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Agenda item 1

LESSONS LEARNT FROM A LIFETIME IN THE STEEL INDUSTRY[1]

by

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Summary

When Mr. Cartwright first entered the steel industry in 1928 it was a very bad period for the world steel industry and in South Wales in particular; works were being closed to concentrate orders in one steel works, and fortyfive years later he sees very similar things happening.

He considers that both investment in and closure of steel works require planning to avoid shortages and surpluses and that it is extremely important that the world steel industry should not only plan new capacity but plan the obsolescence of older works and older processes in order to avoid violent upsets of the work force.

He emphasizes the importance of quality control, describes various innovations that have been developed in his fortyfive years in the steel industry - some disappear, some are quickly adopted, and some are adopted only after a long time. He dwells on the causes of variations in efficiency of steel works and, above all, the human element. Of this tremendously important factor he advocates training by successful managers of their successors and concludes that the excellence of any steel plant will depend as much on the people who manage it as on the equipment they have.

PLANNING

I entered the steel industry in 1928 and after a very short time in a London office I was posted to a steel works at Dowlais, near Cardiff. It was over 100 years old. Throughout the years it had seen numerous changes in technology, nevertheless, as soon as I arrived I realized that it was not only old-fashioned but wrongly located.

I think it was a very bad period for the world steel industry. Nevertheless, it was brought in on me very strongly that the location of iron and steel works is usually based on a combination of transport of raw materials, transport to the market, and very seldom on the location of a particular work force. Nevertheless, when the time comes for a steel works to close because it is obsolete and badly located, a large force of people would have been built up whose tradition is iron and steel manufacture and who know of no other way of life. In quick succession in those days, in about 1930, the South Wales steel works at Tredegar, Blaenavon, Ebbw Vale, Dowlais and East Moors all closed down. At first I thought my career in the iron and steel industry had finished but my then director, who had many good contacts on the Continent, sent me to Europe. There I saw many much more up-to-date steel works, but all in great trouble due to lack of demand. I saw that the demand for steel is never in accordance with its potential capacity. There is always either too much or too little at any given time.

The works in South Wales,of which there were a number, were closed in order to concentrate what orders could be obtained in one steel works, but,even then, the remaining steel works was not profitable.

Fortyfive years later I see very similar things happening. Old, badly located works with a large force of labour who know no other work, being closed and new works started up, sometimes under-employed. I have come to the conclusion that the essential thing for the world steel industry is not only to plan new capacity but to plan the obsolescence of older works and older processes. The violent upsets that have occurred when new processes are invented, new raw material sources discovered, have been accompanied very often by excess capacity which, while eventually absorbed, initially causes great hardship and I believe we must both plan for the construction of new plants and plan the closure of obsolete plants on a very wide almost world basis.

Figure One shows the world production of steel when I entered the steel industry in 1928 until the end of 1972 when I left it. Of course,a product such as steel is highly affected by a world war. Nevertheless, it is perfectly clear that the trend of the demand for steel in tonnes has advanced steadily from 1928 to the end of 1972. What is not soclear is whether the real consumption of steel per head in highly developed nations has increased much. Possibly "tonnes" is not a very good measure. A tonne of stainless steel cannot be compared with a tonne of mild steel. A tonne of thin tinplate cannot easily be compared with a tonne of thick tinplate.

Figure Two shows the consumption per head (again in tonnes) in the most developed nations in 1928 and the least developed nations with those in process of developing in between them.

