 0.11 nm^3 per ton steel per point of carbon oxidised, is adhered from heat to heat with remarkable consistency. Therefore, if the carbon content at the start of blowing is known, the quantity of oxygen required to bring the carbon to below a certain specification can be readily calculated. Recently, Evans and his collaborators have given results on the operation of 220-ton and 400-ton open-hearth furnaces without and with oxygen. Their results are given in Table XIV.

It will be seen from this table that for a given furnace the use of oxygen for flame enrichment during cold charging, and for decarburisation during the final refining period, has led to increased production rates and decreased fuel consumption per ton steel made. Also, an increase in the size of the furnace not using oxygen recorded similar increases in production rate, and decrease in fuel consumption. With the larger furnace using oxygen, the increased fuel consumption is partly due

TABLE XIV

Performance in 220-ton and 400-ton Open-Hearth Furnaces, Without and With Oxygen

	220-ton Furnace		400-ton Furnace	
	Without Oxygen	With Oxygen	Without Oxygen	With Oxygen
Per cent hot metal	54.0	56.8	59.8	70.0
Time, charge-tap (Hr. Mins)	8.40	3.30	11.05	5.20
Fuel, 1./ton	108.0	45.8	94.0	61.4
Production, tons/hr (charge-charge)	24.0	55.1	33.1	62.1
Production, tons/hr (charge-tap)	26.4	60.3	36.6	77.6
Oxygen, nm^3/ton Decarburizing	..	44.2	—	36.1
Oxygen, nm^3/ton Enrichment	—	6.2	—	4.7
Time, cold charging (Hr. Mins)	2.05	0.45	3.50	1.05

to the fact that a much higher specification for the steel was called for.

Ajax Process: The furnace body is similar to that of a normal tilting type open-hearth furnace, and is of 'all basic' construction, and operates in the same way as the modern oxygen processes. Only during charging, fettling, and the final phase of refining, normal fuel is used. The furnace has offtakes of smaller areas due to less waste-gas to be handled.. The furnace has coke-oven gas burners at each end with oxygen-nozzles, capable of passing up to 3910 nm^3/hr of gas, and 1624 nm^3/hr of oxygen. The furnace considered here is automated to the possible extent, and differs in many ways in operation with the open-hearth furnace, and has added advantages. Air filtration is avoided, and consequent gain of preheat and waste heat steam, reduced gas cleaning plant, saving in fan power with facilities for rapid replacements or change-over to various units. The port-end is mounted on a carriage, and makes a tight joint with the down-take by means of a water-seal. The mechanically operated water-cooled oxygen lances enter through the top of the port-end, where steam jets are inserted in each port-end to help to direct the air flow. If required, pitch-creosote burners are introduced at this point. The oxygen can be admitted into this furnace in three ways! (a) through the burners with coke-oven gas, (b) through the water-cooled lances which can discharge either below or above the metal surface, and (c) through the regenerators along with the incoming air. Gaseous volumes of fuel, air, and oxygen are all automatically measured and controlled.

Operating Method: As soon as the previous tap is tapped, the furnace which still contains 20 to 30 tons of molten steel, and all refining slags from the previous heat, is fettled with dolomite. Then the ore, lime or limestone required for the following charge is added. During this period, the furnace is fired with coke-oven gas at up to 3800 nm^3/hr using oxygen at the rate of 420 nm^3/hr to accelerate combustion. Now the charge of molten metal is added, and the oxygen lancing is started at the rate of 1,700 nm^3 to 2,200 nm^3 /hr cutting-off of all the fuel, with air being continued to consume carbon monoxide from the bath. The amount of oxygen to be blown depends on the composition of the pig. Completion of refining takes place under fuel-firing which slows down the rate of reactions in the bath, and allows the steel and slag to come sufficiently nearer to equilibrium, to give the best quality steel. When the correct analysis and temperature are achieved, the furnace is tapped leaving only the refining slag. The normal charge is 200 tonnes to 220 tonnes, and the average tap-to-tap time is seven hours. The heat balance shows that the thermal efficiency, including heat recovery, is 75%. The fuel consumption is about one-fifth of the standard open-hearth practice. The increase in oxygen usage still decreases fuel consumption, but is not, on an overall basis, economic. The production cost, i.e., the conversion cost of charged raw-material to ingots is about 68% of the standard open-hearth practice. Tables XV and XVI give a comparison of the material and heat balance for the newer steel-making processes, with the conventional steel-making process.

VLN Convertor Process: The convertor, which is a pear-shaped vessel made up of steel lined with a highly refractory material, consists of three parts—a detachable bottom, a central cylindrical portion provided with a mechanism to rotate the entire convertor, and the upper slant conical portion. It is mounted on the trunnions, one of which is hollow, and serves as bustle-pipe to lead the blast to the wind-box at the bottom. The convertor considered here is of 74 tonnes capacity. The steam-oxygen blast entering the convertor is distributed throughout the bottom by a number of 12 mm internal diameter copper-lined tuyers. The blow lasts about 12 minutes, and the oxygen is consumed at the rate of 16,800 nm/hr.

Operating Methods: The general operating procedure during the refining of pig-iron to steel in the VLN process is much the same as in the long-established basic Bessemer process. An empty convertor vessel, already hot from a previous blow, is rapidly charged with weighed quantities of lime, steel-scrap, and hot-metal in that order. The vessel is tilted vertically, and the steam-oxygen blast is turned on. The heat generated by the oxidation reactions increases the temperature of the contents of the bath, when lime fluxes silica. The carbon removal is marked by the drop in the flame at the mouth of the convertor. After considerable dephosphorisation has taken place, the convertor is tilted, and the slag formed with high percentage of P_2O_5 is run-off, the steel temperature is measured, a sample is taken and analysed for phosphorous, manganese, and sulphur, and the metal is blown for the second time correct to seconds of the calculated time and poured into laddles. The bottom is renewed after 35 to 50 blows, and the lining is changed after 200 to 250 blows.

KALDO Process: It is a rotating pear-shaped, symmetrical convertor. It is placed in a tiltable cradle resting on trunnions or tilting rings. The convertor can

Assessment of India's Energy Requirements

A recent publication of the National Council of Applied Economic Research ("Demand for Energy in Eastern India") states that, "in the present context of our development, the future requirements of energy cannot be determined by the usual methods of projection from past trends either by simple or exponential types.

In a planned economy with pre-determined magnitudes of development in all economic sectors, an assessment of energy requirements based on these goals should be more realistic and purposeful. If there is any time lag between what is envisaged and what actually materialises, the energy needs are not altered in any sense, but only become phased out over a longer period."

be rotated with a speed that can be varied from 0 to about 30 r.p.m. During refining the furnace is inclined at about 17° to the horizontal, and oxygen is introduced through a water-cooled lance which is fixed to the pivoted hood for the exhaust gases at an angle of 22° to 30° to the horizontal. This furnace can conveniently be used with ore or scrap cooling.

Operating Method: The furnace is tilted to position, first lime and ore or scrap are charged, then it is brought to the charging position, where hot metal is poured into the furnace, all in weighed quantities. Then the furnace is brought to the inclined position, and the swingable hood is fixed mechanically, and the oxygen lancing is commenced. The amount of oxygen required for refining depends on the type of operation, but the use of ore saves about 10% of the hot-metal, and also the amount of oxygen required. During the blow-period, the furnace is rotated at sufficient r.p.m. to create suffcient stirring. There is only a little of carbon monoxide in the gases leaving the Kaldo furnace, and so less air is needed to burn the carbon monoxide than in the case of top-blown vertical reactor.

