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Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September - 9 October 1968

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AUTOMATION IN THE IRON AND STEEL INDUSTRY 1/

prepared by

the Secretariat of the
United Nations Economic Commission for Europe

1/ The document is presented as submitted, without re-editing.

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SUMMARY

As part of the work on automation carried out by the Economic Commission for Europe and its subsidiary bodies, the ECE Steel Committee in March 1961 decided to review the position of automation in the iron and steel industry in various countries. The report was undertaken in response to a widely felt need for factual information on the situation at that time in the main sectors of the iron and steel industry of several steel-producing countries.

Research on automation is generally undertaken in European countries on three different levels:

- research in the steel industry itself and through the equipment makers;
- research in national research institutes;
- research sponsored by international organizations such as for instance the High Authority.

It is shown in the bibliographical part of this report that publications dealing with automation in the iron and steel industry became noticeable around 1960; in this report more than one hundred articles published between 1960 and 1964 have been reviewed in order to assess the progress in this field. From this

* This is a summary of the paper issued under the same title as ID/WG.14/28

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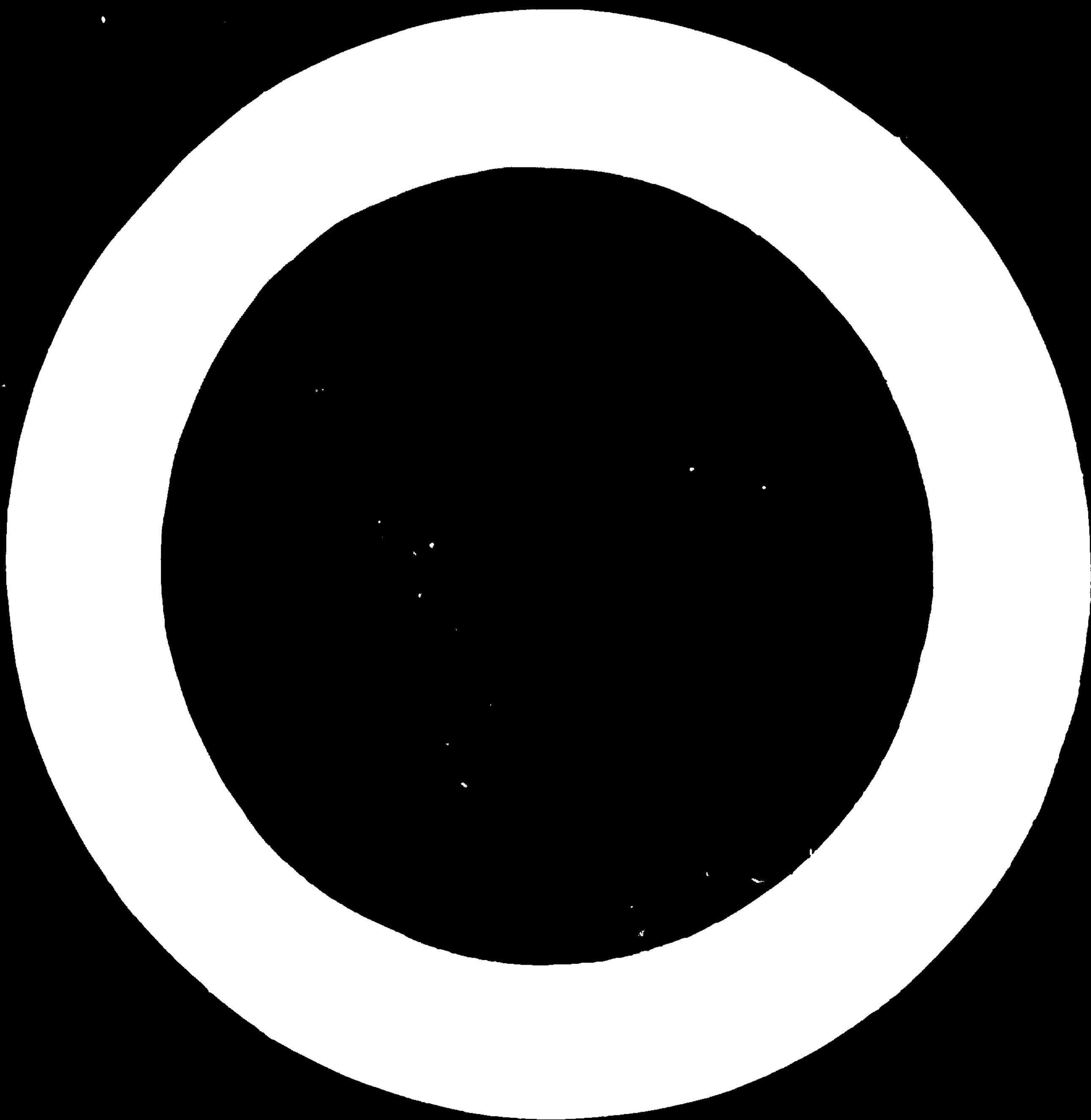

total, about 40 publications deal with automation in rolling mills, 30 publications deal with automation in the steelmaking plant, 10 publications with automation of the ironmaking and 10 publications with automation of iron ore preparation. The greatest development in automation was obviously achieved in rolling which is the most adequate for its application because of the periodicity and continuity of the process. Moreover sensing devices are more easy to develop in this area and environmental conditions, as regards heat and dust are not so severe.

For the departments of ironmaking and steelmaking, equipment is available for many of the computing and control functions, while the arduous conditions encountered in measuring are the reason that equipment for this purpose is not available to the degree of robustness and other accuracy desired. Measurement of the conditions inside a blast-furnace for instance remains to be very difficult, and automatic weighing of raw materials and of semi-products accurate enough for purposes of automation still requires much study. There is a growing need for quality control equipment for example continuous analysis of solids, liquids and gases.

Rapid progress is likely to be made both by iron and steel works and by the manufacturers of automation equipment under the compulsive demand for increased production efficiency which exists in all countries.

It is fairly easy to assess the economic value of individual installations. However, many of the more complex systems of automation have been installed as an inherent part of a programme of complete plant reconstruction. In such cases it is much more difficult to estimate separately the gain due to automation. Moreover many of the advantages realized through automation are due to improved product quality, production scheduling and production co-ordination, which is not always easy to measure in terms of cost/benefit relations.

Since a main feature of automation is its gradual introduction into the production process, through adding consecutively sensing devices and control equipment, the resulting economic effects will also be felt only in a gradual way. Very often automation projects are considered in the framework of an over-all research and development programme which is not subject to the normal economic criteria for assessing their effectiveness, since long range objectives have to be taken into consideration.

One of these long-range objectives of automation is the steady improvement of labour productivity which will be achieved mainly through an improvement of work efficiency (for instance reduced losses, improved quality, less idle time etc.), rather than through a reduction of manpower. Although the number of unskilled and arduous jobs diminish, automation leads to an increased need for skilled workers, and to the need of developing such higher skills.

In the iron and steel industry the biggest savings in manpower come from plant design modifications such as increasing the size of furnaces, mills and handling equipment, all resulting in a higher production rate. This increase in size and in the degree of mechanization calls for more reliable control features to ensure greater safety of the operation, prevention of equipment breakdown, regularity of the production schedule, or closer control of the quality of the product. Thus automation permits to take to a greater extent advantage of the capital investments in the iron and steel industry.

Once the production processes of making, shaping and treating steel will have come under closer control, great advantage of automation can be expected from co-ordination of the different production units and from optimization of the production programme according to the raw material situation and the product structure of demand.

In order to reach this goal an even closer relaionship has to be established between the steel industry experts, who know the requirements for advanced technology and the instrument experts, who know the possibilities of the equipment. Common research projects are currently undertaken to this effect.

The structure of this report is as follows. An introductory chapter and a chapter, dealing with the general aspects of the application of automation to the iron and steel industry, lead to the description of the state of automation in 1964 in the following sectors: coke manufacture and ironmaking; steelmaking; rolling of semi-finished steel, plates and sections; wide strip mills; and other operations in iron and steel making. These five descriptive chapters are followed by a chapter dealing with the economic and social effects of automation. A last chapter summarizes the general conclusions. Bibliographical references, on which the report is largely based, are given in an annex.

Contents

Prefatory Note

As part of the work on automation carried out by the Economic Commission for Europe and its subsidiary bodies, the ECE Steel Committee in March 1961 decided to review the position of automation in the iron and steel industry in various countries. The report was undertaken in response to a widely felt need for factual information on the current situation and degree of automation in the main sectors of the iron and steel industry of several steel-producing countries.

The report was discussed by the ad hoc Meeting of Experts on Automation in the iron and Steel Industry, established by the Steel Committee. The Chairman of the Meeting, Mr. A.H. Leckie, acted as Rapporteur and conducted the enquiry with the assistance of the Secretariat ard on the basis of information made available by Governments.

The report reviews the general aspects of the application of automation and computers in the iron and steel industry and gives examples of automation in the individual stages of the iron- and steel-making process: coke manufacture and iron-making, steel-making, the rolling of semi-finished steel, plates and sections and of wide-strip, and other operations in iron- and steel-making. The report further reviews the economic and social effects of automation; recent bibliographical references are to be found in the annex.

At its thirty-second session, in September 1964, the Steel Committee decided that the report should be published for general distribution. The final text of this report has been prepared in accordance with normal practice on the sole responsibility of the Secretariat.

CHAPTER I

INTRODUCTION

At its twenty-fifth session, in March 1961, the Steel Committee requested the ad hoc Meeting of Experts on Automation in the Iron and Steel Industry to prepare an account of the extent of automation achieved in different countries. Countries were invited to prepare national reports to be considered by the experts, and to make recommendations for further work including, perhaps, a more intensive study of the automation of particular processes.

In response to a request from the Executive Secretary of the Economic Commission for Europe, replies were received from fifteen countries and from the European Coal and Steel Community. Of these replies, twelve contained specific information, the remainder being statements to the effect that the countries concerned had not made sufficient progress with automation to permit the contribution of information. At the request of the Secretariat, Mr A.H. Leckie (United Kingdom) Chairman of the ad hoc Meeting of Experts, kindly agreed to act as Rapporteur, and a preliminary report summarizing the position at the time was presented to the twenty-eighth session of the Steel Committee, in September 1962. At this and the twenty-ninth and thirtieth sessions, in the following year, Governments were asked for further information on the development of automation in the iron-and steel-works of the various countries.

At its thirty-first session, in March 1964, the Steel Committee reviewed briefly the material provided by Governments as well as the work being carried out for the preparation of a new report on automation in the iron and steel industry. The Committee expressed the hope that the ad hoc Meeting of Experts on Automation in the Iron and Steel Industry would at its next session, in September 1964, examine all relevant information and proposals received as well as the new report on automation in the iron and steel industry. It was understood that the new report would include all recent information made available to the Secretariat by Governments since the presentation to the Steel Committee in 1962 of a restricted preliminary report on the same subject.

Subsequent to the presentation of the preliminary report, the Secretariat received relevant information from twelve countries (Austria, Czechoslovakia, the Federal Republic of Germany, France, Hungary, Italy, Romania, Sweden, Turkey, the Ukrainian SSR, the Union of Soviet Socialist Republics and the United Kingdom), of which two countries (Romania and the USSR) provided also bibliographical material. Further replies (received from Belgium, Denmark, Finland, Ireland, the Netherlands, Norway and Spain), stated that the responding Governments had no new information to submit or observation to make.

The present report has been prepared by the Chairman and Rapporteur of the ad hoc Meeting of Experts on Automation in the Iron and Steel Industry, with the help of the Secretariat. This report includes both the relevant parts of the preliminary report and all new information submitted by Governments. Wherever necessary, such information has been reinforced by that in some of the more important papers and articles, published recently in various countries.