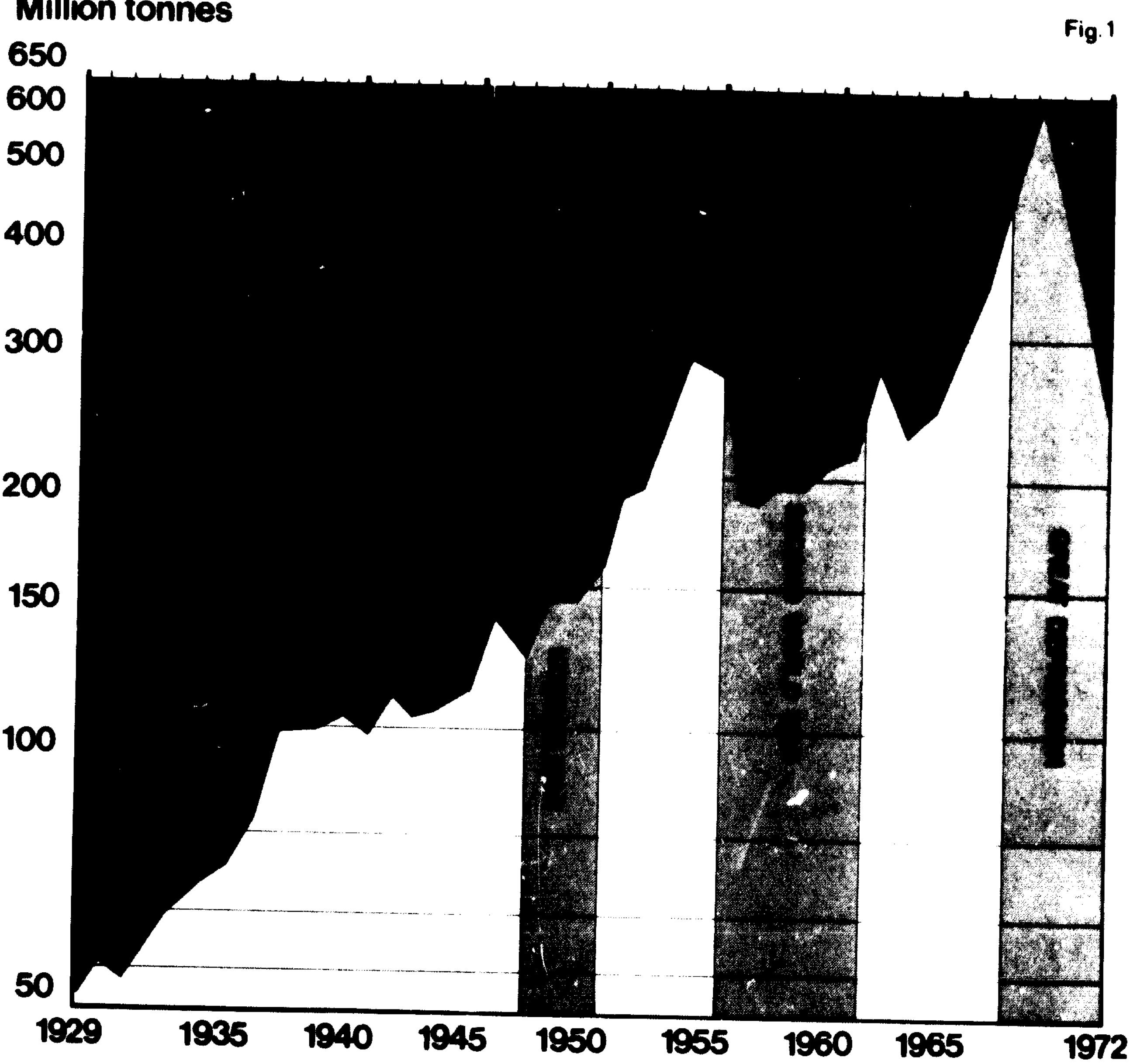
Figure Three shows those same nations 45 years later. This shows how little the growth has been in consumption per head of steel in some areas of the world. I am sure that we are at the beginning of a period when this wide gap between something like 20 kilos per head and 800 kilos per head between the smallest user and the largest user, will be narrowed. The narrowing of it will make a very big difference to world steel production and the consumption of the raw materials required, for, although there has been a trend for steel to intensify so that a tonne goes further, this will not be a material question in those countries which still only use between 20 and 50 kilos per head.

Figure Four shows the relationship in 1928 between heavy sections, rods, bars,and flat products (that is to say, plates, sheets,and coated sheets) in the U.K.

Figure Five shows these relations at the end of 1972. This shows that there has been over these 45 years a steady trend towards the production and consumption of flat-rolled steel in preference to others. No doubt this is partly because the development of roads has changed the demand for steel from a demand for railways (both rolling stock, rails and railway bridges) to a demand for cars, lorries,and reinforced concrete which, for some reason, has always been used more for road bridges than railway bridges. All these developments have taken business away from the heavy section market.

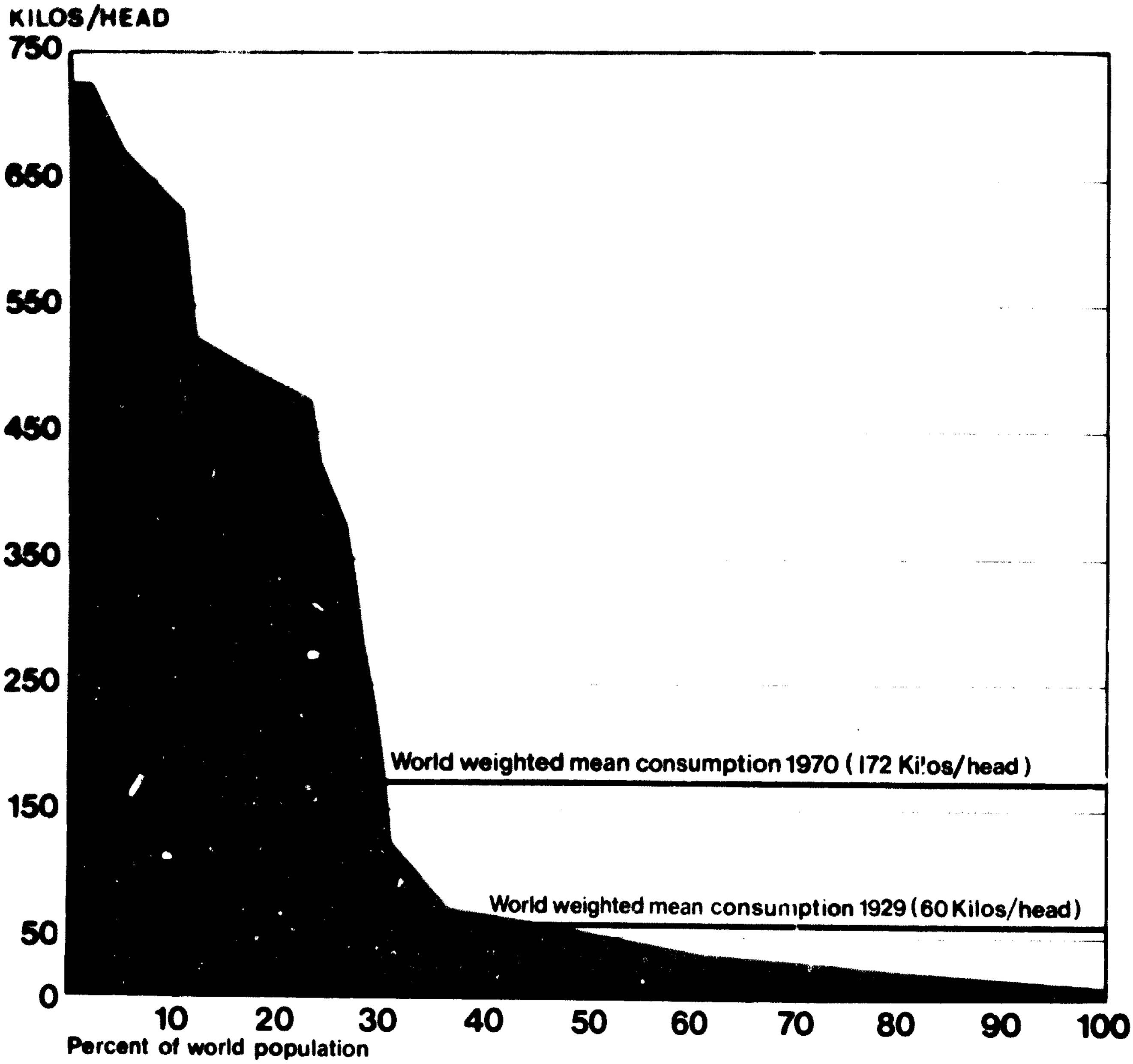
In the case of plates, the development of welding, particularly in ships, has increased the percentage of plates used in structures and decreased the percentage of sections. Tinplate, while always a flat product, has declined in thickness per unit of area more dramatically than any other form of steel and, of course, the invention of double cold-reduced tinplate has made it possible, using even ordinary steels, to produce a can with very great strength compared with its relatively soft predecessor.