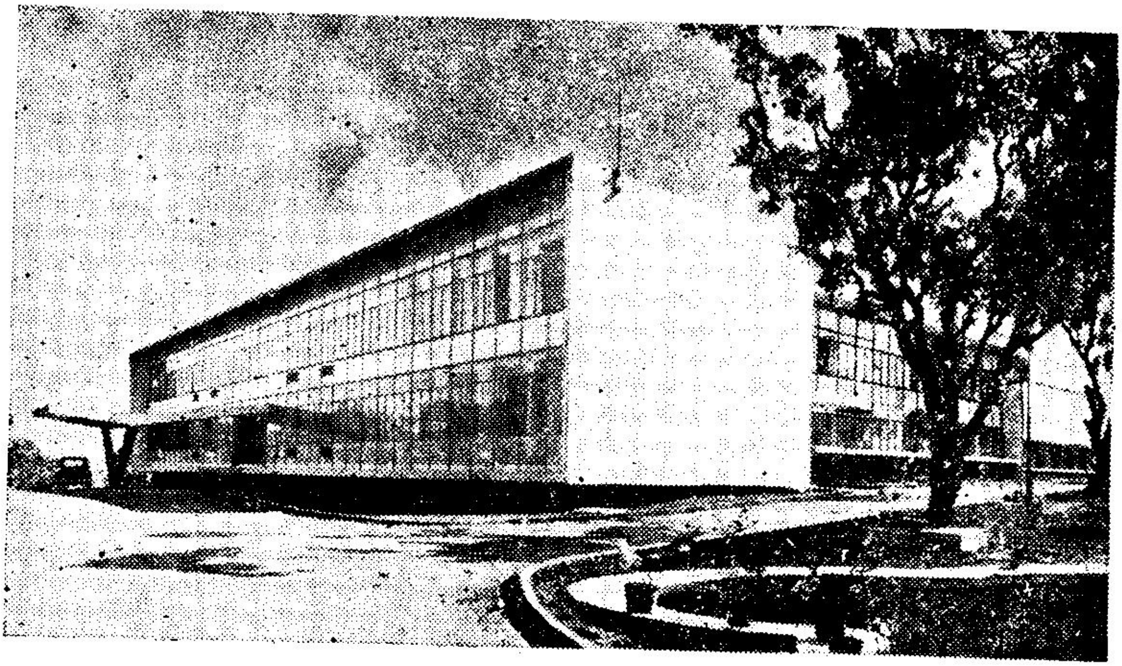
Possible Steel-melting Processes:

(a) **Counterflow Steel Melting**: The most efficient method of melting steel from cold scrap and cold pig iron, by burning conventional fuels, would be one in which the combustion gases were produced from a burner with pre-heated air over the melting bath, and then caused to pass in counterflow to the incoming cold material before leaving and passing through a metallic recuperator. One such furnace was constructed in Germany, in which the scrap was pushed down a gently sloping shaft, and the combustion gases flowed over the top surface of the scrap, using four successive ramps, and with three separate pushers, so that the material can be moved in turn from one to the next. This furnace has successfully melted steel at the desired rate of 10 tons/hr., and at a very satisfactory tapping temperature of 1600°C. The gases leave the preheating chamber for the metallic recuperator at a temperature of about 1050°C, where the air is preheated to about 700°C. The overall thermal efficiency of the furnace is just above 50 per cent and the firing was done by fuel oil. The furnace is being used as melter to feed a number of arc furnaces, etc. The fuel usage per ton of steel melted is of the order of 0.64 million kcals. This type of furnace is one stage nearer to the ultimate dream of fully continuous steel-making.

(b) **Pneumatic Steel-melting Process**: To utilise heat from the combustion of carbon monoxide more efficiently so as to recover heat by pre-heating the scrap or for the next charge, the molten iron is contained in a ladle rather than a Bessemer-shaped vessel, and the ladle is placed underneath a hood which carries four circular arc-shaped oxygen nozzles, and holes for the jet entry of pre-heated air for the combustion of carbon monoxide, and above this combustion chamber a set of water or steam-cooled tubes which support a weight of nearly 30% to 50% of the pig iron in the form of scrap. During the blowing of one charge, the waste gases are burnt and passed through the cold scrap for the next charge, which absorbs a part of fumes and cools to waste gases to pass through a waste heat-boiler.

(c) **Flexible Hot-metal, Cold-scrap Process, Using Both Oxygen-blowing and Fuel-firing:** This is the same as the Ajax process with detachable roof for charging cold scrap, and tilting arrangement as before for the entire body to remove intermediate slag also.

A radio a minute



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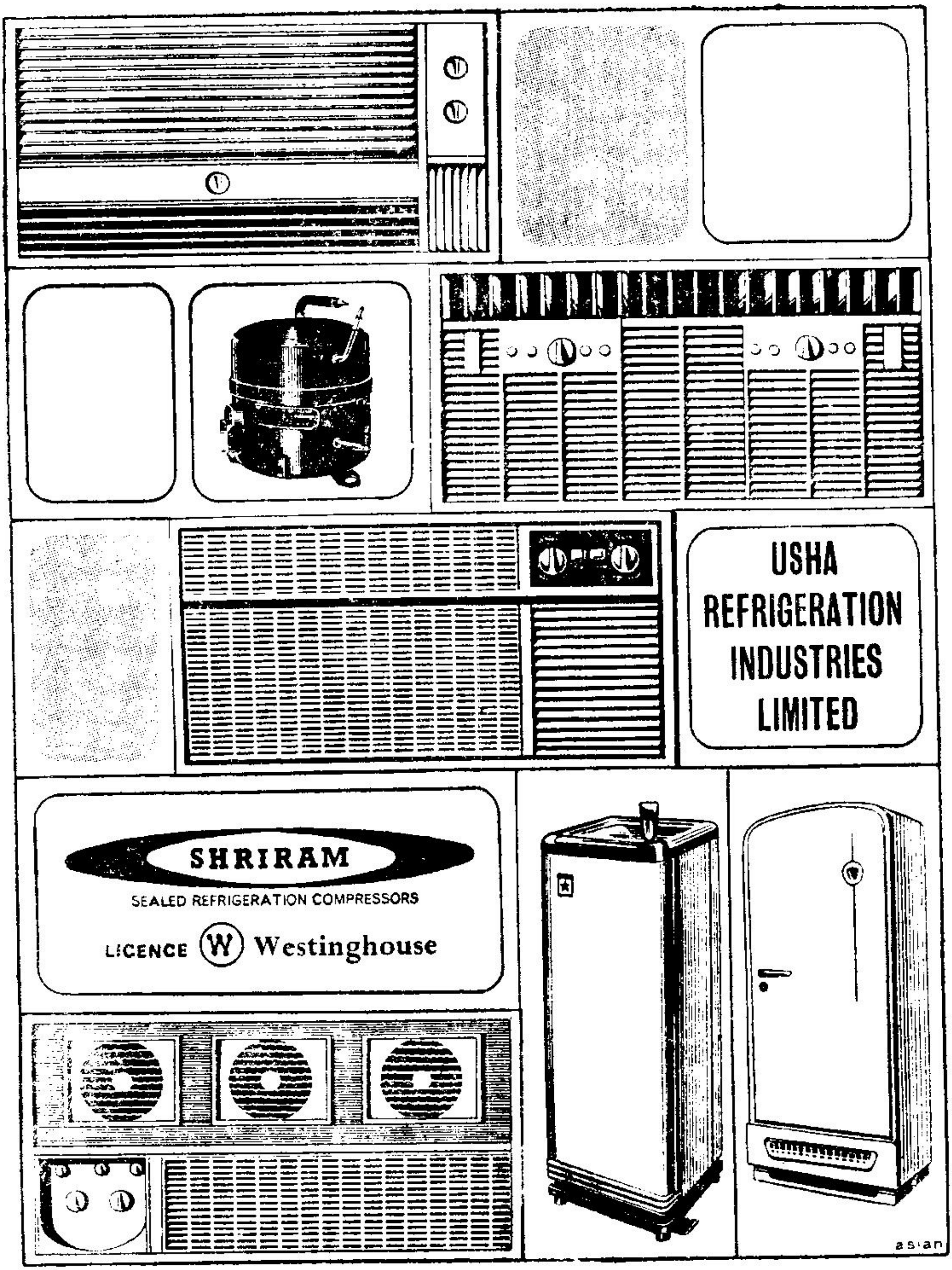
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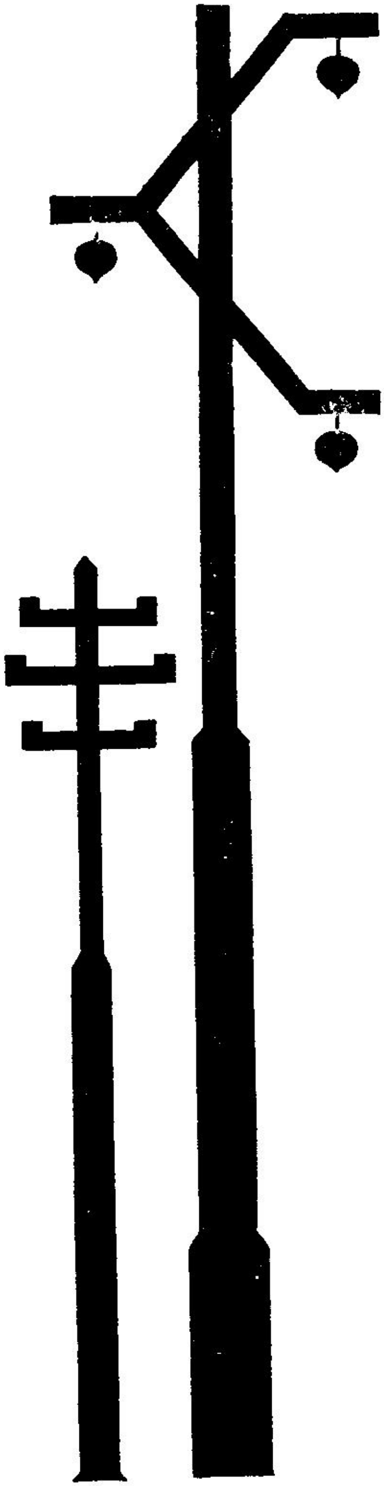