Nearly all the information available is technical. Some time must elapse before any reliable assessment can be made of the economic effect of automation, although a few countries have provided information as indicated in chapter VIII and some estimates can be made.

Another difficulty facing the Secretariat and Rapporteur in preparing a report is that technical progress in automation is very rapid at present, and it is not possible to ensure that information is up-to-date by the time it reaches the reader. It should be understood that the contents of this report apply to the time of writing (1964) and that considerable advances may be made between that time and the time of appearance of the report.

Definition of automation

One difficulty encountered by all students of this subject is the definition of what methods of operation should be included in the term "automation". In an earlier ECE report on the economic implications of automation in general, three stages were distinguished:

(a) the mechanization of productive processes or parts thereof, of links between processes and of the simplest assembly operations, so that the work is done mechanically without direct physical effort on the part of the operatives;

(b) the automatic control, regulation and direction of productive processes or parts thereof;

(c) the use of high-speed calculating machines (especially electronic computers) for automatic control, regulation and direction and for collecting and processing information.

Problems of definition are discussed in a contribution received from the High Authority of the ECSC. This quotes simple examples of several kinds of automation, e.g

(a) those following a rigid programme e.g. automatic record changing for gramophones, and washing machines;

(b) those adjusting themselves according to the result of the operation. In this category falls what is probably the first example of automation - the governor of a steam engine invented by James Watt at the end of the eighteenth century. Other examples are thermostatic control of domestic heating systems and automatic volume control in radio sets.

(c) automatic operation of several processes in sequence, e.g. transfer machines in automobile engineering and the chain of chemical processes in an oil refinery. It will be noted that these three types of automation quoted in the ECSC contributions do not include simple mechanization.

A contribution from Italy solves the problem in terms of the Bright Scale which lists on a scale all types of operation from the simplest hand operation without tools (scale 1) to advanced anticipatory action and control (scale 17). The suggestion is that only operations on scale 12 or above can be regarded as true automation.

The simplest definition would appear to be that an automated, as distinct from a purely mechanized, process is one where certain decisions are made without human agency, e.g. decisions on how far to open a valve according to a temperature or pressure reading, decisions on the screwdown of a rolling-mill according to the temperature of the steel offered to it, and so on.

However, it is proposed that this stage of the study should not spend too much time on problems of definition, and should not exclude study of installations of interest which may be on the borderline of true automation. The information submitted by the various countries reveals considerable variation of opinion on what is worthy of quoting as examples. Some countries include installations of ordinary indicating and recording meters.

In some of the national reports it was not always clear whether examples of automation quoted referred to equipment actually in operation, or to equipment planned for the future. There are not many installations incorporating extended use of high-speed computers throughout the chain of processes. At present such computers are used in a few isolated locations on what is essentially a full-scale experiment. However, it is clear that most of the major iron- and steel-making countries are aware of the wide field there is for integrated automation and are making plans for it.

At present, the trend in the principal iron- and steel-making countries is for full automation where this can be carried out simply and reliably, using well-tried electronic or fluid-actuated control systems. Automatic control of hot-blast temperature and blast humidity in blast-furnaces, automatic draught control (based on furnace chamber pressure) for open-hearth melting furnaces and soaking pits, automatic gas pressure regulation and control of fuel/air mixing rates are widely used. The same applies to speed control in continuous mills. Other types of automation such as automatic gauge control in wide-sheet mills and automatic roof temperature control in open-hearth furnaces are rapidly coming into use.

CHAPTER II

GENERAL ASPECTS OF THE APPLICATION OF AUTOMATION OR COMPUTERS TO THE IRON AND STEEL INDUSTRY

In a fully automated works, the customers' orders would be processed by a computer which would then assemble them into a works schedule which would allow for optimum operation of the plant. Each part of the plant would have its own control system receiving instructions from the central computer, and signals of all the important variables at each stage would be fed back into the system to enable any deviations from the programme instructions to be dealt with.

Although such a system is not yet operating anywhere, a number of works are planning such a system of control. For instance, the system applied to the plate mill in Oxelosunds, Sweden, referred to in Chapter V, is of this kind, and according to the latest information received from the Swedish Government, this experience has caused some other Swedish works to use computers for the planning of their production in the same way.

In Austria, the alloy steelworks of Schoeller Bleckmann will feed details of each incoming order into a computer, which will schedule the order and estimate the delivery date.(1)* One group of steelmakers in Italy is reported to have ten electronic computers in use for commercial and scientific purposes. Three more computers are to be installed for the same purpose and another is intended for controlling the operation of a reversing sheet mill. A process control system using a computer is being planned for the S.K.F. Hofors Works in Sweden. The wide use of data-logging linked to computers in the Japanese steel industry has already been noted in a report from a delegation from the United Kingdom which visited Japan in 1963. The Pittsburgh Steel Company in the United States will be scheduling its operations in the same way.(2)

According to information from the United Kingdom, considerable attention is being given by the iron and steel industry to the installation of mechanized data collection systems to replace handwritten documents for collection of process information. So far, there are at least two installations of data collection equipment in operation. These employ push buttons for information input into the system, multi-point uniselectors for temporary storage and co-ordination of the information, and punched tape or cards for permanent storage with electric typewriters

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* Figures in parentheses refer to the bibliography, reproduced in the annex.

for print-out. One of these installations is at a section mill where about twenty items of data such as date and time, cast number, order number, bloom size, weight and quality, section to be rolled, number of sections rolled, section lengths, etc., are co-ordinated and printed out on electric typewriters. The information emanates from several stations, ranging from the point of arrival of the billets to the position of stacking of the finished sections. The other installation provides centralized recording of the order number of the material being processed and the working and idle time of twelve different items of plant throughout the works, including a tandem mill, temper mills, cleaning lines, slitting machines, and straightening machines, etc. Idle time is capable of being coded under ten headings and the collated information is recorded on punched tape and cards and printed out.

One of the most ambitious integrated automation systems is that at the Spencer Works of Richard Thomas + Baldwins Limited in the United Kingdom. As each order is received from the customer, the details are fed into a computer which calculates the tonnage of steel required at each stage according to normal yields. Orders from each customer are then grouped according to specification, delivery date, and so on, to establish the schedule of steelmaking. This information is fed to a second computer which controls the ingot and slabbing operations, and this in turn feeds into a third computer which passes appropriate instructions regarding the final rolling programme.[3] [4] Some time is likely to elapse before this integrated system is working fully, but it may be assumed that the United Kingdom steel industry will aim at the operation of this kind of comprehensive system at most of the modern works.

So far, there are at least ten digital computers and one analog computer in service in the United Kingdom carrying out on-line process control. Two further units are being used experimentally and another two are on order. About twenty-six computers are in use for office work such as pay-roll calculations, invoicing, stock control and so on.

The function of planning steelworks production, scheduling in detail individual processes and collecting progress information from them, is a vital operation, especially in an integrated steelworks. The object of this function is to match customer requirements with plant capacities and operating criteria so that a high level of over-all efficiency can be maintained. Much attention has been centred on the study of this function since its success or failure can considerably affect a company's profit and loss account. It has been shown that digital computers can be programmed to determine production schedules, etc., in an efficient, predictable, consistent manner by taking into consideration a wide variety of criteria and constraints and by treating works as a single multi-stage process rather than a number of individual processes. Customers' orders are fed into a computer, are processed according to specified rules, and production schedules are calculated. Computer systems are on order for three steel plants for this type of production planning work, and in addition design studies have been completed for three more installations of this type.

The problems of communication, timing and co-ordination of the information arising when the production schedules are implemented, can be dealt with by the use of satellite computers linked to the production processes and communicating with the memory system of the central production scheduling computer. The satellite computers can be programmed to instruct a section of a works by means of teleprinters, displays or direct control of on-line computers and can assimilate progress information derived from push buttons, digitized weighbridges, trip switches, automatic length-measuring devices, etc. This progress information will be used (a) to follow the progress of material through the works, thus enabling the display of schedule instructions to be correctly timed, and (b) as feed-back information for the production scheduling function. An advantage of this system is that schedule changes, however caused, can be rapidly communicated to the relevant parts of the works and considerable re-scheduling can be effected in a short time. It is clear that the maximum speed of response will only be achieved if the various computers in such a system, i.e. the central scheduling computer and the satellite computers, which may number up to six in an integrated steelworks, can directly intercommunicate information.

One practical method of achieving such a communication system involves the use of a large random access store to which every computer in the system has access. Such a store then becomes an electronic clearing house for schedule details being passed from the central machine to the satellite computers, for progress information passed in the reverse direction, and for co-ordination signals passed between the satellite computers. An integrated data processing and information handling system of this nature has been designed for a large integrated steelworks and will be installed.

Although the remarks on information handling and production planning have been taken largely from the United Kingdom report, it is known that similar methods of planning by means of computers are in use in other countries.

Works' central services

In modern integrated works there must be many automatic controls to preserve safe operating conditions. This point is mentioned in the report from Yugoslavia, ranging from automatic control of water level in boilers, to regulators which prevent excessive speed in turbo-generators when the load is reduced. Many works have central fuel control systems by which the distribution of coke-oven gas, blast-furnace gas, and other fuels to the various consuming departments is organized. For the most essential services, such as the cooling water supply to blast-furnace tuyeres and coolers, an emergency water supply which automatically comes into operation if the main circulative system fails, is desirable.

There is scope for a considerable degree of automation in the railway system servicing a large steelworks and one of the new marshalling yards built to serve a large strip mill plant in the United Kingdom is an example. Information on how an arriving train is to be split up by means of "hump" shunting is recorded on punched tape which operates the rail switches and rail brakes automatically. The available capacity in the sidings is signalled into a computer which takes capacity into account when programming the flow of wagons.

Research on automation

The iron and steel industry of many countries is devoting an important proportion of their research budget for research on automation. The information provided by Czechoslovakia mentions work being done in that country on measuring instruments. Of particular interest are: (a) instruments for temperature measurement at the perimeter and in the cross section of the throat of a blast-furnace, (used to regulate charging) and a system for measuring the pressure change between tuyeres and throat and tuyeres and hearth. The Iron and Steel Research Institute has been making a special study of torsion recorders and electromagnetic tensiometers operating on the principle of the Wiedemann effect. This equipment has been used for pressure measurement in rolling mills and in crane and platform weighing machines.

In the USSR, there is a Central Laboratory for Automation much of which is devoted to problems of the iron and steel industry. In the United Kingdom the industry's central research association has departments dealing both with the fundamental physics of automation, and the application of computers to the industry. In addition to this the major steel companies have parts of their own research laboratories devoted to the study of automation. The same applies in the United States of America where, for example, the large central research laboratories of the United States Steel Corporation at Monroeville, Pennsylvania, has an electromechanical engineering building devoted to research on instruments, automatic control systems and computers. This department also offers a consulting and development service to the Company's steel plants. The European Coal and Steel Community has set aside a considerable sum of money for central research on automation, to be allocated on recommendation of its technical research committee to projects as they arise.

Apart from the above-mentioned research by the steel industry itself, the companies who supply equipment such as measuring instruments, automatic control systems and computers, undertake a considerable amount of research work themselves.

Bibliography

World scientific literature is well provided with papers on automation and the references in this report are only a small selection of references included for illustrative purposes. Some of the information received from Governments, notably from the Federal Republic of Germany, Romania and the USSR, contained references to papers on automation in the iron and steel industry.

The following chapters summarize information received from Governments relating to specific sections of the iron and steel industry, supplemented by relevant information from published literature.