World Raw Steel Production 1929-1972



World Raw Steel Consumption per head of Population 1929 and 1970

Fig. 2

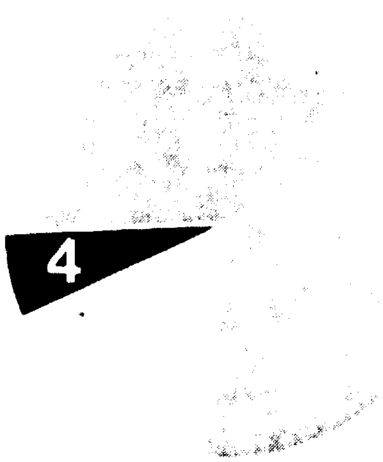


Finished Rolled Steel Production U.S.A.

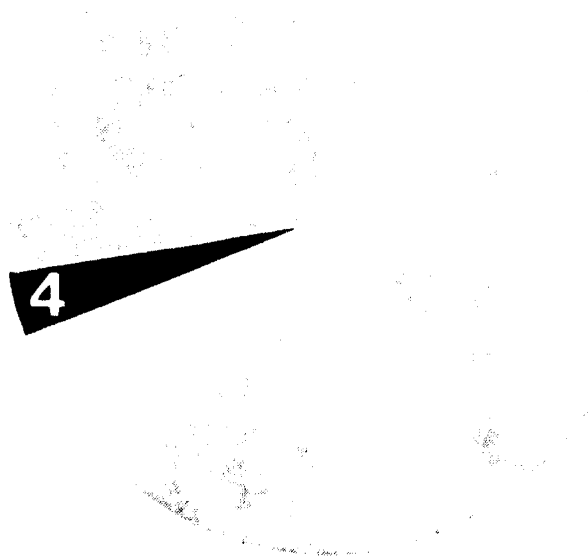
Fig. 3

1. Flat Products
2. Bars and Rods
3. Structural Shapes
4. Rails etc.

1929



1971



When I first entered the steel industry the cold reduction of sheets and the amazing properties which the cold-reduced sheet has had not been discovered. Car bodies were still made of aluminium or fabric as well as steel, and there was extensive use of wood. When cold-reduced sheets were invented the thickness of motor-car sheets settled down to about 20 gauge or thicker. After a time it was thought that with cleaner and better steels it would be possible to produce motor-car pressings at 24 gauge, enabling smaller tyres and smaller engines to be used for a given size of car. But, although at least one car maker (Renault) made extensive use of 24 gauge, generally cars are still made of 20 gauge, one reason being, of course, that we have still not mastered the problem of rust in car bodies. Most surprising is the fact that motor-car press works still make between 35 and 40% scrap.

In the field of bridges there have been some trends to use higher-tensile steels, but, in the field of ships and other structures, very little has been done to lighten the weight of steel by using highly developed steels. A well known structural engineer told me that he preferred all welding to be carried out in the shops using mild steel, and to bolt the welded structures together on site. He was against the use of high-tensile steels and on-site welding if it could possibly be avoided.