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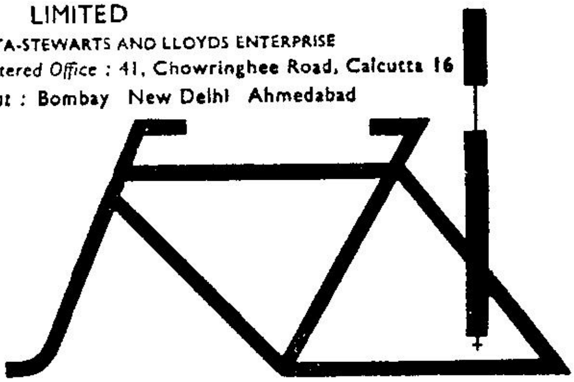

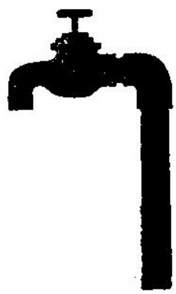

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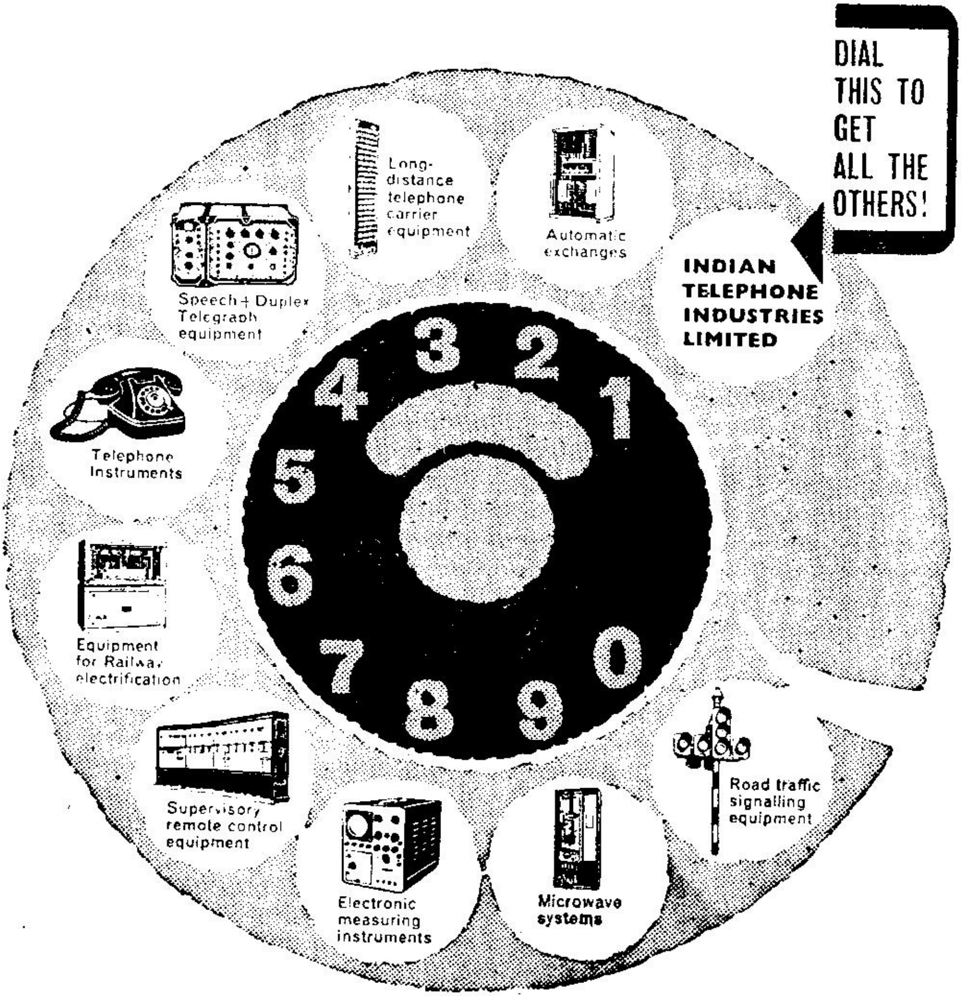

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Daurala Sugar Works
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Fuel Saving: Daurala Experiments

ECONOMISATION of fuel is the first step to the economical working of the sugar industry in India.

At Daurala Sugar Works, three-fourths of the steam is generated by burning bagasse (cane). We, therefore, had a second look at the past practices of steam-generation, to investigate the possibilities of increasing the steam generation per lb of bagasse; and also to find out if steam consumption in the plant could be reduced. On a theoretical calculation of steam requirements, the consumption could be brought down from about 74% to 50% on bagasse. An exhaustive steam economy project was launched for achieving the target steam consumption. A similar programme was launched at the Daurala Distillery for reducing steam consumption from 45 lb/gal. D.A. to 19 lb/gal. of R.S.

The achievements at Daurala, both at the Sugar Factory and the Distillery are discussed below.

SUGAR FACTORY

For reducing steam consumption at the sugar factory the programme was divided broadly into two parts:

i) to reduce the process steam consumption by recovering waste heat from the process itself;

ii) to reduce fuel consumption in the steam-generating plant by improving upon the feed water temperature and recovery of waste heat from the flue gases and modifications of the boiler furnaces.

The theoretical steam requirement was calculated for the sugar factory by running the thermal energy balance around each section. The data is given below:

1.	Grinding capacity	..	2,000 tons/day
2.	Average fibre % cane	..	15.29
3.	Maceration % cane	..	20
4.	Mixed Juice % cane	..	85

5. Water consumption:
   - —Filter Presses .. 7%
   - —Pans .. 7%
   - —Centrifugals .. 2%
6. Lime added 20° Be .. 8%
7. Brix of Syrup .. 62.450
8. Bold grain production .. 60%
9. Direct steam consumption at:
   - —Filter Presses .. 1.5%
   - —High Speed Centrifugals .. 1.5%

The calculated steam requirements of the different sections are given below:

1.	Condensation loss in power generation		0.32×10^4 lb/hr.
2.	Radiation loss		0.10×10^4 "
3.	Clarification (Juice heating)	=	1.65×10^4 "
4.	Evaporators	=	3.816×10^4 "
5.	Pans	=	4.06×10^4 "
6.	Direct consumption at presses and Centrifugals	=	0.55×10^4 "
7.	Miscellaneous	=	1.215×10^4 "
	Total steam consumption	=	62.75% cane.

This calculation of steam consumption does not take into account any addition or alteration to effect recovery or to utilise waste heat from the process streams. It was however, found that with quintuple effect evaporation and vapour bleeding, thermo-consumption could be brought down to as low as 48% on bagasse. It was, therefore, obvious that there was sufficient scope to reduce steam consumption in the factory. The steam economy measures taken at various stations are discussed below:

(a) **Vapour Line Juice Heater:** In sugar factories, vapours from the last body of evaporators and pans are condensed in a barometric condenser by direct contact heat transfer. It is, however, possible to carry on the same condensation by installing a tubular heat-exchanger in the vapour line going to the condenser. In this way much of the total enthalpy of the vapour could be recovered and utilised for heating some of the process streams. By theoretical calculation it was found that raw juice could be heated up to 55°C by passing through the multi-pass tubular heat-exchanger installed in vapour line. It is desirable to condense only 30% to 40% of the vapours in the vapour line juice heater due to technical as well as economic reasons.