CHAPTER III

COKE MANUFACTURE AND IRONMAKING

The manufacture of metallurgical coke at present does not lend itself to true automation, and modern ovens exemplify advanced mechanization rather than true automation. These developments are mainly devoted to remote control of the operations from control desks. There are various devices for alignment of pusher and coke guide during pushing; one involving the use of cobalt or caesium isotope transmitting from one side of the oven to the other. Automatic quenching is standard practice. By-product plants are, of course, very suitable for the types of automatic control common in chemical plants but these developments are outside the scope of the present note.

In the United Kingdom, combustion air and fuel gas pressures, temperatures and flows are centrally monitored and local automatic controls applied to maintain flows for desired combustion conditions. A summary of the position in the United Kingdom coking industry was given at the International Seminar on Automatic Control in the Iron and Steel Industry held in Brussels in 1962.(5)

In the USSR, research work is being carried out on the automatic control of the pushing and thermal cycles of coke-oven batteries on the basis of digital technique. Experimental installations are being used for automatic regulation of heat supply for heating coke-oven batteries, in which consumption of heating gases is maintained at the desired level by control of temperature, moisture content and calorific value of the gas.

Coke quality is not so critically dependent on process conditions as to make more precise control of the process a strong requirement, but it is much influenced by coal quality. However, the quantitative relationship between the two is not sufficiently well defined yet to allow coke quality to be automatically controlled directly from the measurable physical and chemical properties of the coal. This matter is receiving some attention.

Considerable advances have been made in the mechanical handling of the feed materials, including centralized control of coal blending, crushing and conveying, coke screening and the flow of by-product materials. In the United Kingdom the Murton plant of the National Coal Board is a notable example of advanced coke-oven materials handling which has resulted in much improved working conditions and some 50 per cent reduction in manpower requirements - both important features at a type of plant which had previously offered unattractive working conditions and so become increasingly difficult to man. There is still scope for improvement by more remote control of charge hole lids, door cleaning, coke car and pusher positioning, etc., and these matters are receiving attention.

The information from Yugoslavia and Turkey quotes automatic regulation of the gas used for firing, and of the pressure of the raw gas. The main variables in the by-product plants are also under automatic control.

Contributions from other countries make only brief mention of coke-ovens but modern coke-oven practice is almost standardized in the principal iron and steel manufacturing countries of the world and it may be assumed that most installations are provided with the equipment mentioned above.

Iron-ore mining and preparation

In the United Kingdom, the local iron ore deposits are usually of very variable composition and of low iron content, and careful blending of the ore extracted from the working faces of the mine or quarry is necessary to secure a uniform burden. This is commonly done by ore-bedding installations, but one company is using a digital computer to work out an optimum programme of digging ore in open-cast mines so that a specified quantity and blend of feed material is achieved from sites giving varying ore analysis.[6] In modern plants the transportation of ore and coke from stock-yards to crushers and hoppers is fully mechanized by conveyor belts which are centrally controlled. Coke and ore are dispensed from a row of bunkers on to conveyor belts to give the sinter mix. The proportioning of the mixed constituents is controlled by gates, feeder tables and regulating belt feeders. The degree of control varies from works to works. In the most advanced cases the rate of flow of individual mixed components is maintained at a pre-set level by individual regulating belt feeders and provision is also made to alter the total feed rate whilst maintaining the proportion of each constituent unchanged. In other works, only the total ore, coke and limestone are automatically controlled. The proportion of returned fines added, i.e. the circulating load is automatically controlled at some works. The material feed rates are commonly measured using belt weighers. At most works the primary processing conditions at the sinter strand are measured and recorded. These include material feed rates, water addition, wind-box suctions, strand speeds, hood temperatures and sinter quantity. The flow rates and pressures of the fuel and air for combustion are measured and automatically controlled at pre-set levels which are set manually.

In Belgium, there has been a considerable amount of research done on the automatic control of sinter plants aided by financial support from the European Coal and Steel Community. The application of X-ray fluorescence to the analysis and control of the raw materials has been studied.[6a] The use of electrical conductivity measurements to control the humidity of the sinter mix has been studied.[6b] The use of a flame front measurement to control sinter plants has also been described in the literature from that country. The British Iron and Steel Research Association is working on continuous monitoring of iron ore and sinter composition.

The contributions from France, Italy and Yugoslavia refer to the measurement of temperature and analysis of gas at ore preparation and sinter plants. Regulation of the strand speed, permeability and moisture content of the mixture is the subject of continuing research. International literature contains some references to devices which aid the application of automation to sintering plants. There have been a number of references to raw materials control. Apparatus for the determination of the humidity content of sinter mix has been described in a West German paper.[7] An American firm has described how a digital computer can control process data including instantaneous X-ray analysis of raw materials and of the final product.[8] An electronic method of belt weighing for blending by weight has been developed by a United Kingdom firm.[9] Papers from the USSR have described an electronic metal detector for removing metal from material on its way to the crushers,[10] automatic control of strand speed based on the temperature difference between the two last windboxes[11] means for controlling sinter quality by magneto-metric estimation of the ferrous oxide content of sinter[12] and control of return fines temperature.[13] The Ukrainian SSR reports that the introduction of automatic proportioning systems leads to a greater uniformity of the sinter produced and, consequently, to an increase in blast-furnace output by 1 to 2 per cent.

<u>Blast-furnace plants</u>

A considerable amount of information on the automation of blast-furnace plants has come forward in the national reports. These are referred to in the following paragraphs dealing with the different aspects of blast-furnace operation.

Automatic charging is referred to by several countries, notably the USSR, France, Western Germany and the United Kingdom. A report from the Government of France has provided a description of the automatic charging system applied to the blast-furnaces at the works of USINOR at Dunkirk. These furnaces are belt charged. A computer stores the charging programme, which is adjusted according to information of the basic characteristics of the plant and of the charge materials which is fed into the computer. Material is withdrawn from each storage bin according to the control exercised by the computer, and information on the materials charged and time of charging is printed out. By this method a single operator in the control room is provided with a continuous picture of the position at any part of the installation, and the actual charging point at the top of the furnace is visible on a television screen. A similar installation is provided at the USINOR plant at Louvroil.(14)

At new furnaces in Italy and in the United Kingdom, coke and sinter are automatically dispensed by belt weighers and hoppers into charging skips, according to desired quantities and a charging sequence which is manually pre-set. Addition of ore and other ingredients is made via the scale car to the skip and is under manual control. The whole sequence of charging operations is automatic, i.e. sending up and tipping the skips and the complete operations of the bells, including rotating the small bell to produce a definite stock distribution and dumping of both small and larger bells. The quantities of materials charged are often recorded automatically. It is reported from Turkey that there is a blast-furnace in Karabuk which has automatic charging and stove-changing together with automatic regulation of the air and humidity admitted to the furnace and automatic regulation of the temperature at the top of the stoves. The new blast-furnace plant in the United Kingdom i.e. that of Spencer Works of Richard Thomas & Baldwins Limited, includes devices for presetting the various weights of material charged to the blast-furnace scale car. At this works, blast-furnace slag sold for processing is automatically weighed and the weights automatically recorded.(15)

Experiments are going on at the Royal Dutch Blast Furnaces and Steelworks at Ijmuiden to measure a mass of information which will be fed into a data logger and computer. The objectives are control of the burden, control of the heat balance, and control of the gas distribution in shaft and hearth. It is hoped to discover eventually what is the minimum amount of essential data which need be displayed to the operators. Some interesting measurements will be attempted, viz. moisture content of the coke by neutron bombardment, dust content of the top gas by an optical measurement, top gas analysis by gas chromatography and tuyere temperature by a two-colour pyrometer.

The Federal Republic of Germany has drawn the attention of the Steel Committee to an article by W. Liesegang in Stahl und Eisen.(16) This sets out the advantages of automation of blast-furnace plants in terms of decreased raw material inputs.

In Czechoslovakia, devices for measuring the volume and the pressure of the blast at each tuyere have been developed. An automatic blast-heater regulating system has also been reported on. Great importance is being attached to research on the mathematical description of blast-furnace processes. A measurement centre, capable of measuring fifty parameters, has already been developed, and work is now in progress on a monitoring system for about 500 technical parameters in the blast-furnace process.

The Government of Romania provided a brief description of a compressed air drive system for operating the furnace bells, claimed to give easy maintenance, and to facilitate the operation of the automatic charging system, at the Resita and Hunedoara Works.

Blast-furnace production automation in the Ukrainian SSR is proceeding along three main lines, as follows: (a) automatic control of smelting; (b) automation of auxiliary processes and operations; (c) automation of operations involved in switchboard control of blast-furnace production.

In the Dzerzhinsky works, a SM-2 computer has been installed to control the smelting process in accordance with a pre-set programme. The installation of an automatic casting system at the same works has resulted in an increase by 10 per cent in the casting output. Work is in progress on the development of an automatic system for regulating the distribution of air and natural gas to the tuyeres. At the Kommunarsk works an automatic blast distribution system has already been introduced.

Various systems for the automatic switchboard control of blast-furnace and auxiliary operations are being or have already been developed, e.g. at the Dzershinsky and the Asovstal works.

The USSR states that 80 per cent of all furnaces are automatically charged according to signals given by the stockline recorder.

It has been reported that an automatic blast distribution system, operated entirely by pneumatic equipment and ensuring uniform blast distribution to the tuyeres, is in use in a number of blast-furnaces in this country. The main circuit of this automatic system consists of three parts: (a) individual circuits for automatic regulation of the blast to each tuyere; (b) a unit in which the master setting for individual regulators is determined; (c) a circuit which ensures the optimum operation of the entire regulating system. The choice has been made for fully pneumatic equipment, since experience has shown that such equipment is considerably more reliable under blast-furnace operating conditions (intensive dust formation, high temperature, etc.) than electro-mechanical equipment. The use of the above-mentioned system has resulted in an increase by about 2 per cent in blast-furnace output and in a reduction by 1 per cent of specific coke consumption.

In a note from the USSR account has been given of the use of radio-active elements and radiometric probes in blast-furnaces as aids to automation. The URMS-2 device, for instance, is used in several plants for contactless continuous measuring and recording of the charge level. It is suitable for positional, proportional or isodromic regulation of the charge level and may be used as an aid to automatic charging. Its tracing speed is 3m/min, measurement range 5m, with a margin of error of ±5 cm.

The complexity of the problem of automating blast-furnaces is illustrated in a recent article from a research worker at the Tiflis research institute for automation which outlines a comprehensive scheme.[17]

The Government of Romania outlined a system of pneumatic control of the bell operation and emphasized the advantages of this system in facilitating a rapid-operating link for programme-control of charging.

In the United States, the new blast-furnace of the Armco Steel Corporation at Ashland, Kentucky, which will have an ultimate capacity of 3,700 tons a day is charged automatically by a preset programme, and operations are recorded by a comprehensive data logging system. The bell is automatically prevented from operating if the stockline recorder indicates a full furnace.[18] A new blast-furnace at the Duquesne Works of US Steel Corporation will be controlled by punched paper tape. At the Gary Works of the same Corporation the required charge as determined from metallurgical calculations is set up on punched cards which feed instruction to the stockhouse.[19]

Automatic control of blast temperature is commonplace and some works use automatic control of blast humidity. In Italy and in the United Kingdom the gas flow and air-to-gas ratio to stoves are automatically controlled at preset levels until maximum dome temperature is reached, when the ratio is automatically adjusted to maintain maximum dome temperature. Stove changing from gas to air is often mechanized, but the changing operation is usually still initiated manually. In the USSR, however, there are many automated installations and according to the report from Yugoslavia, some stoves are automatically reversed in that country also. Fully automatic stove operation is also practised in Japan.