When putting all these developments together, that is to say, the change from railways to motor cars, for thinner steel in tinplate, for flat products to be used for structures and ships, together with rods and bars rather than heavy sections, naturally the form of steel works has changed. Undoubtedly, the most dramatic invention in my time in the steel industry has been that of the wide hot strip mill. This invention has not only revolutionized the production of thin wide sheets but also tinplate and, latterly, plates.

A modern wide strip mill may be up to 25.4 m wide, roll plates 19.05 mm thick in coil, and wide strip down to 1.59 mm thick. All of its output probably being intended to be of a high metallurgical standard ard, yet, a modern mill such as this may well have an output of up to 6 million tonnes a year. It is small surprise when units such as this come into production they cause an upset in the plans for keeping demand and capacity in step. Forty or fifty years ago no mill in the world produced much more than a million tonnes a year and thus increments in the capacity of different products were reasonable in size as each unit came into production.

The wide hot strip mill owed its great success to the motor-car industry and the tinplate industry, as it is only comparatively recently that they have been used for the production of large coils of plates up to 19.05 mm for processing into welded-steel pipes for natural gas, oil, and water.

A huge investment is tied to the products of the wide hot strip mill in the shape of canning plants and motor-car press works. There is always a possibility that a change may come. For example, the boat industry makes boats of up to 21.336 m and longer almost entirely from reinforced glass fibre and 10-15 years ago such boats were entirely made from wood or steel. What if some similar change were to strike the car industry and steel should be no longer used for the main body structure? This would have a dramatic effect on capacity plans in the steel industry and in Figure Six I endeavour to show the effects on world steel industry should, overnight, all car bodies and their chassis be made of some alternative material such as light alloy or fibre glass, although transmission steering and suspension would still be in steel.

Thus planners for investment are faced with a number of extremely difficult problems - the resistance to closure of old works whose original reasons for existence have disappeared, the invention of new methods and new materials which may almost overnight revolutionize an industry whose main raw material was previously steel.

So, if I can summarize, it is that I feel it may be asking for the moon, but that we should endeavour to ensure that there is some cooperation between countries and companies so that two large steel plants do not come into production at about the same time both intending to serve the same market That we should take great care that a plant is not installed to manufacture a product which is about to die or find the demand for it reduced. It is this over-production at quite frequent intervals that has had the most disastrous effect on the viability of the steel industry, which in general is not considered to have a highly profitable history. Needless to say, when a unit such as a 10,000 tonne a day blast furnace or a 6 million tonne a year strip mill comes on stream its effect on other plants within range of its product must be dramatic. Therefore, when plans are made for new instalment, plans should also be made for obsolescence, for otherwise unemployment results in areas where old and inefficient plant exists because no plans have been made to take up the labour force whose livelihood has suddenly disappeared.

I believe that, to avoid social disturbance, plans for obsolescence need to be made approximately seven years in advance of any decision to close a plant and substitute it by a new one elsewhere.

The difference between Figures 2 and 3 (showing so little change in the use of a large proportion of the world's use of steel per head in 45 years) is something which I believe is now about to change and we should be planning for a large-scale increase in the consumption of steel while in Asia and other areas consumption is now not much more than 30-40 kilos per head.

THE IMPORTANCE OF QUALITY

While I learnt the hard way of the importance of matching capacity to demand and the dangers of unplanned obsolescence in the very early stage of my steel career, I have to admit it was some years before I learnt that almost the most important thing in any steel works was the insistence on a very high standard of quality maintained at all times irrespective of demand.

When I entered the steel industry there were still a considerable number of works in Europe which existed by the production of low-cost, low-grade steel. I did not realise how poor the quality of some of the material sold was. For example, rails were still being sold made by the basic Bessemer process, varying considerably in properties and, by modern standards, being very low in shock resistance. Structural buildings were also being sold made from basic Bessemer steel with very high nitrogen and phosphorus, resulting in many failures, particularly where welding had been used. Tinplate (which was then made entirely by the hot-dipped process) was coated with so much tin that the variation in the surface quality of the steel was disguised and at that time steel for tinplate was regarded as of the lowest possible quality. A high specification for cold-reduced steel had not yet arrived. Such sheet steel as was used being made from sheet bar of a moderate specification. When it did arrive then at last, the sheet steel-maker began to understand what control of quality really meant and the steel maker is still having to learn.

In the world of ship-building, plates were also being sold of low physical standards except in the case of some Admiralty specifications, as for destroyers a steel known as "D" Steel which was sold on a limit of proportionality test. Should such a test have been applied to ordinary ship plates they would have failed at a very low figure. I think it was the arrival of welding more than anything else which concentrated people's attention on the quality requirements, particularly in the question of the thicker-section plates.

Plates over 25.4 mm thick are still being found to have an unusually high failure rate due, usually, to poor control of de-oxidation and high inclusions. I am sure that we shall shortly see a high percentage of thick plates made out of vacuum de-gassed steel, an idea which 20 or 30 years ago would have seemed extraordinary.

Most recently there has been the question of how to make high-grade steel for welding into pipes for the gas and oil industries. Here control of quality has reached heights never thought of 30 or 40 years ago, when welded pipes were regarded as a fairly simple quality.