From theoretical calculations it was found that 8,000 lb/hr. of steam could be saved by installing two vapour line juice-heaters of 1290 and 925 ft H.S. in the existing evaporator sets at Daurala.

Two vapour line juice heaters of 1150 and 950 ft^2 H.S. were installed at Daurala, and these heated the juice to 50-55°C, and resulted in a saving of 4% steam on bagasse, as stipulated.

(b) **Pre-heater:** The efficiency of the evaporators depends on the feed temperature. The optimum temperature of feed should be close to the boiling temperature of the liquid inside the body. In that case, only latent heat needs to be supplied in the evaporator body. If exhaust steam is used in a pre-heater, it does not as such result in any steam economy, but it does increase the evaporator capacity. With the same heating surface of the first body it produces more vapours for utilisation in the subsequent bodies. In natural-circulation evaporators, the contact time between hot and fluid is very low. In a pre-heater, however, since velocity of juice can be made reasonably high, the heating surface required is much less than what would be required in the evaporator. In Daurala, since we use vapours from the first body, there is a steam saving of the order of 0.5% bagasse by providing a pre-heater of 2,000 ft^2 H.S.

(c) **Vapour-bleeding:** For steam economy, bleeding of vapour is nowadays widely adopted. Second body vapour is extensively used for juice heating, while first body vapour is employed for boiling pans.

Quadruple-effect evaporator has become an ideal set up for a sugar factory. The general opinion is that quintuple set is not economical for factories crushing less than 1000 T/hr. because extra capital investment and radiation losses may nullify the return by heat economy. By theoretical calculation, however, it was found that quintuple-effect evaporator with a large H.S. first body would result in greater steam economy than obtained in a conventional quintuple effect. At Daurala, it was decided to install a 11,500 ft^2 H.S. first body, and to bleed vapours from this body for boiling pans.

The distribution of the heating surfaces of the evaporator set is as follows:

1st body effect	=	11,500 ft^2
2nd body effect	=	7,500 ft^2
3rd body effect	=	6,500 ft
4th & 5th body effect	=	6,000 ft^2

With this arrangement, the entire exhaust steam is fed in the first body, and extensive bleeding from the Ist and

2nd effects is done to meet the requirements at the pans and juice heaters respectively.

The distribution of vapour and steam are shown below:

Exhaust steam		Pans	
35.5%	Pre-evaporator (1st body)	21.8%	Juice heaters
	2nd bodies 13.7%		7.92%
			3rd bodies 6.41%

A reduction in steam consumption of 6.53% cane has been achieved by this arrangement.

(d) **Flashing of Condensate:** Usually the condensates of first and second bodies of evaporator sets are sent as boiler feed water. The condensates of third and fourth bodies can be utilised to generate extra vapour in the succeeding calandria, thus enhancing evaporator capacity.

The quantity of flash from the third and the fourth bodies at Daurala are 0.091% and 0.215% cane respectively. The heat of the condensate, lost by evaporation in open tanks, can be recovered by flashing in evaporator bodies, thus saving heat as well as increasing evaporator capacity.

(e) **Recirculation of de-sweetening water:** Fresh water was being used at Daurala for de-sweetening the press-cake. This amounted to a water consumption of 5% to 7% on cane. As a result, the clear juice brix was low. This also decreased the evaporator performance.

By recirculating the low brix de-sweetening water, the added water % would be decreased; and the evaporator efficiency would be higher. This would cut down water consumption in the press-station by 2 to 3% cane. The net result would be a saving of steam in the evaporator to the extent of 1.1% cane, with the existing evaporator set.

(f) **Radiation loss:** To avoid loss of heat due to radiation, all steam lines, other pipelines carrying hot fluids, and other vessels containing hot water, juice, etc., should be perfectly lagged. By lagging alone 500 lb/hr. of steam can be saved which amounts to 0.2% saving on cane.

The total saving anticipated at various stations are given below:

a)	Vapour line juice heater	=	4.00%	on cane
b)	Pre-heater	=	0.50	,,
c)	Vapour-bleeding	=	6.53	,,
d)	Flashing of condensate	=	0.30	,,
e)	De-sweetening water	=	1.10	,,
f)	Lagging	=	0.20	,,
	Total		12.63	,,

Steam consumption after implementation of these proposals would be (62.75-12.63) 50.12% cane. Actually, steam consumption in the normal working of the factory has been brought down to 52-53% cane, which conforms to the theoretically anticipated steam consumption.

Steam Generation

In the steam generating station, the overall thermal efficiency of boiler depends upon the following factors:

a) Initial enthalpy of feed water
b) Heating value of fuel
c) Temperature of air
d) Stripping of flue gas
e) Utilisation of radiant heat

We have tried to deal independently with the above-mentioned items for economising on fuel consumption at the generating station, in order to improve the overall thermal efficiency of steam generation.

a) **Initial Enthalpy of Feed-water:** If boiler feed water is above 180°F, the savings which could be obtained at different feed water temperatures are given in Table I.

TABLE I

Initial temp. of boiler feed water	Enthalpy available from feed water/hr. (Btu/hr.)	Extra enthalpy available with reference to 180°F boiler feed tem. (Btu/hr.)	Available enthalpy/lb bagasse for generating steam (3298 x 0.62)	Equivalent bagasse saved in tonnes/season	Saving (In thousand Rupees)
180°F	16.2×10^6	—	2050 Btu/lb	—	—
190°F	17.4×10^6	1.2×10^6	"	768	18.40
200°F	18.5×10^6	2.3×10^6	"	1470	35.20
210°F	19.6×10^6	3.4×10^6	"	2180	52.10

b) **Heating Value of Fuel:** The heating value of fuel, or in other words the calorific value of bagasse, is a function of its moisture content. The calorific value increases with the decrease in moisture content and vice versa. The table given below shows the calorific value of bagasse, and its rating at varying moisture content. This rating has been calculated on a feed water temperature of 200°F, assuming boiler efficiency as 62%, and working pressure 150 psig.

TABLE II

Moisture in bagassee	N.C.V. Btu/lb	Raising/lb bagasse
39.0%	4219.0	2.56
42.0%	3988.0	2.42
44.0%	3812.4	2.31
46.0%	3649.5	2.21
47.0%	3467.0	2.10
50.0%	3298.5	2.00
52.5%	3044.5	1.84

Normally, the moisture content of bagasse varies from 48% to 50%. If the initial moisture content is reduced to near about 44.46%, which is desirable for the existing bagasse furnace, the calorific value of bagasse as well as its rating are improved. If the moisture content is further reduced, the arches in the bagasse-furnace collapse, and this results in an increase in recurring expenditure for the maintenance of bagasse-furnace. The table printed above shows that if bagasse of 52.5% moisture content is partially dried to reduce moisture content to 44%, the increase in calorific value is (3812.4 —3044.5) 767.9 Btu/lb., and the corresponding rating is increased from 1.84 to 2.318 or a net gain of 0.478 lb/lb of bagasse.

For instance, the factory which is crushing 2,000 tonnes cane per day, and consuming 60% steam, the bagasse required for the generating process steam will be:

$$= \frac{2000 \times 0.6}{1.84} = 653 \text{ tonnes/day of } 52.5\%$$

moisture content or 310 tonnes/day of bone-dry bagasse

and $\frac{2000 \times 0.6}{2.32} = 518$ tonnes/day of 44%

moisture content or=290 tonnes/day of bone-dry bagasse. This will result in a saving of (310 – 290)x120 x 50=Rs. 120,000 per season, taking the cost of bone-dry bagasse as Rs. 50 per ton, and 120 net working days.

Thus, a net saving of Rs. 120,000 per season can be obtained, if bagasse is partially dried before it is fired in the boilers.

(c) **Temperature of Air:** For burning bagasse in the bagasse furnace, air is required. A considerable amount of combustion heat can be spared by preheating air with the aid of fine tube heat exchanger imposed in the flue passage before the chimney and after the economiser. An air heater providing combustion air at temperatures ranging upwards from 300°F will often effect savings in fuel, ranging from 5% to 10%.