There is growing awareness of the advantages of constant humidity control, and automatic control of this is to be found in the Federal Republic of Germany, Italy, the United States, the United Kingdom and the USSR.

It is probable that the use of high top pressure has made the most progress in the USSR and there are many installations of automatic control of this. The USSR report also refers to experimental automatic control of many operating variables such as gas distribution, zone temperatures based on thermal conductivity and top gas composition based on infra-red analysis.

There is growing interest in the control of the distribution of blast to each tuyere. This is of particular importance in relation to the modern practice of adding hydro-carbon fuels at the tuyeres. There are installations of blast distribution control in the Federal Republic of Germany, the United States, the USSR and France. Computers have been frequently used to calculate the effect of changes in operating conditions on performance.

Two countries (Italy and Yugoslavia) report automatic control of electrodes in the Tysland Hole type of electric reduction furnace much used in countries where hydro-electric power is available.

According to a team from the United Kingdom which visited Japan in March 1963 automatic control of sintering plants and blast-furnaces is well advanced in Japan. However, few details of the installations are available. The team noted particularly a continuous moisture recording device for the sinter mix at the Hirohata works of the Fuji Iron & Steel Company Limited. This uses the moderating effect of moisture on fast neutrons as a measure of the moisture content. A number of sinter plants are provided with automatic speed control. Although there is, as yet, no true "on-line" automatic control of blast-furnace operation in Japan, comprehensive data logging systems are widely used, and the information analysed by computer. This technique is perhaps most fully exercised at the Mitsue Works of Nippon Kokan K.K. where the computer calculates the charge composition and operating conditions.

As regards casting machines, automatic control of the ladle tilt to regulate the filling of the moulds of a pig-casting machine has been developed in the USSR.(20)

A general paper on automation applied to agglomeration plants and blast furnaces was given at a Paris conference in April 1963.(21)

CHAPTER IV

STEEL-MAKING

Open-hearth furnaces

Automation of parts of these furnaces has been commonplace for many years. In the later 1930s many furnaces in Europe were equipped with automatic pressure control of the fuel gas and automatic adjustment of the chimney damper according to the pressure in the furnace working chamber. Some furnaces in the United States were equipped with automatic reversal. Attempts had been made to control fuel gas flow according to the roof temperature but the control systems available at that time were not advanced enough to avoid troubles with "hunting" or violent oscillation of the fuel flow. Since the war, rapid progress has been made, and the more notable developments mentioned in the information received from Governments and in the published literature, are given below. It is clear that the open-hearth furnace process is already subject to a high degree of automation in many parts of the world. Unfortunately there is little reliable information on the economic advantages of such automation. Automatic control of air/fuel ratio and of chimney draught eliminate heat losses caused by excess air entering the furnace. Automatic control of roof temperature at the highest permissible level ensures that the rate of working of the furnace is kept high. But in practice the installation of automatic controls has usually taken place at the same time as rebuilding and modernization of the melting shop generally, and it is not possible to separate the effect of automation alone from the effect of other improvements.

Italy

In several Italian works air/fuel ratio is controlled according to the oxygen content of the waste gases. Steel bath temperatures, chequer temperatures and frequently waste gas composition are measured and recorded. Furnace reversal is commonly automatically carried out on a time cycle or manually initiated. The refinement of automatic control of combustion from measurement of oxygen in waste gas is under development. Direct reading spectrographs are commonly used for steel and slag analysis, so giving the quick results necessary for better control of the melt. Oxygen lancing is now commonly employed. This speeds up the process and provides another control parameter on both carbon content and temperature so that tapping times can be held to a tighter schedule. The main scope for improvement is thus now in over-all control of operations to provide a steadier flow of steel to the casting bay at the correct temperature without having to hold furnaces back or drive some too hard. This requires improvement in scrap and hot metal delivery and charging practice and more centralized control of melting shop and casting pit operations. These matters are the subject of research and development at many steel plants.

Instruments analysing oxygen in waste gases have been installed in the six furnaces of the open-hearth steel works "Oscar Sinigaglia" of Italsider. By using these instruments, tests can be done in 15 to 20 seconds and the percentage of oxygen can be maintained at a set value. The economic gains from this installation are referred to in chapter VIII.

<u>Turkey</u>

Recently constructed open-hearth furnaces in Turkey are equipped with automatic recording and control of: change of gas, pressure in the furnace, air fuel ratio, gas pressure, fuel and air temperature, chimney draught, roof temperature, measurement of oxygen in waste gas.

Some recent improvements have led to a reduction of furnace time, longer life and higher yield of furnaces and resulted in savings of labour, material and fuel. The improvements reported are: (a) use of combustion controlling system; (b) control and regulation of fuel, air and temperature through an "Askania" type control system; (c) use of mixers; (d) use of a dolomite throwing machine.

<u>Ukrainian SSR</u>

Automatic control of temperature conditions of open-hearth furnaces have been widely introduced. Some of the control systems used for this purpose at the Dzerzhinsky and Krivorozhstal works include devices for the automatic adjustment of fuel combustion according to the oxygen content of the waste products of combustion. Experience shows that the duration of heats can be reduced by 3 to 4 per cent and the specific fuel consumption by 4 to 5 per cent.

Further progress is being made on automatic operational and organizational control of the whole open-hearth shop by means of computers. Calculations show that the expenditure on equipping a modern open-hearth shop with such a centralised control system can be recovered in six months.

USSR

According to the information from the USSR, all open-hearth furnaces in that country are equipped completely or partly for measuring and recording fuel input, pressure and temperature at the roof of the working chamber, regenerator, flue, and liquid steel temperature (the latter by immersion thermocouple). There is also continuous recording of the oxygen content of flue gases. Automatic controls are provided for maintaining the desired pressure of fuel gases and of oxygen, the desired fuel/air ratio, and the desired furnace pressure. There is also automatic reversal based on time, or temperature difference, or a combination of both.

The availability of these automatic controls makes it possible to provide the operators of the furnace with detailed schedules of furnace conditions to be maintained during each stage of working the furnace charge.

The report from the USSR also mentions as future aims the automatic control of operations, such as weighing the slag-forming material and ferro-alloys, weighing the slag and metal at tapping, control of the tapping operation, and mechanization of sampling procedure, as well as many operational factors.

Papers from the USSR report how automation has improved roof life[22] and productivity.[23]

United Kingdom

Since the war, rapid progress had been made. Open-hearth furnaces are now usually well equipped with instrumentation and automatic control of the main furnace variables, i.e. control of fuel input according to roof temperature (which may be measured in several places) and control of air/fuel and steam/oil ratio.

Technical details of some of the control systems used in open-hearth furnaces have been summarized recently.[24] Computers are now frequently used to analyse ordinary production data from open-hearths; the results of one such study have been published.[25][26] The use of a computer to plan the production of a cold metal open-hearth melting shop has been described.[27]

Other countries

Although similar examples of open-hearth furnace automation receive only brief mention in the contributions from other countries it is known that such methods of control are widespread, in both Europe and the United States. Thus, although no specific information on the automation of open-hearth furnaces has been provided by the United States, many furnaces in that country are very fully automated; in past years published United States literature contains many references to the subject.

In many countries interest in steelmaking plant has shifted from the open-hearth furnace to the newer oxygen processes, where, owing to their speed of operation, automation will play an important part.

Oxygen converters

Requirements for improved charging practice and centralized control are even more vital in the case of converter steelmaking processes. Their speed of working is such that process time is little longer than the time required for fettling and charging. The absence of a fuel in this process, other than the hot-metal constituents removes a vlauable control parameter from the process, so that if time and iron are not to be wasted in after-blows, there must be close control of the quantities of hot metal and scrap charged and also accurate knowledge of the composition of each. However, because of the relatively short period for which oxygen steelmaking has been in wide use, information on the application of automatic control has been rather limited; what has been made available is summarized below:

ECSC Countries

In the Federal Republic of Germany a method of continuous measurement of bath temperature in converters of the LD type has been developed.[28] A ceramic tube containing a thermocouple is inserted through the converter wall. The French steel research institute (IRSID) has given details of a technique for continuously measuring the CO and CO_2 in the waste gases from a converter and for using this data to compute the rate of decarburization of the bath.[29] Both of these developments are likely to prove valuable in providing information on which computer control of LD converters could be based. An analog computer is used to calculate the charge weight at the LD converter shop at the Royal Dutch Steel Works, Ijmuiden; a data logger collects operating information.[30]

Japan

The use of data logging in LD converter process is not yet so developed as in ironmaking. The most promising advances seem to be the end-point analog computer installed at Hirohata Works (Fuji) and the oxygen and raw material control computer at Kawasaki Works (Nippon Kokan).[31] This latter is an on-line computer, getting some of its inputs directly from automatic sensing and measuring devices. The system's loop is partially closed - the computer automatically actuates oxygen flow control valves and hopper outlets for raw materials. Nine mathematical models are stored in the computer for a variety of steels, including alloys.[32]

Ukrainian SSR

Automatic control systems are being used on an experimental basis at the Krivorzhstal steel works for the automatic tilting of the converters to maintain a given carbon content, for the measurement of the temperature of steel in the converter, and for the switchboard control of converter steel production.

USSR

Oxygen-blown converters now in operation are equipped with BRU or REG automatic regulators for the instantaneous rate of flow of oxygen, basing on the measurement of a number of parameters. In the next few years, most of the new converter shops will be constructed to a standard design, with three 100-130 ton converters and an annual production of 2.1 - 2.2 million tons. Such plants require a further progress of automation, and a recent paper outlines a scheme for the complete automation of an LD plant.[33]

United Kingdom

The new LD-AC plant at John Lysaght's Scunthorpe Works is highly automated. The KDN 2 computer calculates for each cast the optimum weight of hot metal, scrap, refining additions, and quantity of oxygen necessary to meet the required steel specification and temperature, thus enabling the operator to make the ultimate decisions needed.[34]

United States of America

Information published in the United States in 1962 suggested that an interesting automation system would be applied to the Kaldo converters being installed at the Roemer works of the Sharon Steel Corporation, Farrell, Pennsylvania, planned to start late in that year.[35]. The computer controls two, 150 ton Stora-Kaldo furnaces with an annual capacity of about 1 million ingot tons. Virtually every significant steelmaking variable, beginning with order requirements and raw materials and ending with the ingot is to be controlled by the system to give optimum operation, and control of the materials entering the converter is very important. The Jones and Laughlin Steel Corporation uses an analog computer to calculate the proportions of raw materials which must be charged to LD converters to tap a particular type of steel at a specified temperature.[36] The Great Lakes Steel Corporation was reported to be installing full computer control of its new LD installation with 275 ton vessels,[37] but no news of progress has been published. Proposals for a more advanced control system for the converters at this works based on continuous measurement of the CO and CO_2 content of the waste gases have been made[38] and the technique of gas analysis proposed has been published.[39]

Bottom-blown converters

A method of recording and integrating the total flow of blast to a bottom-blown converter has been developed in France.[40] Computers are used to control the Thomas process in Belgium[41] and the Federal Republic of Germany.[42] There are only brief references to automatic control of such converters in the reports from countries, mostly referring to items mentioned in the foregoing paragraphs. The USSR refers to the control of converter operations according to measurements made on the flame, a method which is also used in Belgium and France.