I think the basic lesson that I learnt rather late is that,in periods of strong demand for steel,quality standards must not be allowed to slip. Men are only human and if they once get into the habit of thinking that anything will do, those same men will find great difficulty in reaching the standards of quality control which are necessary to achieve the consistency demanded by the customer today. I remember learning this lesson at the hands of the Royal Dutch Steel Company who, in spite of the fact that directly after the war anything that looked roughly like a steel sheet could be sold at the full price, even if it was manifestly defective, nevertheless insisted that there should be no let-up in their quality control standards even at the very height of demand and steel shortage.

Another firm which has earned an enviable reputation in this connection, through foul weather and fair, is the Armco Corporation of America, who must have taught a great many firms all over the world the great importance of quality control and sticking at all times to one's standards.

In U.K. our most famous centre of excellence for consistent quality has perhaps been the razor-blade steel of Samuel Fox.

It is interesting to note that the Japanese steel industry has managed to instill into its management and men from top to bottom the importance of quality control at all times, and by this they mean quality of dimension, analysis, cleanliness and adhering to the specification or improving upon it. I am sure that all those who manage a steel works would do well to remember that a reputation for high quality ensures orders during bad times better than anything else

Various methods of endeavouring to achieve high quality standards have been tried. In America the Zero Defects Program, originally started in the aircraft industry but adopted by some steel companies, was carried over into Japan and in Japan they have improved upon it. There is there a true understanding of the meaning of quality control and quality from the very top to the very bottom which I do not think is equalled in any other steel industry. Men are told off into groups of approximately ten, under their foremen, to discuss in their own time, in their foremen's houses, safety, improvement in productivity, improving the job from the point of view of those who work in it in the department, and also quality. I believe that this involvement of the whole work-force from the top to the bottom is equally important as written standards of practice which, of course, are essential too.

INNOVATIONS

Almost all innovations are resisted. The open-hearth manager resents the introduction of basic oxygen steel-making.

So far the blast furnace has reigned supreme for the manufacture of liquid iron or, at any rate, for the main materials required for steel making from iron ore. But should eventually some alternative process appear, I am sure, from my experience, it will be resisted by all those concerned with the management of blast-furnace plants.

I think the lesson I have learnt regarding revolutionary innovations is that not only are they resisted (partly because a man who has been trained, say, to operate an open-hearth plant sees himself as losing his job if a basic oxygen steelmaking process is introduced) but also because one is not quite sure whether a revolutionary innovation is but a flash in the pan and will never really succeed, or whether it is indeed something new which is going to entirely upset the industry and involve the construction of an entirely new type of plant.

During my lifetime, starting at the beginning of the process, I have seen the very slow acknowledgement of the importance of preparing ore for use in the blast furnace. At first sinter plants were considered purely a method of using up fine ore or flue dust. It was quite a time before it was realized that the proper preparation of ore which, at that time, was considered an agglomeration of everything, say, below 9.525 mm and crushing all pieces down to, say, 25.4 mm, to the modern idea that perhaps it is best to crush everything down to below 9.525 mm and then agglomerate it - sometimes in the form of 100% sinter, sometimes in a proportion of pellets and sinter, but definitely all of it pre-agglomerated and fed as a consistent-sized feed.

There was also a great deal of hesitation about the preparation of coke. It is interesting to note that, although I entered the industry in 1928, a coke-oven battery completed at the end of 1972 can bear such a close resemblance to the one I might have seen completed in '28 that from a photograph it would be difficult to see what changes have been made. Recently, it is true that ovens have become higher, that there is experimentation in the field of pre-heating, but the main idea within the ovens is to improve the brickwork to lengthen the life, running them at perhaps a slightly higher temperature. Quenching is always done with water (making a very serious environmental problem) and the resulting coke is far from an ideal fuel for a blast furnace, varying as it does, in size, and frequently bearing a considerable amount of sulphur, and even ash may vary according to the size.

It seems to me that the coke-oven section of the plant is long overdue for some change. The blast furnace itself I have seen change a great deal - in sheer size, for instance. When I entered the industry the largest blast furnace made 1000 tonnes a day and when I left it, 10,000 tonnes a day.

But the methods of running them have also changed considerably, not only in the pre-preparation of both coke and ore for size, but the acknowledgement that certain ores must be crushed and sintered, and cannot be fed as uncrushed material or rubble ore because of their tendency to decrepitate at low temperatures or to be too irreducible. Although there are some who are loath to crush a sized lump ore, although only in this way can a really satisfactory burden be created.

On the other hand, various other ideas have been introduced to do with the operating of blast furnaces, and some have failed. When I entered the industry the refrigeration of blast had been tried out on a number of blast furnaces and the protagonists argued that it paid well. Fortyfive years later, as far as I know, no refrigerated-blast plant exists. Rather is steam added to ensure a constant humidity of the air. This is but one example of a revolutionary innovation of which much was promised but little came.

On the other hand, an example of an invention which eventually succeeded but only after many years, is high blast top pressure. When it was first introduced it was opposed by almost everyone on the grounds of the difficulty of preserving the top of the blast furnace which at that time was in a pretty crude state of development compared to the furnace tops used today. High blast pressure was tried out for the first time at Cleveland, Ohio, in 1944 but at that time it had only the relatively low pressure of 2.270 kg at the top, whereas today the highest top blast pressure known is 17.252 kg per 6.452 cm^2 (ie 38 lb per sq. inch).