Stripping of Flue Gas: A large part of the heat of combustion gases is wasted, if the existing flue gas is not properly stripped off. Till recently, the economy of bagasse was not given proper importance; bagasse-fired boilers were generally not fitted with economisers or air-preheater, and the temperature of the exit gases was somewhat high. The thermal efficiency of the boilers was very low. If by installation of preheater and economiser, gas temperature is reduced to 401°F which is approximately the minimum temperature (recommended for exit gases with this percentage of H_2O), thermal efficiency would be increased to 68% and 0.906 tons of bagasse would be burnt for the same steam production. Therefore, saving in bagasse of 9.4% would be achieved. In terms of money this would amount to:

$$\frac{(0{\cdot}094 \times 33 \times 2000 \times 120 \times 27.5)}{10 \times 100} = \text{Rs. } 2{,}18{,}000$$

assuming bagasse 33% on cane, 120 working days and cost of bagasse Rs. 27.5 per tonne @ 45% moisture.

(e) **Utilisation of Radiant Heat:** In furnaces and other high temperature equipment where radiation is particularly important, the usual objective is to obtain a controlled rate of net heat exchanged between one or more hot surfaces and cold surfaces. To make the best use of radiant energy, furnaces of modern boilers are provided with embedded tubes (i.e., water-walled). The addition of water jacket increases the heating surface. The evaporation capacity of such furnace is 10% to 15% higher than that of a boiler without water-walled furnace. In addition to increase in evaporation rate, water walls extend a protection to the furnace refractories and substantially reduce conservation cost.

DISTILLERY

In the rectified spirit distillation plant, coal consumption per unit of product can be brought down by giving proper attention to the outgoing streams of the distillery and conserving their waste heat. In the present process, measures have been taken for conserving waste heat to utilise it for heating the incoming streams to the distillation column, thereby reducing live steam consumption.

In the alcohol-distillation plant, spirit is manufactured with the help of two distillation columns, the first one known as the 'Analyser column', and the second the 'Rectifier column'. The feed to the 'Analyser column' is the wash from the fermentation house. The fermented wash generally has a temperature of 32°C to 33°C, which is maintained by circulating cold water around the fermenters. The overhead product of this column (Analyser vapour) is then fed to the Rectifier column for further purification. The bottom product or the spent wash has a temperature of 220°F. The waste heat of this spent wash is partly recovered, and then is thrown out.

The overhead product of the Rectifier column has 95% alcohol by volume which is condensed in three condensers in series. In the existing process, cold feed wash is used as cooling medium in the first condenser, and water is used as coolant in the other two condensers. The bottom product of this column or the spent lees is fed back to the Analyser column for recovering the alcohol in it.

Experience shows that direct steam consumption can be reduced by preheating the feed wash to a temperature at which it boils in the analyser column depending on the characteristics of the wash. The increase in temperature of the feed wash has the added advantage of preventing scale formation in the Analyser column, because at high temperature, the solubility of calcium salt is less.

Recovery of Waste Heat

In the new scheme, the following method has been adopted to heat the the cold feed wash: The feed wash at a temperature of 32°C to 33°C is first passed through the second condenser of the Rectifier column. This condenser is a multipass type heat exchanger where the heating fluid is the partly condensing rectifier vapour. The cold wash in this heat exchanger is heated to around 45°C.

The warm feed wash then enters the first condenser of the Rectifier column. It is also a counter-current multipass-type heat exchanger and the rectifier vapour enters this condenser at a temperature of 78.5°C (173°F). In this condenser, the

Not at all wasted

A number of products are left over in the manufacture of coal gas. But these are not wasted at all. Just the reverse!

Let us, for example, take coal tar. On examination, it seems a gummy black substance. But some amazing miracles are performed with it by the modern chemists. Some of the things which find their origin in coal tar are disinfectants, perfumes, grease-spot removers, sweets, and explosives that could blow you to atoms. The following passage, taken from an essay in "Marvels in Science and Industry," explains the process:

"It (coal tar) is first heated in cylindrical iron holders. The first substances—or 'fraction', as it is correctly called—to be discharged are the light oils, benzol, and toluol. The former is extensively employed in the manufacture of motor spirit and the preparation of aniline, which offers a wide choice of dye colours to the enterprising modern chemist.

"From toluol we obtain benzoic acid—often used as a preservative; picric acid—the basis of more dyes and an exceptionally high explosive; sacchrine—which is 300 times sweeter than sugar and was widely used in war-time when ordinary sugar supplies were cut down.

"At a later stage carbolic oils are discharged which can be used in the preparation of various disinfectants and perfumes. The ordinary household mothballs are largely manufactured from the naphthalene in coal tar, and lamp-black, used for black lead, has the same origin. Even the black pitch left behind is put to good use for waterproofing and road-paving purposes."

warm feed wash is heated to 70°C by the latent heat of condensation of low volatile components of the rectifier vapour. The heated wash then enters a chamber provided with air vent allowing the entrapped air to escape. From the chamber the feed wash is fed to a Plate type Heat Exchanger, and heated again by hot spent wash of the Analyser column.

The spent wash is first taken into a Degassing chamber where the vapour is separated and fed back to the bottom section of the Analyser column, while the liquid is taken for either flashing in a Flash chamber with the help of a thermo-compressor (during season) or directly taken through the pump for circulation in the Plate type heat exchangers. During the season when live steam is available, the waste heat in the spent wash is recovered in two stages—Firstly by flashing spent wash in a Flash chamber, and, secondly, circulating it under pressure through the heat exchangers. In the Flash chamber a vacuum of 10" Hg. is created by means of a Steam Ejector where 2.46% (or 1350 lb. steam per hour) of spent wash emerging from the bottom of Analyser column at 105°C (221°F) flashes. The flashed steam is utilised in the Analyser column. The temperature of spent wash after flashing is brought down to 90°C (194°F). This spent wash is then pumped through the Plate-type heat exchanger No. 1 where the feed wash is heated from 70° to 80°C by the waste heat of the spent wash.

Additional Heat

The hot feed wash is collected in a small receiving chamber from where it is pumped through a multipass heat exchanger for further heating. It is well known that the Analyser vapour contains more heat than what is required in the Rectifier column. Taking the advantage of this additional heat the feed wash is heated to equilibrium temperature of 93°C, which is very close to the boiling temperature of the wash in the column. The analyser vapour evolving at 95°C (203°F) passes through this heat exchanger where it is partially condensed to heat up the hot feed wash from 80°C to 93°C. This equipment is a multipass counter-current heat exchanger where vapour is on the shell side and feed wash on the tube side. The feed wash temperature approaches closely to the vapour temperature because of condensing vapour as well as the multipass heat exchanger. The condensate from this exchanger is fed to the stripping section whereas the vapour goes to the Rectifier column.

In the distillation plant generally all the steam is used up in the process, and no condensate is available. In the new process, we have taken measures to use cooling water as boiler feed after preheating the water by means of waste heat.

Rectified vapour is used at present only in one heat exchanger for heating feed wash; and for final condensation, water is used in two condensers. In the

Acceptable Performance

According to Mr Lawrence A. Appley, an American expert on management, "there is only one kind of acceptable performance — that which measures up to the highest standards. The highest standard for each individual is that which his conscience tells him is best. The best in terms of the individual's conscience is the result of his environment, associations, knowledge, and training."

new scheme, Rectifier vapour will be used for heating feed wash in two heat exchangers. Thus this process will eliminate water requirement in the bigger condenser. Finally the rectifier vapour will be condensed in a multipass condenser where the water efficiency will be 100% more than what is now obtained in a single pass condenser. This will further cut down the water consumption in the distillation house by about 102%.

In the fermentation house it is essential to keep fermentation temperature at 32°C—35°C for efficient fermentation, and also for maximum production of alcohol by yeast. This temperature can be maintained by continuously circulating the fermenting wash through para-flow exchanger, using water as a coolant. This cooling water is further circulated through the third condenser of Rectifier column where the temperature of the water is increased from 33°C to 58°C.

The spent wash coming out of the Plate-type heat Exchanger No. 1 is used to raise the temperature of the water further; and for this heat transfer, another plate-type exchanger is called for. The partly cooled spent wash having a temperature of 80°C is passed through the Heat Exchanger No. 2 where the water is heated from 58°C to 70°C. The spent wash is cooled down to 62°—63°C against 80°C in the old scheme and then drained. The water thus preheated to 70°C can be now used as boiler feed. This preheating of water extracts heat from the waste streams with a resultant 550 lb/hr. of equivalent steam-saving.