Other computer systems to control oxygen-converter processes have also been designed, e.g. a computer called "Oscar" by AEI Automation[43] and another called "Prodac" by Westinghouse Electric Corp.[44] It is generally admitted that the advantages offered by oxygen steelmaking cannot be fully exploited without computer control. According to an American estimate, producers who control an oxygen converter with a digital computer stand to save more than 1 million dollars a year.[45]

Steelmaking - electric arc furnaces

The most important item of automatic control, without which it would be difficult - if not impossible - to operate an arc furnace with any degree of efficiency is automatic control of electrode position. Improved methods of control, giving more rapid response and greater sensitivity of control, have been introduced. These lead to better electrical conditions and to fewer electrode breakages. The report from the United Kingdom mentions equipment for automatically programming the power input to the arc, so that the maximum proportion of the heat generated is usefully absorbed in the charge. This has recently been installed for trials on a number of production furnaces.[46] As a result of the improvements shown in power and electrode consumption per ton and in refractory life this method of control will be more widely used. A few large arc furnaces have been equipped with thermocouples in the hearth bottom from which isothermal diagrams can be drawn. These records enable melters to keep the furnace bottom in good repair.

A Ferranti Argus 108 computer will control the power input to six 40 MVA electric arc furnaces at the world's largest electric melting plant at the works of Steel, Peech & Tozer in Rotherham, United Kingdom. The computer plan is to control the power input to furnaces adjusted to both a production programme and availability of power. It is also to log continuously the process variables, thus enabling analysis to be carried out at a later date. The installation of this system also helps to meet the obligation of the plant to shed up to 25 megawatts of load on demand and after only five minutes' notice.[47]

The report from the USSR mentions the various items of automation equipment which should be found associated with electric furnaces and which are used in that country. In addition to electrode position control, various devices for minimizing electrical losses by better control of the electrical system are being brought into use. There are improved mechanized methods for changing electrodes. Mention is made of an automatic immersion thermocouple which periodically measures liquid steel temperatures.

Several countries report the use of thermocouples to measure refractory wear. Also electromagnetic stirring of the bath is widely used; it is not stated whether this is put into operation automatically (e.g. according to measurements of bath conditions) in any plant, but such a method of operation can be visualized.

An interesting example of automation applied to ingot mould preparation is found at the new Tinsley Park works of the English Steel Corporation in the United Kingdom. Steel, melted in big electric-arc furnaces, is fed directly to the rolling-mills in ingot sizes of 2.5 tons to 5 tons. A unique system has been developed for the automatic shot-blasting of hot ingot moulds. The ingot moulds pass automatically on motorized trolleys, which run on a continuous circuit, through the various stages. Once placed on a trolley, the mould is handled automatically. The various moulds stop automatically at the appointed cleaning station and selecte the correct shot-blasting cycle. The speed of the rotary blast head is controlled by an electronic speed selection gear, which in turn is equipped with a time clock to regulate the dwell period. The system is also equipped with a special air-cooling device for the handling of moulds at high temperatures.[48]

CHAPTER V

ROLLING OF SEMI-FINISHED STEEL, PLATES AND SECTIONS

Soaking pits and reheating furnaces

All modern soaking pits are well equipped for measurements of temperature, fuel and air flows. Considerable advantages have been found to arise from control of the chimney draught automatically linked to the pressure in the heating chamber. This leads to saving in fuel and reduced scaling losses. The latter is not always 100 per cent advantageous as sometimes scaling losses help to remove surface defects in the ingot. Fully automated soaking pits with equipment along the above lines are to be found in several countries, and are specifically mentioned in reports from Denmark and Czechoslovakia. In the United Kingdom an on-line computer has been ordered to control operation of the soaking pits at the works of Samuel Fox and Company Limited, near Sheffield.(49) A speeding up of heating rate by 15 per cent and a fuel saving of 12 per cent following automation have been reported in a paper from the USSR.(50)

Similar forms of control are to be found in slab and bloom heating furnaces for plate, sheet, and section mills, with the additional controls needed by the fact that these furnaces are generally divided into temperature zones. Automation of such furnaces is mentioned specially by Yugoslavia. It is intended to install on-line computer control of slab reheating furnaces at two major works in the United Kingdom.

Apart from the above, there is little mention of this part of the iron and steel-making process in the national reports. Italy mentions the items described above, and the Federal Republic of Germany refers to study of programme control of the fuel supply to reheating furnaces for heavy forging ingots. Since heating costs are a major part of forging costs and temperature control is important to avoid cracked ingots, this latter example of automation would seem to have important advantages.

Primary mills

In at least two works in the United Kingdom and in one in Italy the buggies transporting ingots from the soaking pit area to the primary mill delivery table are equipped with remote position control so that the buggy can be accurately positioned at a station which is well out of sight of the operator. The positioning accuracy achieved is approximately 0.6 m in 300 m of travel.

A simple form of automation of the roll screwdown movement in primary mills is being used extensively in many countries. The basic principle is that the appropriate signals to the screwdown motors are stored either on punched cards or tape, or on a plug board, separate programmes being constructed for different kinds of steel, ingot size, bloom or slab size, and so on. The Czechoslovakian Government reports that such systems, using punched cards, are in use in blooming mills in that country.

The use of magnetic tape in conjunction with electronic computers to derive performance, energies, rotational speed functions and efficiencies has been described following investigations on blooming/slabbing mills in the Federal Republic of Germany.(51) This technique should help in the study of rolling-mill procedure and enable automatic control to be designed for optimum rolling conditions. A series of papers on the designs of programmed blooming and slabbing mills in the Federal Republic of Germany was published in 1963.(52)

France reports that for screwdown in a primary mill a static programmer is used which carries out the desired programmes with the aid of a ten-position switch unit. The decimal display system applied facilitates greatly the operations. The operator selects one of the ten available programmes. The dimensions can vary from 0 to 999 mm. The "next dimension" of any forthcoming pass is written on the operator's board in numerals and lights indicate when a pass is over. If necessary, the operator can omit some passes and he can also make corrections of 1 to 2 mm if calibration is slightly defective. The elements of the main circuits of the system are continuously verified by four automatic control devices. The results are an increase in the rate of production and in the uniformity of products, a decreased burden on the operator and the possibility of perfect reproduction of programmes.

Italy has provided information on the punched card control of a primary stand at the hot-strip mill at the Cornigliano Works of Italsider.

A detailed description of a programmed installation has been reported from Sweden referring to the slabbing mill at Surahammars Bruks A.B. For each combination of steel analysis, ingot size, and slab dimension, the optimum rolling programme is calculated and programmed on a punched card. The card is fed into a computer which sets the spacing of both the main rolls and the edging rolls. The computer also controls the speed ratio between the edger, the two-high mill and the roller tables. A similar type of installation is to be installed at Taranto in Italy.

The Government of the Ukrainian SSR reports that over the period 1960-1963 contactless control was introduced for the main electric drives and for the drives of the principal mechanisms of the 900 reversing mill and the 1,150 blooming mill at the Dzerzhinsky works. These control systems have considerably improved performance and increased reliability. Mill output has risen by 2.5 to 5 per cent. Digital systems have been introduced for programmed automatic control of screwdown.

There are numerous programmed primary mills in the United States, e.g. the slabbing mill at the Inland Steel Co., near Chicago.(53) At the Armco plant in Houston, a 160 in. slab and plate mill's operations are completely controlled by a Westinghouse computer. Conversion from slab to plate can be made within less than one hour.(54)

At the Steel Company of Wales Limited in the United Kingdom, the width of steel slabs will be measured by light beams registering in a telescope the angle of which is used as a measurement of the slab width.(55) At the new works of the Park Gate Iron and Steel Company Limited near Sheffield, the rolling programme at the blooming mill is selected by computer in accordance with ingot weight and the required bloom size.(56)

Billet and structural mills

Available information comes mainly from the USSR, the United Kingdom, and the United States.

The USSR Government reports that at the Magnitogorsk integrated steel works there is a continuous billet mill, with a 630 mm set of stands followed by a 450 mm set of stands. Length of piece coming from the 630 mm stands varies between 45 and 60 m; length of piece coming from the 450 stands may vary up to 30 per cent below the maximum length of 350 m. For efficient shearing of billets an automatic method with optimum programming is applied. Before the application of this system wastage only in the form of trimmings and uneven lengths was at an average 2-2.5 per cent of total rolled. With the application of the Stal I special computer this wastage has been reduced by about 87-92 per cent.

The principle of the operation of the system is to shear the optimum number of billets of a strip of a given length, manoeuvring within the tolerated limits set for the length of one billet. For a single piece, the machine works out a shearing programme in 0.5 to 0.7 seconds. The machine - consisting of the computer element, feeder, control panel, punch, switchboard and instrument panel - works without human intervention.

In the United Kingdom, the reversing billet mill at the Hallside works of Colvilles Ltd in Scotland is operated by a punched card system in which the complete sequence of screwdown, manipulator, mill speed settings and number of passes is stored.[57] Several works use a computer to calculate the optimum shearing of the complete billet length into the ordered lengths so as to minimise scrap; an example is the computer installed at Samuel Fox & Company Ltd., Sheffield.[58] A particularly interesting installation is the new continuous billet mill at the Scunthorpe works of Richard Thomas and Baldwins Ltd.[59] Flexibility in production planning to meet the market needs required that changes in rolling programmes should be made in two minutes. The mill has complete programme setting equipment to allow a programme to be pre-set during rolling and the change initiated by push-button. The flying shear has a length-setting control which eliminates trial cutting. An optimum yield computer makes use of this and of cut length tolerance to set the cut length to give minimum scrap from each piece rolled. Continuous inspection lines with automatic classifiers are used to inspect and sort out billets in the minimum space. The control systems of all the drives and the operation of the optimum yield computer and the classifiers are described. Operational performance is compared with the design figures.

A much more comprehensive information handling system is on order for a works which will provide for the collection and automatic co-ordination of all the relevant production information in a billet and section mill and includes automatic actuation of the displays which give instructions to the operators at each processing station. The process information and the instructions to operators are carried forward from station to station on punched tape, the information on the tape being automatically displayed at each station with the additional information from that station added to it. The initial tape containing order number, cast number, ingot serial number and processing instructions, is prepared automatically from a punched card and the total information collected on the tape at the end of the process is automatically converted on to punched cards and printed out. Print-out of data at some intermediate positions is also provided. The system provides for twenty stations for collection of information from the line and about the same number of points of automatic display of instructions. The total number of digits handled is over 300, covering over 100 items. Six page prints are furnished and the final one, summarizing all the commands and subsequently recorded information, comprises fifty-five digits spread over twenty-three items.

There is punched card control of the structural mill at the South Chicago works of the United States Steel Corporation.[60] Preselected data stored on cards control and sequence forty-three operations; as many as twenty-one passes through the five stands can be programmed. The new structural mills built in the United Kingdom are provided with means for presetting the rolling screwdown programme, e.g. in the structural mill at the Lackenby works of Dorman Long and Co. Ltd. this is done on a slider board[61] and at the Lanarkshire Steel Co's works the entire rolling is controlled by one push-button.[62] Remote position control is also being used to position saw stops on the cut-up tables at the end of section mills. On the United Kingdom wide-flange beam mill mentioned above, the saw stops are positioned from push button settings, giving an accuracy of 6 mm over a total length of 20 m.

There is a similar push-button control system at the universal beam mill of the Fuji Iron and Steel Company's Hirohata works, Japan.

Plate mills

The report from Sweden describes how the scheduling of plate manufacture at Oxelosunds Jarnverk is carried out by computer. The plate mill consists of the following main equipment:

(a) soaking pits
(b) 42-in. two-high mill for rolling slabs of maximum 1,500 mm width from maximum 22 ton ingot
(c) slab reheating furnace of a heating capacity of 100 t/h
(d) reversing four-high finishing mill, 920/1,550 mm ø roll length 3,650 mm
(e) cooling beds
(f) continuous shearing line.