In 1968 or thereabouts I read a paper in Japan on The Economic Survival of the Blast Furnace and I reached the conclusion that, whilst it was possible that pre-reduced pellets might make quite serious inroads into the blast-furnace world, they would only work with very high-grade ores indeed - say, over 65% Fe and $1\frac{1}{2}$% silicon. For any ores below this specification there was no challenger in sight for the blast furnace.

But in the meantime certain ideas about the blast furnace have changed: with careful preparation of the burden it is possible that we may see a steady decrease in the amount of coke added for the purpose of reduction and heat, and a steady increase in the amount of reformed oil and gas (thus stealing some the pre-reduced pellet plant-makers' clothes!).

Another revolutionary invention that came to but very little was the Kaldo process. At the time of my last visit to Latin America I was considering whether we should use the oxygen-steam process for the use of high-phosphorus ores or the use of the Kaldo process. In the event, we adopted the oxygen-steam process with which we made very good steel, but with a very low yield. Now, only 15 years later, both of those processes are virtually dead, being overtaken by the tremendous expansion of low-phosphorus iron ore mining in Australia, Canada,and Africa, making it possible to use the basic oxygen steel-making process, with or without some form of lime injection to reduce the last little bit of phosphorus,depending on the amount of phosphorus actually in the iron. This revolutionary innovation came to pretty quick success. It was invented in 1949 and the first commercial-scale plant operated in 1952. By 1973 about 50% of the total steel-making capacity of the world was in the form of basic oxygen steel-making. So far there has been little to challenge it except some of the new processes of blowing oxygen with fuel oil or modified fuel through the bottom. It may indeed displace the conventional oxygen steel-making process,but this process is in reality only a small modification rather than an entirely new process.

I do not think there is any doubt that there will be a large-scale expansion in electric arc steel-making aided by the gradual success of the various methods of pre-reducing high-grade iron ore. To mention just a few - HyL in Mexico, Midland-Ross (or Midrex) in America, Canada and Germany, and the Purofer process now being installed in Latin America. It has been proved possible to make almost all grades of steel using pre-reduced pellets and scrap and the arc process.

Also in steel-making another process which was invented a long time ago - vacuum de-gassing - but it was considered a purely high-grade steel tool. It was never expected it would be used for anything important in tonnage. But it was the invention of continuous casting (another very contentious innovation) which introduced vacuum de-gassing into large-scale steel-making. Now, not only with continuous casting but ordinary ingots, vacuum de-gassing is being used on a very large scale indeed and excellent steels are being made with it using big 300-tonne converters. In fact it is possible to make electric silicon steels using vacuum de-gassing from 300-tonne converters in a very simple manner - far cheaper and simpler than the old 3-ladle process using the open hearth.

Continuous casting was a very long time succeeding but I think I can say that,when I left the industry, for most fields it seemed as though there had been a complete breakthrough. It is possible to cast slabs of great width and thickness, shall we say up to 2540 mm wide and 381 mm thick, and blooms 381 mm x 381 mm. The great problem is how sound is the resulting steel if not vacuum de-gassed? For instance, for roller bearings electric arc steel is continuous cast into slabs or blooms 304.8 mm x 203.2 mm. These are then reheated and rolled down into billets by conventional blooming and billet mill methods. While at least one firm is finding it possible to produce high-grade auto-body sheets from continuously cast slabs,albeit using a very large slab from a universal blooming mill to reduce the slab, another very large firm uses vacuum de-gassing for all continuously cast tinplate slabs. I consider the real problem is going to arise when it is decided to plan a very large heavy plate mill. Will it be possible to manufacture plates several inches thick from slabs that are not more than 304.8 mm thick continuously cast? Clearly, when the plates are, say, over 254 mm thick then the old-fashioned method of rolling the plates from slabs will have to be resorted to. In this connection some of the newer plate mills are fitted to roll large ingots of 60 tonnes or more into slabs. These slabs are then reheated and finished off into plates on the same mill, the plate mill or slabbing mill being fitted with manipulators in the normal slabbing mill fashion.

At least one plant (the plate mill in Finland) is equipped only to use continuously cast slabs and yet is producing satisfactory plates up to 50.8 mm or 76.2 mm thick. Taking the conventional idea that a reduction of 7 or 8 to 1 must be used, when using continuously cast material, means to say that the continuously cast slab would have to be 406.4 mm or 431.8 mm thick,which is thicker than any continuously cast slab they make.

As I have mentioned, there are those who believe that this problem can only be overcome by vacuum de-gassing and thus rendering the continuously cast slab more sound than it otherwise would be, but it is possible that argon stirring or some other method may yet render it possible to avoid this expense. At the moment I would unhesitatingly recommend production of a very thick plate from a very large ingot.

At the same time it is wonderful how new processes succeed in overcoming the apparently insuperable obstacles and objections which their detractors suggest they may have.

One interesting case of an invention which was considered unlikely to succeed is the Hot Sendzimir or Planetary Mill. When this first came out it was regarded by those who have wide hot strip mills as something of a freak; it was not considered that it would ever really succeed. But recently in Japan such improvements have been made to this mill that the product from it is now competitive in the stainless-steel field with anything that can be produced off a normal wide hot strip mill and, in view of the fact that it is a low-tonnage plant, at considerably lower capital cost.