Removal of scales from the heat exchangers by means of chemicals has also been incorporated in this process. At present heat exchangers have to be taken out of service for opening, once or twice in a week, because of heavy deposits of scales in them. They are cleaned mostly by mechanical means, with the help of wire brush, etc. This process not only involves time, but also hinders smooth operation.

The steam consumption in distillery will come down to 23 lb./gal. R.S., when all the steam economy devices are actually adopted.

Heat economy in distillery is capable of great exploitation as can be seen from the calculated reduction in steam consumption/gal. R.S., the return on investment being almost 90% to 100%.

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LA NATESAN

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Railway Board

Railway's Fuel Efficiency Problems

EXPENDITURE on fuel has attracted the attention of railway managements from the very beginning of rail transportation. Fuel accounts for a considerable proportion of the working expenses of the railways the world over. On Indian Railways the expenditure on fuel amounts to about 20% of the ordinary working expenses (excluding the appropriation to the Depreciation Reserve Fund). During the current year, the budget estimates for the expenditure on fuel is placed at Rs. 95 crores out of a total of Rs. 458 crores. This indicates the magnitude of the annual outlay on fuel on the Indian Railways.

The rapid increase in economic activity in the country, consequent on the development projects being carried out under the successive Plans, has necessarily called for more and more transportation, particularly by rail. The increase in the volume of traffic has meant more transportation — more trains, more train kilometres, more engine kilometres, and more tonne kilometres and, therefore, more consumption of fuel. The trend is clearly indicated even in so short a period as the seven years since 1959-60. The expenditrue on fuel, as compared with the ordinary working expenses, is shown in Table I.

TABLE I

(Rs. in crores)

Period	**Fuel**	**Ordy. working expenses**
1959–60	57.98	289.53
1960– 1	62.80	315.15
1961– 2	68.35	325.33
1962– 3	75.73	362.38
1963– 4	86.61	392.13
1964– 5*	91.14	432.68
1965– 6**	94.74	457.84

* Revised estimates; ** Budget estimates

It will be observed that the expenditure on fuel has recorded an increase of about 64% in 1965-6, as compared with 1959-60.

Fuel for motive power is mostly coal, by far the largest item, and costs about

Rs. 40 crores. But the cost of freight and handling borne by the railways on this account has been only a little less than this figure, viz., about Rs. 37 crores. Owing to the economy of oil fuel, there has been an increasing resort to this, and from Rs. 11.23 crores in 1963-4 the anticipated increase in 1965-6 is to Rs. 17.12 crores. The use of electricity for traction purposes is also on the increase — from Rs. 4.92 crores to Rs. 7.76 crores. The comparative figures against the several items entering into fuel costs are shown in Table II.

TABLE II

	(Rs. in crores)		
	1963-4	1964-65*	1965-6**
Cost of coal	40.21	39.84	40.67
Sales tax, excise duty cess	4.50	4.32	4.29
Cost of other fuel	11.23	15.33	17.12
Freight and handling charges	36.57	36.68	37.07
Cost of electricity for traction	4.92	7.08	7.76
Loss of fuel less recoveries &c	0.96	0.92	0.87
Total (net)	86.61	91.14	94.74

*Revised estimates; **Budget estimates.

Fuel for the railways used to be synonymous with coal, and for this reason a considerable amount of study has gone into the economy of coal utilisation. There are two aspects of fuel economy. One relates to the rather poor thermal efficiency of the steam locomotive. Mechanical engineering had effected many improvements by 1890, such as the introduction of link motion, longer tubing, and raising of the boiler pressure. These changes helped to raise the efficiency from 1.7% to 6%. The development of the compound steam engine, a further raising of the boiler pressure, superheating, and feed water preheating through exhaust steam had, in the succeeding years, helped to raise the value of the total efficiency at the rim of the wheel up to 11%. These are problems for the locomotive designer, the mechanical engineering researcher, and the manufacturer. Every advance in their work means better economy, and efficiency for the fuel consumed.

The second aspect is related to the actual efficiency aimed at, and achieved in practical operation. This tends to be much lower than the figures stated earlier, because of the losses from heating up, slagraking, and washing out, as well as frequent starting and cut-offs, and the heat losses during the idle periods. The efficiency drops even in the more advanced countries to 7% on main-line operation, and to 4% in branch line working. The difference between the actual and the attainable represents the scope for the fuel economy experts in regard to coal.

A considerable amount of study has gone into the economics of fuel on the railways. Writing about 80 years ago, A.M.Wellington, in his **Economic Theory of the Location of Railways,** had drawn attention to many aspects of the problem of fuel economy. A few of these are referred to in the extracts reproduced below as his observations on these well deserve to be remembered even today.

"The effect of difference of temperature alone, the length of train, and all other conditions being equal, is to increase or diminish coal consumption at the rate of 1% for each two degrees Fahrenheit (and a small fraction more) difference of external temperature."(P. 137).

* * * *

"A very considerable percentage of the consumption of fuel is a constant wastage independent of the exact distance run. The cost of kindling fires alone averages 8% or 10% of the total.... A fire-box full of coal is wasted every time the fire is drawn, which was formerly 100 miles run, but is now on an average of a whole railroad, nearer to every 1,000 miles owing to the introduction of the practice of banking fires, especially with long-trip system." (p. 199).

* * * *

"The consumption due to stopping and staring, and to standing still in yards and in sideyards, is alone a heavy item....On a grade of less than 16 ft per mile, we have from stopping and starting alone a waste of power sufficient to run a train one half mile in one case, and two miles in the other, causing a loss for an average number of stops for stations and crossings of something very close to 10% of the total consumption" (p. 199-200).

* * * *

"An economy of 10%, is claimed on the Lake Shore by the lagging of the fire-box (which used to be left exposed by negligence)" (p. 313).

* * * *

"When coal is more than can properly be used in combustion, the excess is ejected at once from the smoke stack unconsumed. As much as 20% of the entire coal put into the fire-box has actually been caught in the smoke box...... The minimum waste of coal in this way is probably 5%" (p. 449).

It is because of the numerous stages from transportation, storage, issues, handling, and actual use, where care and lack of it can make a great deal of difference in the amount of fuel utilised for a given volume of transportation, that mechanical engineers and operating officers have for many years past devoted continuing attention to the consumption of coal. The principal statistics that is carefully watched in this connection is the ratio of fuel consumption to the work performed. This is expressed in terms of the kgs of coal per 1000 gross tonne kilometres compiled separately for passenger and goods services. The position on the broad and metre gauge lines of the Indian Railways since 1950-1 is shown in Table III.

Declining Trend in Coal Production

The production of coal in India has shown a declining trend in recent years. Many experts have advanced reasons for this – some convincing, some not so.

Writing in "The Economic Times," SS Parikh points out that the declining trend in production "is attributed to the low offtake by industrial coal consumers, and the rising pit-head stocks. The factors responsible for the reduction in coal consumption include, according to him, dieselisation and electrification of railway traction in the coalfield and other congested areas; use of substitute sources of energy like furnace oil; improved fuel technology practices; and overestimation of demand by several coal-consuming industries due to considerable scarcity of coal at the end of the Second Plan.

Owing to lack of adequate railway transport, several industries in the Western and Southern regions have switched over to other fuels as a consequence of which demand for coal in these industries has gone down steeply. The easier rail transport situation has resulted in coal consumers reducing their stocks. Some coal-consuming industries have not come up according to schedule. Some of the thermal power stations are taking less and less coal owing to the development of hydro-electric energy. Further trade in Indian coal, which was regularly exported to Burma, Ceylon, Japan, Middle East and South-East Asia, started declining from 1962 when it touched the maximum level."