The planning carried out by computer includes for the moment only prescheduling. At a later stage any necessary rescheduling of ingots, slabs and plates for other orders will also be undertaken by means of computer.

The prescheduling includes the following steps:

(a) Incoming customer orders are punched on paper tapes. The tapes are fed into an electronic computer on which the information is stored on magnetic tapes with a capacity of ca 60,000 order positions corresponding roughly to one year's production;
(b) The computer calculates extras according to alternative price lists;

(c) The order forms completed with quality code number and current numbers for identification are stored on magnetic tapes in the computer forming a "production order register". The same information as given in the order tapes is punched on a paper tape and is also written in clear writing by means of a telex machine;

(d) The production order register is completed with data about delivery time, thus forming an "operation register" which is also stored on magnetic tapes in the computer;

(e) The computer then starts the detail scheduling :

(i) The individual plates specified by the customers are combined to slabs of optimum size and a "slab register", stored in the computer, is thus built up;

(ii) From the slab register usable slabs in store are sorted out;

(iii) The remaining slabs of the register are combined to ingots of which four standard sizes are used. An "ingot register" is thus formed and stored in the computer;

(iv) The rolling sequence of the ingots within the rolling cycle (determined by the intervals between the necessary change of work rolls) is scheduled;

(v) Ingots from store are also scheduled into the rolling sequence;

(vi) Ingots that are planned to be taken from the store are sorted out from the ingots register;

(vii) Remaining ingots are combined to melts forming a "melt register" stored in the computer. In connexion with the ingot scheduling, the testing of the material is also scheduled according to the specification of the classifying societies concerned;

(viii) The melt register is punched on cards. These can be sorted according to different needs or wishes - e.g. according to plate dimensions, steel quality and so on. The information on the cards is written in clear writing on lists, constituting the programme for the melting shop and rolling-mills respectively. These melt lists contain information for which specification plates and melt are intended. If something goes wrong in the melting plant or in the rolling-mills the necessary adjustments in the melting and rolling programme can be done. The whole scheduling process, as described, can be performed twice a week, which corresponds to the expected maximum number of rolling cycles in the same time.

Regarding rescheduling, the company plans to have several stations for registering the errors at suitable points in the production process. By means of teleprinters at these points information is transferred to the computer about in which respect the product differs from the aimed standard e.g. analysis and weight differences, type and location of surface and rolling errors. The computer gives information about the most suitable (economic) purpose for which the "defect" material (a melt, an ingot, a slab or a rolled plate) ought to be used and also starts scheduling the production of substituting material.

With automation the company is aiming to obtain the following advantages:

(a) Higher yield both as a result of pre-scheduling and also to a still high extent of the future rescheduling;

(b) Higher output of the rolling mills resulting from optimum ingot and slab weights. The number of necessary slabs for a given production on a tonnage basis is calculated to decrease by some 20 per cent;

(c) Lower costs for material handling throughout the whole production process as a consequence of bigger sizes of ingots and slabs.

As the company has used a scheduling system including computers practically from the start of rolling operation in the newly built Oxelosunds plant, it is not possible to make any technical and economic comparisons with a manual system. The investment cost is about 500,000 US dollars. Only standard apparatus has been used.

In the United Kingdom, BISRA is at present designing a computer control system for a plate mill in which measurement in the early passes will give information on the hardness of the piece so that the computer can control the programme for the rest of the rolling operations. This should improve dimensions and increase yield. This work is part of a large project aimed at complete automation of a plate mill. Consideration is also being given to the use of a computer for calculating the best shearing programme to produce ordered sizes from the plate as rolled. The new universal plate mill at the Middlesbrough works of Dorman Long and Co. Ltd. will have full on-line computer control.[63]

In the United States, a computer-controlled plate mill at Lukens[64] has completely automatic sequencing of mill operations during rolling and the intermediate screwdown settings, calculated from the dimensions of the slab and finished plate, are set automatically during rolling. A computer-controlled plate mill to be installed at the Gary works of US Steel Corporation has also been described in the literature.[65] The plate mill at the Gadsden works of Republic Steel Corporation has completely automatic operation under punched-card programme control.[66] The plate mill at the Sparrows Point works of Bethlehem Steel Company has automatic screwdown under punched card programme control and an automatic control system to ensure maximum utilization of the main motor.[67]

At the four-high plate mill of the Mont St-Martin works in France, automatic control devices for controlling edge thickness have been developed.[68]

Remote position control of screwdown in plate mills is mentioned in the report from Yugoslavia.

<u>Light section mills, bar mills and rod mills</u>

According to the report from the United Kingdom, mechanization is highly developed on modern high production rod and bar mills. As yet, little automatic feed-back control is applied in production, but automatic gauge control is under development. At present, photocells located at the mill initiate operation of flying shears to crop the front and rear end of the bar. Photoelectric cells also initiate the action of rotary shears to cut a bar into lengths after it leaves the bar mills, actuate guides to deflect the cut sections onto roller tables, and actuate devices to lift the bar onto a cooling table.

Examples of such modern mills in the United Kingdom are the light section mill at the Dalzell works of Colvilles Ltd.,[69] the bar mill at the Roundwood works of the Park Gate Iron and Steel Co. Ltd.,[70] and modern rod mills in Cardiff and Scunthorpe. The three-high bar mill at the Cleveland works of Dorman Long (Steel) Ltd. is controlled by programmes pre-set on a plug board.[71] An example on the Continent of Europe is the new mill at the works of Gebr. Bohler, Kapfenberg[72] and a modern wire-rod mill in the USSR has been described by M.L. Zaraschinskii.[73] Automatic operation and speed control of individual stands of hot narrow strip and bar mills is reported by Italy.

Some of these mills, as with the billet mills mentioned earlier, have computer control of the shearing to give maximum yield of sold product, i.e. minimum loss in short ends. For instance the section mill shearing at the Shelton Iron and Steel works in the United Kingdom is controlled by a KDN 2 computer. An automatic measuring stop for a hot saw has been developed in the United Kingdom.(75)

Some light sections are formed from strip and a computer can be used to calculate the optimum form to combine strength and lightness.

CHAPTER VI

WIDE-STRIP MILLS

Wide-strip mills

Probably the greatest advances on mill automation have been made with the wide-strip mills producing sheet for automobile bodies and the numerous kinds of light steel pressings required for industrial and domestic equipment. It is understandable that this should be so because for this product quality is particularly critical, and matters such as gauge uniformity, accurate speed control between the various stands, and control of strip temperature are important. One of the most important advances has been automatic gauge control by which any detected deviation from gauge is signalled back to either the screwdown or tensioning operation. This was first developed for cold mills by the British Iron and Steel Research Association some ten years ago, and rapidly taken up in the United States, where considerable progress has been made in developing it for hot mills. A considerable amount of information has been provided by Governments, and this is summarized below:

Austria

The Austrian Government has provided detailed information about the automatic gauge control system used at the Voest works.

Italy

The Government of Italy has provided very complete descriptions of the "Exatest" units used in that country to measure both thickness and width of strip. The principles are based on the use of X-rays for thickness, and of optical-cum-electronic methods for widths measurements.

An earlier report from Italy says that cold-rolling mills are provided with automatic gauge control actuated by signals from a B-ray thickness gauge, and can act on the speed of the last stand and on the screws of the first stand to regulate the tension between the stands and therefore the strip thickness. Automatic control devices are also used for tension control during strip uncoiling and recoiling. There is also automatic control of Sendzimir cold mills.

Japan

Information on the state of automation at the Japanese strip mills was reported by a team from the United Kingdom which visited Japan in April 1963.

As far as could be ascertained, no hot-strip mill was operating with full automatic gauge control but both Fuji Iron and Steel and Sumitomo Metal Industries were operating automatic control by speed on stand 6. Most of the strip mills were semi-continuous and considerable progress has been made in the application of punched-card or push-button programming of reversing roughers.

It was evident that the electrical manufacturers were sufficiently advanced with the collection of operating data to install automatic gauge control on new mills under construction. American-made controls were still highly favoured since it was felt that they had a significant lead in "know-how".

Data logging equipment had been installed at only one hot-strip mill - the 80 in. 6-stand mill of Sumitomo Metal Industries. Cold reduction mills were fitted mainly with conventional automatic gauge control systems. Closeness of control was comparable with current performances in the United Kingdom and the tail-end gauge problem was less severe only to the extent that Japanese hot-mill run-down was fairly satisfactory. The 5-stand cold-reduction mill at Chiba Works (Kawasaki Steel Corporation) had a British system of automatic gauge control which was being commissioned during the visit to the works. Altogether, eighteen installations of AGC were in operation in Japanese strip mills at the time of the visit.

Data logging appeared to have been installed only on the 6-stand mill at Yawata and the 4-stand mill at Amagasaki, though further work was going on prior to placing orders for other plants.

__Sweden__

Information from Sweden, received early in the course of the work of the group of experts, referred to the automation of the Steckel mills which are often used where the throughput required does not justify the use of a continuous multistand mill.

This describes the equipment installed at Surahammars Bruks A.B. The speed of the mill's main drive motors, as well as the speed of the heated coilers, the roller tables, and the end coiler are automatically co-ordinated. The tension of the strip during rolling is automatically controlled; starting and stopping of the strip at the different passes is also automatically controlled by a combination of photocells and air-operated units. The mill is equipped with automatic gauge control on the BISRA-Davy-United system working with constant holding of the distance between the work rolls. A continuous radiation automatic thickness gauge feeds back impulses for correcting the automatic gauge control. However, the reduction of the separate passes is regulated manually. Automatic co-ordination of the speed of rolls, coilers, and roller tables, as well as automatic control of strip tension, must be considered almost as a technical necessity. The thickness tolerances are much improved with automatic gauge control.

The report says that automation of the Steckel mill coupled with that of the slabbing mill of Surahammars Bruks, A.B. mentioned in chapter V has increased productivity by 25 per cent. Investment costs are about 200,000 US dollars.

A reversing cold mill for stainless steel sheets (width up to 1,250 mm) at the Avesta works is automatically controlled in the same way and with the same type of equipment as used in the hot mill at Surahammars.

Ukrainian SSR

The report from this Government mentions an automatic speed regulator for the finishing train at the Illich works. Speeds can be maintained within 1 per cent of the desired figure, thus improving gauge and simplifying the work of the operators. Automatic gauge control will be introduced at a number of strip mills during 1964. Research is in progress on the possibility of using a computer to control the finishing train and of developing an over-all automation system for the entire mill. On one reversing cold-rolling mill new automatic tension and speed regulator systems (using analog elements) and new automatic slow-down and reversing systems (using digital equipment) are now functioning operationally at one mill, where AGC will also be fitted. The introduction of these systems has increased mill output by 20 to 25 per cent and improved the regularity of strip gauge.

USSR

The report from the USSR mentions the need for more accurate measurement of strip thickness and points out that the contact, pneumatic, and induction micrometers formerly used are no longer good enough. The use of radioisotope devices which measure the thickness by absorption is recommended. Using beta and gamma ray absorption the ITU-495 and the ITSh-496 devices measure sheets of a thickness between 0.03-0.8 and 0.05-1.0, respectively, with a margin of error of $\pm$1.5 per cent of the thickness measured. For 0.4-3.0 mm cold sheets the IT-5250 is used with the same margin of error and a measuring time of 0.2 seconds. For the measurement of the thickness of tinning the ITP-476 is used for tinning of 0-5 microns, with a margin of error of + 0.1 micron. Checking with this device is rapid and accurate. Tin consumption is consequently reduced.