A lesson I have learnt in this regard is that all new inventions have to be examined very carefully and one must also be prepared for the fact that because they fail initially they will not necessarily fail in the long run.

EFFICIENCY AND YIELD

While most steel-makers would agree that it is obvious that a high yield in each section of the plant is important, few are aware of the immense differences that exist with equal plant and equal raw materials between the various works of the world. In some ways I feel from the lessons I have learnt that the reasons for this variation is one of the most important lessons I have learnt in all my time in the steel industry. Obviously, given absolutely equal raw materials, equal equipment, any difference there is must be basically due to the human factor, but the human factor is in control of a very important part of the equipment - the measuring equipment (volumes, weights, flows, temperatures, dimensions are very important factors in yield and, unless the equipment which deals with measurement is maintained at a very high standard, then yields will be unknown and inaccurately reported).

I well remember on my first visit to Japan being impressed by the extent to which they employed data loggers compared to the British steel industry. Such data loggers recorded times and movements of a very large number of operations, thus enabling a study to be made of the complete operation after integrating with the records such things as weights, flow of gas, temperatures of ingots, and the like. The accurate recording of all operations in this way makes it possible (to use an inelegant but descriptive phrase) to de-bottleneck any process where it is necessary. Bottlenecks are only too common in various parts of the iron and steel works and frequently performance is handicapped due, for example, to insufficient space for cooling ingot moulds, resulting in ingot moulds being teemed too hot and, if no proper records are kept, then it is unusual for this limitation to be discovered. If the scale-car operator on the blast furnace does not accurately fill the scale car with the ores which he was told to put in then, quite clearly, the blast furnace will not perform in accordance with the plan but the blast-furnace manager will not know why.

Gradually a number of these variables have been eliminated. It is now possible to build a blast furnace in which the charging of the ore is fully automatic and, in the latest blast furnaces of all, the burden is totally pre-prepared and the addition of any small amounts of limestone or silica which may be required is done by a computer feedback. But it is by the use of data loggers and accurate weighing machines, analysis methods, and measuring methods that it has been possible to devise these computer controls.

It is always easier to automate any process if the variations have already been reduced to the very minimum. That is why it is so much easier to run a blast furnace accurately and with close limits if both the coke and the ore are also within close side limits and close analysis limits.

But this question of maintenance of measuring instruments is still a very thorny problem. Much of the weighing in blast furnace and steel plants is of large volumes of materials, and in many cases weighing is carried out on belts (and everybody knows how difficult belt-weighing machines are to maintain). Another case is the weighing of very large liquid masses such as molten iron or molten steel from the converter - everybody realises when the payload is small in comparison with the total load, the accuracy of the weight is very difficult to determine.

But I would say the first step to ensure a high percentage of material being produced against original order is to ensure that all measuring devices throughout the plant are not only accurate when installed but are frequently checked and,when not working, immediately replaced. It always used to interest me when visiting open-hearth plants and blast furnaces to check how many of the instruments in the Instrument Cabin were in fact in operation. It was only too common to note quite a high percentage were in fact no longer working or manifestly recording incorrect information. Very few Instrument Cabins record such things as weights of scrap charged or weights of materials such as limestone and lime, fed into the furnace, and practically no plants keep accurate records of the weights of steel and slag being delivered on to the pit side.

If iron and steel manufacture is to be changed into a more accurate science,then I consider it is vital for virtually everything to be measured and cross-checked, for only in this way can it be possible to obtain a really detailed Fe balance at every stage in the process. At the moment such a blance is virtually impossible. Though, having said that, it is interesting to note that the first steel works on the Continent that I worked in in 1929 was in Germany, and a record was kept of the carbon and Fe balance throughout the blast furnace. The only snag was that many of the facts that were recorded were in fact estimates,as the weighing machines were known not to be accurate. The volume of blast was measured by the revolutions of the gas blowing engine. The true quantity of carbon fed into the blast furnace was not really known,as the difference between the ash in the large coke and the medium coke and the small coke was not known. Thus they built up an elaborate record but it was no more accurate than the information that was fed into it which, at that time, was very inaccurate indeed.

Nowadays it is common to use computers for the control of blast furnaces, BOF plants, and hot stiip mills and, in fact, a large percentage of the iron and steel manufacture, and I am sure that, with the introduction of these computers, a greater realisation will come that it is only possible to make satisfactory use of them if the volumes, weights, temperatures, flows and dimensions and analyses fed to the computer are within the limits of accuracy required to indicate true yields and true failures of the process. Possibly this may be considered obvious, and yet it cannot be really obvious, or there would be a closer similarity between the yields of perfect finished material against original order produced from a tonne of liquid steel from the large number of hot strip mills in the world processing through into cold-reduced sheet for the motorcar business. Any motorcar manufacturer can tell you that there is still a very considerable difference between the quality of cold-reduced sheets supplied from the different makers.

THE IMPORTANCE OF MAINTENANCE

The standard of maintenance varies from plant to plant just as the standard of metallurgical skill. I have been in a big steel works where the standard of metallurgical skill was very high but the standard of maintenance was poor. Sometimes this indicates the presence of, say, a general superintendent who is an ex-metallurgist but not an engineer. This results in a lack of attention to the maintenance problem. But it is not always the explanation. Sometimes the problem is sheer bad design of the plant originally and a shortage of money to re-design it. Sometimes it is because the plant is used in a way for which it was not originally intended and yet nobody has seen how to overcome the problem.