TABLE III

Fuel consumption on Indian Railways
(Kgs. per 1000 tonne kilometres)

	Broad Gauge		Metre Gauge	
	Passenger & prop. of mixed	Goods & prop. of mixed	Passenger & prop. of mixed	Goods & prop. of mixed
1924-5	52.71	39.95	51.32	43.27
1925-6	52.71	39.67	54.09	44.11
1926-7	51.60	38.56	52.71	42.72
1927-8	50.21	37.73	53.26	42.16
1928-9	49.27	37.17	53.54	43.00
1929-30	47.71	37.45	55.48	43.00
1930-1	47.71	36.63	54.65	43.00
1931-2	45.49	34.67	53.26	41.33
1932-3	45.49	34.40	51.60	41.33
1933-4	46.05	34.95	50.21	39.67
1934-5	46.88	35.78	49.65	39.39
1935-6	46.88	36.34	49.93	38.83
1936-7*	46.88	36.34	50.21	38.00
1950-1	53.3	45.5	64.9	56.3
1951-2	51.2	44.6	64.0	56.0
1952-3	51.7	46.2	62.9	55.8
1953-4	50.6	45.3	62.4	56.2
1954-5	51.2	44.7	61.4	52.8
1955-6	50.5	42.7	61.3	51.8
1956-7	51.4	42.3	60.6	49.5
1957-8	50.8	41.4	57.7	49.3
1958-9	51.5	40.8	59.9	52.3
1959-60	51.8	40.2	59.8	53.1
1960-1	52.4	40.0	57.5	52.1
1961-2	52.7	49.9	57.7	52.1
1962-3	54.9	41.3	59.1	53.3
1963-4	54.5	40.8	58.1	53.4

* The figures for the period 1924-25 to 1936-7 relate to the class I Indian Railways, and the figures for the period 1950-1 to 1963-4 to the Indian Government Railways.

Source: Railway Board's Annual Reports, Volume II

The comparison with the earlier set of figures shows that fuel consumption has tended to remain at substantially higher levels since 1950-51. It should also be remembered that efforts to control fuel costs were not wanting. There may have been special factors which need to be gone into more carefully than seems to have been done. Prior to world war II there were certain established practices which rendered examination of fuel consumption statistics quite useful from the point of view of correcting procedures which led to uneconomical use. During wartime, these practices were subjected to changes,

Ill-Effects of Atmospheric Pollution

Discussing the ill-effects of atmospheric pollution, the Anglo-American Council on Productivity, in its report on Fuel Conservation, refers to the great deal of research carried out in the United Kingdom.

"Household chimneys alone," says the report, "pour out each year 1¾ million tons of polluting matter black with soot, abrasive with grit, sticky with tar and corrosive with acid. The data published by the Fuel Research Station, Department of Scientific and Industrial Research, show that industry is responsible for less soot and tar, but more grit and acid.

The Smoke Abatement Society of Great Britain estimates that the nation pays at least £100 million a year on account of smoke and gets nothing in return, apart altogether from the ill-effects of smoke-laden fog on health and vegetation, and the grave interruption that it brings to daily life. Science and technology have shown that much of this nuisance can be avoided by practical means, and in the process we could obtain more heat from the fuel consumed.

The Fuel Research Station has determined the quantity of suspended matter in smokes, the physical and chemical properties of the suspended matter, the composition of flue gas and the variation of these properties with the density of the smoke."

and instead of particular collieries (the quality of the output of which was known to the individual railway and its loco men), railways shed began to receive coal varying considerably in type, in quality and characteristics. The immediate consequence of this was that coal issues for trip rationing of locotmotives became unreliable, and firing conditions deteriorated. Not only this, the supply itself gave rise to rather serious uncertainties. Individual railways had, on occasions, to work on rather slender reserves of coal stocks. Consequently, in such a situation, short of having to cancel or cut down trains, the railways concerned found it better to have some supplies, even if they were not of the quality desired, than not at all. The effect of this was seen in the frequency of engine failures, and poor operating performance.

In 1951, a Railway Fuel Economy Inquiry Committee was appointed to examine the supply, consumption and reserve stocks of coal on railways, and to make recommendations for economy in expenditure on coal used as fuel. The final report, submitted in March 1953, covered a wide range of recommendations dealing with issues bearing on coal production; preparation, grading and pricing of coal; production and utilisation of lignite in the South; rationalisation of coal supplies; short and long-term plans for development of coal transport; electric and diesel traction on railways; fuel control organisations and training schemes; fuel accounts and statistics; and power and fuel research.

Among the measures which were taken in the following years to secure economy in fuel were the gradation of coal for different categories of locomotives, research in efficiency of existing boilers, steam distribution to improve thermal efficiency, and fuel-saving devices. A Central Fuel Training School was established at Dhanbad.

In November 1957, an Expert

Fuel Consumption for 1000 Gross Tonne. Kms

		Broad Gauge		Meter Gauge	
		Passenger and pro portion of mixed.	Goods and proportion of mixed.	Passenger and proportion of mixed.	Goods and proportion of mixed.
Coal	1962—3	53.9	43.6	59.5	54.5
(Kg.)	1963—4	54.5	46.2	58.8	55.5
Diesel Oil	1962—3	7.20	3.52	8.90	5.31
(Litres)	1963—4	6.77	3.53	7.95	4.52

Committee was appointed to study railway coal problems connected with the increase of railway expenditure, such as poor quality coal, costs of handlng, waste and losses in transit, and the future requirements of high-grade coal. The committee found that the supply of inferior quality coal was responsible for 11% increase in consumption. In view of the shortage of high-grade coals for traction, the committee recommended washing low-grade coals, and, where justified, introduction of electrification and dieselisation.

Consumption targets for fuel performance of the individual railways enabled a clearer assessment of the effectiveness of the economy measures. The efforts to secure optimum results have often been frustrated by the poor quality of coal supply. If to this is added the consideration that, even under best conditions, the thermal efficiency of steam is still low, say 12%, the advantages of alternative motive power become clear. The diesel locomotives are expected to attain up to 32% and the electric locomotives up to 21% of their respective total efficiency. There has been a rapid increase on Indian railways under both electric traction and diesel traction in recent years. With diversification of the motive power, it becomes necessary to keep a watch on the respective performance of each. To convert alternative traction into steam equivalents might seem to simplify, but actually it tends to blur the character of performance under each.

The recent figures under Steam and Diesel are given above.

It is necessary to remember that too much should not be read into the fuel performance indices without reference to factors not directly or even unconnected with locomotive efficiency or economic utilisation of fuel. Some of these have been mentioned earlier. Others are increased train speeds, heavier passenger equipment, unusual mainteance work interfering with train operations, unusual weather conditions, all tending to increase fuel consumption. Hence the importance of a constant appraisal of the factors affecting fuel economy.

The change from steam to alternative motive power will, of course, change the character of the problem of fuel economy. Economic use of coal involves a larger organisation spread over a wide range of separate activities. The extent of this might be reduced by electric or diesel-traction. But the importance of the problem will always remain with the transport industry. For the magnitude of transportation is so vast that the quantum of energy to be generated to supply the motive power in connexion therewith is large commensurately, and the utilisation of the fuel to yield the maximum productive use, is a continuing problem for the Railway Managements.

PRODUCTIVITY

PRODUCTIVITY is key to prosperity
Repeatedly told with dexterity
Ordained to bring clarity
Demonstrated without barbarity
Undisputedly, its applications are universality
Causes international fraternity
Try we must, to have happiness of Trinity
Individuals always contribute because of inquisity
Very often its practitioners are clothed with venerability
Input-output ratio, shows respectability
Technique is simple, without much technicality
Yearn we must only for universal prosperity.

—Kuldip Singh Aneja

Book Reviews:

A New Discipline

ERGONOMICS: By KFH Murrell (Chapman & Hall, 1965, 63 sh)

ERGONOMICS has been defined as the scientific study of the relationship between man and his working environment. In the context of this definition, different categories of people would be interested in this discipline. Management would want to know how it would help increase productivity. Trade union leaders would like to be convinced that it really contributes to increased job satisfaction. Designers will want to know how it would help them design better plant, equipment and furniture. The student would need a thorough treatment of all facets of the subject. Although the type of information required by each category is different, the author has succeeded in bringing out a manual which caters adequately for the needs of all.

Quite appropriately, the book is in two parts: The Elements of Ergonomic Practice; and, Practical Ergonomics. In the first part, the author has given an exhaustive treatment of the physical characteristics of the human body which enables the reader to appreciate the capabilities and limitations of the human being as a 'system component'.

In the second part, the author has dealt with the subject of Practical Ergonomics under three different factors: Design, Environmental, and Organisational. The coverage of design factors is quite comprehensive, and easily understandable. The author's treatment of environmental factors is excellent.