It is reported in the literature[76] that in a Leningrad steelworks automatic gauge control is applied to a four-high cold-rolling reversing mill. This measures strip thickness as the gap between the working rolls of the mill, using the stand itself as the micrometer in order to eliminate time lag in measurement. Correction of the system's errors are done through a system consisting of two flying micrometers, an electronic potentiometer, a pulse generator, and an amplifying integrating device.

United Kingdom

At least six single-stand reversing cold mills ranging in size from 9 in. to 48 in. width are operating with automatic gauge control. Most of these use the BISRA gaugemeter (a system in which gauge is computed from roll force and screw setting) to monitor gauge and initiate corrective action on the mill screws. Others use a flying micrometer or an electromagnetic micrometer to monitor gauge. At least four multi-stand tandem mills are working with an automatic gauge control system. The control systems differ in each case as they are still the subject of development work. The preferred arrangement appears to be to measure gauge at stand 1 using a gaugemeter at that stand or an X-ray gauge following it, and to use the signal to control the screws of stand 1. In addition, the gauge is measured after the last stand and this signal is used to control the tension between the last two stands. This interstand tension is automatically maintained within desired limits by control of the screws of the last or penultimate stand. Another system in use employs a sampling servo technique in which interstand tensions are automatically controlled at desired values by control of the screws of each following stand and the entry speed is automatically controlled according to the strip gauge leaving the following stand. The time delay through the mill is taken into account in the design of the sampling servo. On at least one reversing cold-strip mill a system of automatic reversal of the mill and its reelers at the end of each pass is in operation and has resulted in an increase of 10 per cent in the mill throughput over that achieved with manual control of reversal. The system is based on counting the turns on the reelers at each pass so that when uncoiling from one reeler a signal can be given to initiate deceleration of the mill automatically at just the right time to bring the mill to rest when there are still one or two laps on that reeler. The improvement in throughput compared with a human operator is due to the man's tendency to start slowing the mill too soon for each reversal. A description of the system used at one 5-stand mill in the United Kingdom has been published.[77]

The Steel Company of Wales has ordered a digital computer which will be connected directly to a 4-stand tandem mill which it will set up automatically. In addition it will supervise the automatic gauge control. The operator will feed in the values of gauge, width and quality of the strip, and the computer will calculate the required tensions and reductions at each stand.(78)

A start has also been made on the more difficult problem of hot-mill automation. The complete programme for the Spencer Works of Richard Thomas and Baldwins Ltd., referred to in chapter II, involves of course a considerable degree of hot-mill automation. The task of the hot-strip mill controller will be to carry out the final rolling programme prepared by the finishing-end scheduler itself prepared from reports from the ingot to slab controller. The hot-mill controller will report back the specifications of each coil produced, enabling the scheduler to take corrective action if any coil departs from specification. A recent report says that the automated crop shear at the finishing end of the mill has reduced cropping losses by about one half.(79)

The Steel Company of Wales Ltd. are also installing a computer to control their 80 in. hot-strip mill.

One of the most interesting developments in the United Kingdom is the production of a mechanical system of automatic gauge control (controlling roll gap) in a hot mill, instead of expensive electronic gear normally regarded as necessary. A brief description of this system was publicized recently.(80) Signals from an X-ray gauge at the exit end of the mill are fed into a mechanically operated static switching system occupying about one-seventh of the space required by the computer techniques. The direction of change of each roll gap is stored in the logic circuitry of the static switching, while the magnitude of change is stored in the movement of a differential unit which, after making the necessary adjustments to bring the strip to the correct gauge, automatically returns the roll gaps to their initial settings ready for the entry of the next slab. In doing so, account is taken of roll wear and other factors which normally need calculation. With the equipment, gauge is maintained within the limits of two thousandths of an inch either way, even in silicon steels.

<u>United States of America</u>

No information on the automation of wide-strip mills has been transmitted by the United States Government, no doubt because progress is well documented in the published literature. What is claimed to be the world's first computer controlled hot-strip mill has been operating at the Trenton, Michigan, works of the

McLouth Steel Corporation since November 1962.[81] Other American references to automated hot-strip mills are given at numbers (82) to (85) in the bibliography at the end of the report. One specific installation mentioned is the 1,120 mm semi-continuous hot-strip mill at the Aliquippa works near Pittsburgh where punched cards are used to control the screwdown and other mill controls.[86] The 80-in. hot-strip mill being built by the Bethlehem Steel Company in Indiana will be controlled by computer; this mill will have a number of original control features.[87] Many cold mills in the United States are fitted with automatic gauge control. Information on a data-logging system applied to a cold mill has been published,[88] also a description of an installation in Canada.[89]

It is not possible in this report to mention more than a very few of the numerous references to mill automation in the literature but, the series of papers given at the International Seminar on Automatic Control in the Iron and Steel Industry, held at Brussels in February, 1962, includes a number on mill automation.

Sheet and strip processing, coating and finishing

The report from the Austrian Government mentions two examples of automation in this field. Fully automatic control has been provided for a sheet-picking plant where twelve transporters move on a circular track on which they have to perform four prescribed movements - i.e., there are forty-eight commands. These are performed by means of a programme control which not only actuates the required movements but also provides for variable pickling times.

Another interesting development is an automatic sorter at a sheet shearing line which detects surface defects and errors in gauge, as well as performing automatic counting of sheets.

A report from Italy refers to measurement and control of temperature, electrolyte concentration, and current density in electrolytic cleaning and electrolytic plating. Automatic control and line speed, looping arrangements and tension on recoilers are found in continuous pickling and annealing.

According to the report from the United Kingdom, finishing processes such as electrolytic tinning lines, cleaning lines, and strip galvanizing lines, are generally well instrumented as regards the main process parameters such as furnace and treatment bath temperatures, line speeds and tensions, coil build-up, currents fed to electrolytic pickling, cleaning, plating and flow melting stages. Electroplating currents are automatically controlled according to line speed, strip width and desired coating weight. Flow melting current is also automatically controlled according to line speed, and photocells monitor the position on the strip at which melting of the tin coating occurs. Automatic on-line inspection devices are commonly installed to detect defects in tinplate such as off-guage (using B-ray gauges) and pin holes (using photoelectric techniques). X-ray fluorescence coating thickness gauges are coming into use. Single sheet classifiers are in operation which automatically deflect sheets into their appropriate stacks at the end of the line according to the signals from the pin hole and off-gauge detectors. These employ magnetic drum memory devices, although a more recent development is the use of a shift register for the purpose. Methods of in-line detection of tinplate surface defects are under development, using closed circuit television combined with optical stopping of the moving strip by stroboscopic techniques. On strip-galvanising lines a back scattering B-ray technique is used to monitor, in-line, the zinc coating weight. For sheet inspection lines, an ultrasonic technique for in-line detection of laminations has recently been developed and will soon be in service. On recoiling at the end of a strip-cleaning or annealing line it is desirable to make a coil with smooth sides so that strip edges are not damaged in handling. This is now being achieved by an automatic control on the coiler which moves the coiler along its own axis according to a signal obtained from a device sensing the position of the strip edge. Thus, as the strip wanders laterally due to variations in tracking, the coiler spindle moves automatically to follow it.

Advanced forms of automation are installed in the United States on some continuous annealing lines for tinplate. For instance, at the Aliquippa works of the Jones and Laughlin Steel Company, an electronic computer controls production and quality on a new continuous annealing line which started operation in 1960.[90]

Some electrolytic tinning lines in Japan are provided with data-logging equipment of United States manufacture.

General articles on automatic inspection methods for surface quality and defects have appeared in the United Kingdom [91] and the United States.[92] [93]

Automatic temperature control is an important feature of heat treatment furnaces, and programme control by means of a card cut in the appropriate way has been well known for many years. Automatic methods of atmosphere control are also reported.[94]

CHAPTER VII

OTHER OPERATIONS IN IRON- AND STEEL-MAKING

Continuous casting

Continuous casting is making rapid progress as an alternative to primary rolling.

Successful operation of a continuous casting plant at high rates of output requires a considerable degree of automation, particularly as regards the level of the metal in the tundish and mould. In the report from the USSR it is stated that the level of metal in the tundish (intermediate ladle) is controlled by continuous weighing of the metal in the ladle. In a later report the USSR gives full details of devices by which the level of metal in the mould is measured by emission from caesium 137 or cobalt 60, absorption of which is measured at various levels and used to control the metal flow.

This appears similar to that used in the United Kingdom, where a method for automatic control of the level of metal in the mould by γ-radiation from caesium 137 or cobalt 60 was developed at the Barrow continuous casting plant in 1958.

The report from Italy gives details of how automatic cutting of continuously cast billets into the required lengths is performed at the Terni Works. During descent the billets speed is measured by contact rollers which regulate the speed of descent of the oxy-acetylene cutter.

Forging presses

Automation of these is referred to in the report from the United Kingdom. The operation of a forging press requires the use of skilled labour in arduous working conditions. This is a situation in which automation can offer particular advantages, and there have been considerable advances recently in forging press control technology. Remote position control enables the forging tool to be precisely positioned at each stroke and a high rate of stroking to be achieved. The manipulator can be similarly fitted with remote position control to locate the workpiece in the press. With these facilities the operation of the press tool and manipulator can be automatically controlled and co-ordinated according to a predetermined programme of forging. This has been done on an experimental press at BISRA, Sheffield. At least five production forges are in operation with remote position control of the press tool so as to control the penetration automatically. One of these, a light forge recently installed, comprising a press, manipulator and furnace, is arranged so that the manipulator is on a turntable and the press and furnace are located on extended diameters of the turntable and at 90° to each other. By this arrangement the manipulator can enter the workpiece into the furnace, withdraw it, and then by rotating through 90° present the workpiece to the press. The turntable and furnace door are both push-button controlled. The automatic position control on the press tool permits automatic planishing at up to 120 strokes per minute. The first installation comprising a remote position control controlled press and a remote controlled manipulator, so allowing one-man operation, will be commissioned soon.

At the 1,500 ton press of Henry Wiggin & Co., Hereford, England, one set of punched cards automatically operates both press and manipulator. Automatic control of a high-speed manipulator and integrated 800-ton press is found at the Ince Forge Works of Parks Forge Ltd.[96] Programmed control of a 3,000 ton press at the works of A. Finkle & Sons, Chicago, United States, has been reported[97] and at Dusseldorf in the Federal Republic of Germany, a 630-ton open die forging press is automatically controlled from a desk by means of a digital measuring system.[98]

As mentioned in Chapter V, study of the programme control of heat supply to reheating furnaces for heavy forging ingots is proceeding in the Federal Republic of Germany.

Analysis, testing and inspection

Although, as far as is known, chemical analysis of metal samples has not been automated to the point where samples are taken and analysed automatically, the analysis can be performed automatically once a suitable sample has been prepared by manual methods. Methods of automatic spectrum analysis such as the "Quantometer" or "Quantovac" are now well known. An automatic method of conventional wet chemical analysis has been used in the United States and the United Kingdom. Without supervision the system will sample firm solutions, accurately proportion reagents and mix them at appropriate times, heat them when required, separate by analysis, and record automatically a final measurement by any suitable physical technique such as colour density.

Analysis of the oxygen content of waste gases by paramagnetic methods has already been mentioned in Chapter IV, referring to the installation at the open hearth furnace plant, at Italsider's works. Another method of continuous oxygen analysis recommended by the British Iron and Steel Research Association compares the e.m.f. of a reversible electrochemical cell in which the gas of unknown oxygen content is applied at one electrode and a gas of known oxygen content at the other.