A wellknown example is the shunting of large trains of ingot moulds on ingot bogeys with stripper cranes (or with soaking-pit chargers), the side load on the cranes being something for which they never were designed,resulting in frequent breakdowns and a large departure very often from the intended temperature of charging of the ingot moulds, with ensuing metallurgical troubles.

I would think that, just as important as it is to record volumes, weights, temperatures, &c. it is to develop a better system of recording availability and maintenance of plant so that the performance of the plant is not so often limited by breakdown of mechanical or electrical equipment and where, for instance, recurring mechanical or electrical failure occurs, then re-design takes place automatically to ensure that it will not recur. This mechanical failure and electrical failure is not something that has been eliminated in the steel industry.
I have seen a slabbing mill only recently, a few years old, whose availability is now basically low because the original plant, when put in, was not up to the weight of ingots which were being processed on the mill.

This could perhaps have been overcome by fairly frequent shutdowns for repair of the foundations, replacement of rollers and bearings, but in fact this was not done. The foundations gave way, rollers broke, no re-design took place, and the length of stoppage for maintenance became longer and longer, and finally it has been decided that the whole mill shall be shut down for a period and rebuilt. Crane design has improved with the passage of years but still, only too frequently, the performance of slabbing and blooming mills has been regulated by the availability of stripper and soaking-pit charges. In continuous rolling mills,maintenance has interfered with accuracy and cleanliness of the surface due to the difficulty of maintaining clean water and therefore the descaling sprays. With the demand for higher and higher pressures,the ability of the pumps to handle impure water has not kept pace. Only now do we see the designers of water systems beginning to appreciate their importance for such purposes as blast-furnace cooling water and the water used in all forms of mill.

THE HUMAN ELEMENT

I now come to the last and perhaps most important question of all - the human element. How can a work-force from manager to newest recruit on the shop floor work together as a team to ensure the best possible use of raw materials and equipment?

While the Japanese have settled on a unit of ten for studying the problem of safety, quality, efficiency and also the wellbeing of those working in the department, this, to the best of my knowledge, has not been done elsewhere and it does imply that there is in some way a division between the worker, the foreman and the manager. I think in the long run it would be better if everybody from top to bottom involved in the business were to feel that there should be no break, but a smooth transition from the most responsible and highest authority at the top right through to the person with lowest authority and the least responsibility at the bottom. There would thus be no dividing line between top-floor supervisory staff and executive staff. Whether this idea would succeed where other ideas have failed in involving everybody equally in the success of the venture I do not know. One thing is certain - that at the moment all those employed in a large steel works do not feel equally involved in the success of the venture and the reasons for this are argued at all levels. Ideas have been put forward for profit sharing, publication of accounts, discussion groups, all kinds of methods are being tried throughout the world and yet none of them can be considered to be totally successful because nearly always at the bottom is the feeling that there is very little argument about anybody's individual pay - the argument is always about one person's pay compared with that of somebody else. And thus to get total satisfaction within a works it is necessary to evolve a system of job evaluation which is believed in by everybody and everybody believes they are paid about the right money relative to everybody else. Most job-evaluation methods tend to leave the man in the lowest-paid job with a feeling that he is doing a job which some of the better-paid people would not do even if they were paid more money. I think this is one of the problems in ensuring that the manning of a steelworks is carried out in a way so that there is more flexibility. I would hope that it was not necessary in the future for the most unpleasant job to be done all the time by the same man. A method should be evolved for job rotation within departments and, perhaps ultimately, between departments. Of course seniority rules militate against this and probably a method of moving from job to job within a department would require an entirely new pay structure in most European works. One thing is clear, that some motorcar manufacturers, notably Saab in Sweden, are considering whether groups in which jobs are rotated would not be a better method of getting job satisfaction than merely having a system of seniority promotion. Since many of the jobs which have to be done still in a steel works are so unpleasant that nobody would wish to stay at them for a lifetime, I think it important the steel industry should consider this matter.

Finally, I wish to dwell on the question of training. Having been lucky enough to have been supervised by a Managing Director who believed in personal training, I still believe the greatest piece of luck that any man could have is to have a tutor who is interested in training his pupil. Obviously this cannot happen to everybody and it makes it all the more important that management should be trained at an early age that they too will grow old and that before they grow old it is their job to ensure that their successor is better equipped to do the job they are doing than they are. Everybody respects the Master of his trade - the good artist, the good musician, the good actor. In the same way everybody respects the good steelmaker, the good roller, the good engineer, and we should be sure that training is carried out by people who really know what they are trying to teach. I am sure occasionally we have the blind leading the blind. It is not necessary and I am sure can be avoided if, for example, in a large steel company the manager who achieves the best results trains others to equal his performance and teaches them how he does it.

Again mentioning the Japanese, they have clearly learnt there is no sense in starting from behind and trying to catch up. One should start from the point where the best already are. So, after 45 years I can say, without fear of contradiction, that the excellence of any steel plant will depend as much on the people who manage it as on the equipment they have. I have seen the most amazing performances in what looked like tired old plants and excellent management, and I hope that all of you before you leave the steel industry will be proud to say that you are being succeeded by someone who is better than you.

3. 9. 74