The book contains a full review of research contributions to the various aspects of practical ergonomics. The findings of research are discussed in a lucid fashion, the emphasis throughout being on their application to industrial problems.

The author has been an eminent figure in the field of ergonomics, both as a preceptor and researcher. His contribution to the productivity movement, in the form of this textbook on ergonomics, is very valuable.—**K. Pennathur.**

ELEMENTS OF ERGONOMICS: By K Pennathur and Dr. (Mrs) Avtar H. S. Goshal (Messrs Popams, K-3 South Extension Part I, New Delhi-3, Pp. x + 140, Price Rs. 12.50)

ERGONOMICS is a new entrant in the field of industrial and business management. As the joint authors have stated, it may be defined as a study of the effects of a work system on the human operator with a view to increase his efficiency, comfort, and satisfaction at work. While it is concerned with increased productivity, the main emphasis, it is stated, is on the job satisfaction of the worker.

Ergonomics comes on the heels of a number of approaches to the study of the worker and his work. The movement of Scientific Management and the contributions of FW Taylor on motion studies and the further elaborations of the same techniques by the Gilbreths have now evolved into a more understanding and comprehensive development. It takes into account the design of equipment, tools, jigs and fixtures; displays and warning systems; lay-out, environment, placement of personnel, motivation of worker, etc. The aim of all these is to let the management into a better appreciation of the human factors involved in a work system and, what is more, in enabling managerial performance to produce optimum results.

In successive chapters the joint authors deal with the different aspects of the work system. Taking up first the perception and inputs of displays, the significance of visibility, sound and hearing and displays is explained with reference to the effect on the worker. The means adopted to eliminate undesirable effects —such as, say noise of machines by use of carpets, acoustic material, glass panes, and baffle-boards—is set out in lucid style.

The treatment of the physical characteristics and designs of control is taken up in the next chapter. Anthropometric data are brought into use and the significance of human motor activities, design of controls, and panel lay-out are described. This is followed by the description of motion economy and fatigue. The concluding chapter deals with effects of environment which include factors such as temperature, humidity, ventilation, illumination, colour, altitude and music. There are three appendices containing check-lists, schedule, and the headings to be used in ergonomic job analysis.

This book is not only extraordinarily interesting, but also very useful. Some of the topics dealt with have been referred to from time to time in connection with the innovations introduced by progressive industrial managements. A systematic treatment of all the relevant factors involved is necessary for Managements to appreciate and apply sound practices in connection with the undertakings controlled by them. Mr. Pennathur and Mrs Goshal have written an instructive handbook on the subject, and should be congratulated on the standard of their performance.—**L.A.N.**

X-Ray of Jute Industry

ASPECTS OF PRODUCTIVITY IN INDIAN JUTE INDUSTRY (Report of NPC Study Group): National Productivity Council, 38 Golf Links, New Delhi-3, 1966, Rs. 10.

SOME years ago, Mr. Manubhai Shah, the then President of NPC, had a brilliant idea that the National Productivity

Council should do a close Productivity X-Ray of some of the problem industries; and the jute industry was a natural selection. Dr Lokanathan, Chairman of NPC, offered that he would organise a Group Study of this industry. The intention apparently was to make it a thorough-going job, analysing in depth the problems that have plagued this important export industry. The report has now been published; and for once we have, in some considerable depth, a peep into the whole cost structure of the jute industry, and the problems, internal and external, that it faces.

The Report has naturally a productivity slant, concentrating on such aspects as Quality Control, Work Study, Labour Productivity, Norms of Production, Inter-firm Comparison, and the application of modern technology to the industry. The competition from Pakistan has come under close scrutiny, and the Study Group has recommended that immediate steps be taken to work out appropriate programmes to offset comparative disabilities of the Indian industry, specially in regard to improvement of raw material and export promotion in the context of Pakistan offering an export bonus to its own jute industry. Regarding labour productivity, the Group has recommended that the piece-rate system be extended in the industry as an accepted programme for better labour performance. The Study Group has given considerable importance to market research and product diversification for solving some of the intractable problems of the industry.

The report furnishes ample statistical background material, besides analysis in depth, which might well make it the Bible of the Jute Industry for quite some time.—**D.H.B.**

...India's economic problems can only be overcome by production-oriented people who would also take care of the distribution of what was produced... —Sachindra Choudhri, Union Finance Minister (at a Press Conference)

...It was not enough to achieve import substitution, for "import substitution" signified only adolescence in a nation's economy and real maturity consisted in the ability to export... —Asoka Mehta (addressing the annual meeting in New Delhi of the Indian Electrical Manufacturers' Association)

...A joint crusade against outdated ideas and outmoded tools in agriculture and the bubbling population would have to be launched simultaneously if India was to achieve self-sufficiency in food and economic prosperity...—C Subramaniam (at Convocation of Indian Institute of Agricultural Research).

...Just as a child cannot get back into the security of the womb, so also the youth of today cannot get back into the era of slow-moving changes...—Asoka Mehta (addressing the Bharat Yuvak Samaj).

...Faith is everything, and if people lose faith, you cannot expect them to put in more effort in return for fewer rewards...—GL Nanda (addressing I.A.S. Trainees in New Delhi).

...In our country we measure the status of a person not in inches, but by statesmanship... —Lord Mountbatten (condoling the demise of Sri Lal Bahadur Shastri).

...We must think constantly of what lies beyond our diversities, beyond the particular traditions and values of the different communities that constitute our people, beyond the individual of the census report who belongs to a particular region, speaks a particular language, professes a particular religion...—Zakir Husain (at Jodhpur University Convocation).

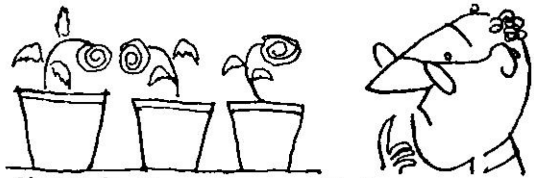
...The relation between the Prime Minister and the Finance Minister is like that of a man and his wife...—T T Krishnamachari at a Press Conference following his resignation from the Union Government).

...We must implicitly believe as well as convince others that in Free India, which wants to give a new life to the millions of its people, it is not necessary to weaken anybody to strengthen others...—Zakir Husain (addressing the Dhakshina Bharat Hindi Prachar Sabha Convocation at Madras).

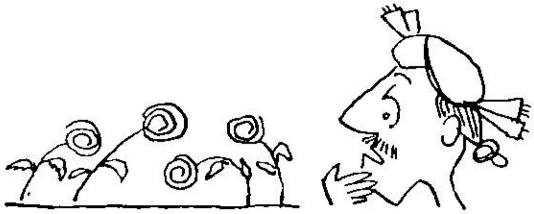
...A particular person had wasted 8,490 hours waiting for a bus to and from his office during the past 10 years. ...—A report in "The Statesman" (on the Delhi Transport System).

"There had been a colossal waste of manhours. In January, there had been 14 public holidays, including five Sundays. Can a poor country, like ours, under a developing economy, afford to waste so many precious days? More than the holidays is the fact that Government employees and workers availed of all eligible privilege and casual leave during this period, increasing the loss in manhours..." — Tiruloka Sitaraman, Tamil writer, at a Plan Publicity meeting at Madurai.

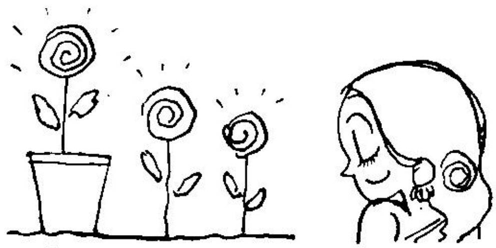
Saying it with flowers
(of speech)



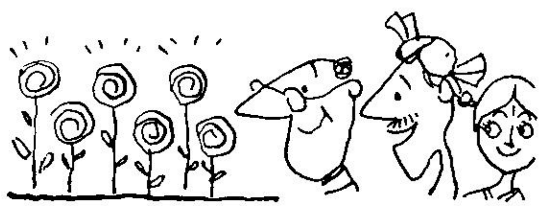
If you don't want your potted roses — sort of — go to pot . . .



and your bedded roses — er, well — to be bedridden . . .



and you wish to bring the roses back to their pots and beds — and your cheeks



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