One of the newest analytical methods is that developed by Plessey Nucleonics Ltd., in the United Kingdom, for automatically determining the oxygen content of metals. The sample is irradiated with neutrons which react with oxygen 16 to give nitrogen 16; measuring the decay-activity of this gives a measure of the original oxygen content.[99]

Although many of the modern methods of chemical analysis are not in themselves examples of automation, their speed and simplicity will be of great help in advancing the automation of the process to which they are applied.

Methods of automatically finding and marking defects in billets have been reported from the United States. At the Chicago plant of the Republic Steel Corporation, an "electronic inspector" locates seams by eddy current and marks the position.[100] At the Keystone Steel & Wire Co. Peoria, billets for rolling are automatically picked up off the run-in roller table and magnetized. Flucrescent magnetic particles are then applied which makes the location of defects immediately visible when viewed in suitable light.[101]

CHAPTER VIII

ECONOMIC AND SOCIAL EFFECTS OF AUTOMATION

Very little information on the economic effects of automation has been provided by Governments. The most comprehensive comes from Hungary, and the table below summarizes the anticipated gains arising from the quoted investment expenditure over the years 1961-1980. The Government of Italy states that an expenditure of 31 million lire on the equipment for waste gas analysis on open-hearth furnaces (Chapter IV) saves 75 million lire per annum. The maintenance cost is 14.6 million lire, so the net gain is over 60 million lire per annum. As mentioned in Chapter V, the USSR Government states that control by computer of shearing billets at Magnitogorsk has reduced scrap by around 90 per cent and the production of billets of the specified lengths has been increased by 15,000 tons a year. A steelworks in the United Kingdom has published information showing that the instrumentation (including a small amount of automatic control) applied to a new heat-treatment installation has earned 28 per cent per annum on the capital cost of the instruments.[102]

It is fairly easy for individual works to compute the value of individual installations - e.g., if the installation of automatic damper control at an open-hearth furnace reduces the infiltration of cold air and saves a known number of calories per ton the saving is known. However, many of the more complex systems of automation have been installed as only one item in a programme of complete plant reconstruction, when it is much more difficult to estimate separately the gain due to automation. Many of the advantages realized by automation are in the direction of improved quality which is not always easy to measure in terms of cost or profit.

Some guidance on the economics of applying automation to strip mills can be deduced from the fact that automation should make it possible to maintain quality at higher rates of output. Where the attainment of quality depends on manual observation or control, it is inevitable that speeding up output may lead to some deterioration in quality. As referred to in Chapter VI, the Ukrainian Government reports that the automation of a cold mill has increased output by 20 to 25 per cent with some actual improvement of quality. This would seem also to be obtainable at hot-strip mills. On this basis the improvement of a hot-strip mill output by 20 per cent would reduce capital cost per ton by about 1 US dollar and operating cost, allowing for extra maintenance by about 0.5 dollars per ton. The capital cost of applying the automation would probably be in the

The Economic Effects of the Automation of Metallurgical Processes in Hungary

Definitions of principal processes	Total expenses allocated for automation (in thousand forints)				Savings (in thousand forints)				Allocated term of return (years)	Apparent savings				Anticipated lifetime of the automated equipment (years)
	1961-1965	1966-1970	1971-1975	1976-1980	1965	1970	1975	1980		improvement of quality (%)	surplus production (1,000 forints per year)	improvement of working safety (%)	labour safety (%)	
Ore preparation	250	17,500	15,530	690	85	5,700	5,200	230	3	30	20,000	35	10	10
Pig-iron production:					-	-	-	-			50,000			
Blast-furnaces	6,000	10,443	5,920	5,100	2,000	3,500	1,920	1,700	3	25		50	30	10
Cowper stove	1,200	5,800	4,200	1,900	600	1,900	2,100	950	2	-		40	50	10
Steel-production:											26,000			
Open-hearth furnaces	6,500	11,500	5,600	2,700	2,600	2,250	1,080		2.5	30		20	40	10
Electric furnaces	-	3,300	-	-	-	830			4	25		15	20	10
Rolled-steel production											30,000			
Furnaces	27,500	27,700	25,500	9,500	13,800	13,900	12,800	4,750	2	35		30	50	10
Rolling-mills	41,400	13,300	13,900	4,700	13,700	4,450	4,460	1,570	3	20		50	30	10
Preparation	10,300	12,800	13,200	8,500	3,450	4,280	4,400	2,800	3	20		30	25	10

Source: Information provided by the Government of Hungary.

region of 3.5 dollars per annual ton and thus the return on the investment would be about 15 per cent.(*)

Social aspects of automation

Since one of the objectives of automation is to improve labour productivity it would be expected that automation will lead to a reduced demand for labour unless total production is raised correspondingly with productivity. This has caused some concern, particularly in the United States, that large numbers of workmen will become unemployed following automation. One American firm making automation equipment is reported to have set up a fund to study and alleviate the effects of automation[103] and studies in this field are also planned in the United Kingdom.

This aspect of automation has received some study in the report from the European Coal and Steel Community. This states that if the development of automation is carried out with care and proper organization no hardship should be caused in an expanding industry. Although unskilled and arduous jobs are diminished, there is an increased need for skilled workers, and the need for developing such higher skills is emphasized. The report says the social aspect will not be lost sight of in the programme of research being carried out by the High Authority of the Community.

A measure of the extent to which mechanization and automation can save labour is quoted in the report from Czechoslovakia, where a factory for making wheel centres reduced total manpower from 124 to fourteen.

So far, no reports have been received of serious social consequence arising from the introduction of true automation in the iron and steel industry. In the United Kingdom, the effect of true automation has been to improve quality rather than to reduce manpower, for instance the introduction of automatic roof temperature control in open-hearth steelmaking furnaces has not resulted in the release of members of the furnace crew because the crew can devote more time to control of the steelmaking, slag condition, and so on, if they are released of minute watching of the roof. The introduction of automatic spectrographic analysis in steelworks analytical laboratories has not led to the reduction in number of analytical chemists employed which might have been expected. What has happened is that many more analyses have been carried out, particularly of slags, so that improved control of the steelmaking process has been achieved.

(*) These figures have been estimated by the Rapporteur.

In the iron and steel industry the biggest savings in manpower come from plant design modifications such as increasing the size of furnaces, mills and handling equipment, and speeding up output, so that each man handles a greater weight of material in a given time. Thus it is mechanization, rather than true automation, which has led to greatly reduced demand for labour per ton of product. Typical figures for employment in the United Kingdom in a modern strip-mill plant are 1,000 tons of hot-rolled sheet per man/year in a modern plant compared with 100 tons per man/year in the old hand-mill process. Cases of hardship caused by the replacement of hand tinplate mills in the United Kingdom by modern continuous plants have been met by compensation from a central fund financed by a small levy on each box of tinplate sold. In the countries of the European Coal and Steel Community, any adverse effect on employment caused by technical changes such as automation is met by re-adaptation and resettlement grants to which the central funds of the High Authority and the Governments concerned contribute. In the United States, funds have been allocated for research on the social consequences of introducing a high degree of automation in industry.

Since 1957, the International Labour Office has been studying the social effects of automation. Because of the increasing complexity of these problems and the need for a better understanding of them, the ILO has just inaugurated a new programme aimed at encouraging research and providing for the dissemination and exchange of knowledge acquired about the current repercussions of the new techniques and their probable implications for the future.

A meeting in March 1964 represented a first step towards international exchange of the knowledge gained from experience. The purpose was to work out methods for the study and collection of information about the social repercussions of automation and technical progress in general. A series of conclusions and recommendations was adopted concerning the methods and techniques which could be used in studying technical progress and its implications.

Another purpose of this programme was the establishment of an international clearing-house of information on the economic and social consequences of automation and technical progress. This is still at an early stage but has already published certain bibliographical studies on

(a) the material available in the ILO Library;

(b) a review of recent Soviet literature on the social aspects of automation and technological change in the USSR;

(c) other abstracts of articles on the social aspects of automation.

The ILO has undertaken a certain number of projects concerning various aspects of the social effects of technical development. The subjects dealt with include: effects on occupational safety; vocational training of maintenance workers; trends in apprenticeship in certain countries of Europe; factors affecting the mobility of the labour force; repercussions on the structure and training of the labour force at blast furnaces, steel mills and rolling mills; repercussions on the composition of the skilled labour force in the mechanical engineering industry of the USSR and so on. Other research projects are envisaged, viz. problems of automation in the developing countries; effects of automation on the system of remuneration; and national programmes for the solution of social problems arising from automation.

CHAPTER IX

CONCLUSIONS

Progress with automation in the iron and steel industry is so rapid that preparation of a statement of the position at any particular time is difficult and the statement is likely to be out-of-date when it is published. One of the difficulties arises from the fact that there is a great volume of published papers, and it is seldom clear whether information given on automation refers to equipment actually installed and in operation or merely to equipment in course of manufacture, at the drawing board stage, or is only present as an idea in the mind of the author of the paper. Even in the reports received from the various countries in connexion with the present study, this difficulty is sometimes present.

Automation equipment may be divided into three main groups:

(a) The signalling equipment which measures a condition or a deviation from a desired condition, e.g. a temperature, pressure or gauge measurement. The signal is commonly in the form of a pressure difference or an electrical potential;

(b) The computing equipment which receives the signal and translates it into instructions to the control equipment. This may range from a simple mechanism, which introduces the necessary anticipatory or delay reactions in the movements needed to control a changing variable, to elaborate computers capable of integrating instructions from a number of signals;

(c) The control equipment which takes these instructions from the computing equipment and operates valves or other mechanical devices to control the plant.

There is ample equipment now available for many of the functions (b) and (c), although the arduous conditions encountered in the steel industry mean that measuring equipment for function (a) is not available to the degree of accuracy and robustness for all the cases in which a measurement is required. Measurement of the conditions inside a blast-furnace is still very difficult, and automatic weighing of raw materials and of slag and metal to a degree accurate enough for automation purposes still requires much study. There is still a need for equipment for function (c) in some cases, e.g. opening and closing tap holes for metal and slag. Some of these problems are mentioned in the report from the USSR.

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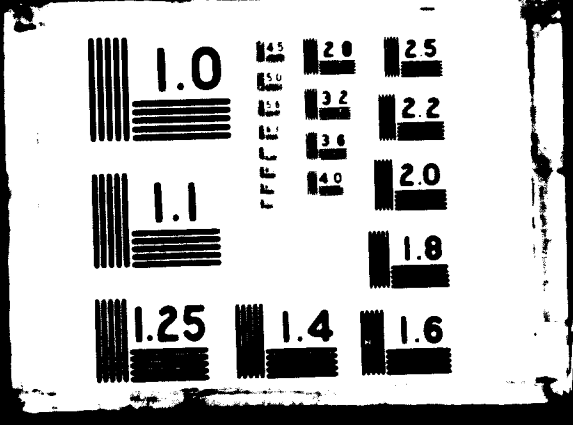

Another obstacle in the way of rapid progress in automation is uncertainty regarding the economics of some installations. Many of the advantages realized by automation are in the direction of improved quality, which is not always easy to measure in terms of cost or profit.

It is evident from the reports received that many countries have made significant advances in automation techniques. It is not possible, or desirable, to say whether any countries have a clear lead in any particular field, but there is no doubt that exchange of useful advice can take place. Rapid progress is likely to be made by both iron and steel works engineers and by the manufacturers of automation equipment under the compulsive demand for increased productivity which exists in all countries. It will be useful for the Steel Committee to keep such progress under review and to emphasize the importance of encouraging research and its application in this field.

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