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Computer Application in the Steel Industry: Control of Basic Oxygen Furnaces and Integrated Management Systems in Large Plants

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COMPUTER APPLICATION IN THE STEEL INDUSTRY:

CONTROL OF BASIC OXYGEN FURNACES AND INTEGRATED MANAGEMENT SYSTEMS IN LARGE PLANTS

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PREFACE

Industrial problems of a universal character have been an integral part of IIASA's activities since the Institute started its work in 1973. These activities were initially carried out by the Integrated Industrial Systems Project, which has now been incorporated into the Management and Technology Area.

The Project's objectives included a study of the international experience in computer-aided design (CAD), and the development of the concept of CAD for industrial implementation. The study concluded that CAD is currently in a state of dynamic development, with corporations investing heavily in this area, and large numbers of highly qualified, specialized personnel assigned to the development of CAD projects.

In 1974-75, IIASA studied the development and implementation of computer-based management systems in the steel industry. The steel industry was selected as the first case study of the integrated systems approach for several reasons. First, steel is a basic industry that is of interest to most of the countries of IIASA's national member organizations. Second, steel is a complex industry with different types of processing and manufacturing facilities. Third, and most important, the steel industry is perhaps the most advanced area of technology with respect to the application of both an integrated systems approach and computers for real-time information processing and decisionmaking. The major goal of IIASA in this field is to identify the most advanced methods for planning, scheduling, and production control, and to determine how these can be implemented and coordinated to achieve systems integration.

The concept of integrated systems control in the steel industry was discussed in a state-of-the-art survey and at the 1975 IIASA Conference on Integrated Systems Control in the Steel Industry.

Work continued in this field, focusing on problems of implementing computer-based management information systems at the sectoral, regional, and national levels. The experiences of countries with planned economies and those with market economies were considered for this purpose. The next step in this direction was the study of problem-oriented models for industrial technology. A case study was made of the application of computers for the control of basic oxygen furnaces (BOFs).

This topic is of particular interest to industry as evidenced by their support of IIASA's work in this field. IIASA is grateful for this support in many countries, in particular that of Austrian industry.

In May 1977, IIASA sponsored a Workshop on this subject, oriented toward problems of interest to industry and institutions connected with industry.

These proceedings include invited papers and discussions of the Workshop. Twenty-seven participants from nine countries met to review the current state of the art, and to make suggestions about future IIASA research in this field. Appended to these proceedings are the Workshop suggestions, agenda, and list of participants, respectively.

I am indebted to Jeanne Anderer, editor, and to Eryl Ley, Workshop secretary, who made essential contributions to this work.

German D. Surguchov
July 1977

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Welcoming Address

R.E. Levien

It is a pleasure to welcome you to our workshop on the control of basic oxygen furnaces and integrated management systems in steel plants.

In order to explain why we are working on this topic, and how it fits into our overall program, I would like to say a few words about the history and research program of the Institute, and about the way we function.

The Institute will be five years old in October, though the notion of IIASA is over ten years old. It was first proposed at the end of 1966, when US President Lyndon Johnson suggested that an Institute might be created to work on the common problems of industrialized nations and to bring together scientists from East and West, thereby serving as a bridge between different societies. In 1967, he sent McGeorge Bundy to Moscow to meet with Jermen Gvishiani, Deputy Chairman of the USSR State Committee for Science and Technology. The Soviet response was very positive. There followed five years of negotiations, during which the USA, the USSR, and ten other nations agreed to participate in the founding of such an institute.

The founders made a crucial decision: to establish the Institute not as an intergovernmental organization, like the United Nations agencies, but as a nongovernmental organization. That is what IIASA is today. Our membership consists of one scientific organization from each of the seventeen participating countries--the National Academy of Sciences in the USA, the Academy of Sciences in the USSR, and similar institutions in, now, 15 other countries. The first 12 National Member Organizations (NMOs) met in October 1972 to establish IIASA, and scientific work began in June 1973. In May of last year, we held the first IIASA Conference, to sum up the progress of the Institute up to that point.

At the same time as the Charter was signed, Austria offered IIASA the use of this magnificent Schloss.

The seventeen NMOs provide the basic funds for the Institute, the USA and the USSR NMOs each granting 1.4 million dollars a year, and each of the others 216,000 dollars a year: a total budget of about 6 million dollars. Each NMO has a representative on the Council which sets the overall policy for IIASA. The research activities are the responsibility of the Director. Then of course there are the normal scientific services, which include computing, library, publications, and the basic administration functions.

What are the research activities of the Institute? They are reflected in two phrases in our title: *international applied*, and *systems analysis*. *International applied* means that IIASA has as its basic function work on real problems of international importance. We distinguish two kinds of such problems. The first we call *global*: issues that inherently cut across national boundaries and cannot be resolved by the actions of single nations. So, for example, we have global climate problems; exploitation and protection of oceans; the problem of global development--how, within the next 50 to 70 years, we can meet the needs of a growing population for food, clothing, housing, a safe environment, health, and so on. But rather than treat the problem as a whole, as the global modeling enthusiasts do, we study specific sectors of global development in turn. The first sector we have chosen is energy. A major program at IIASA is concerned with the evolution of a global energy system, particularly its smooth transition, about 15 to 50 years from now, from one based on oil and gas to one based on virtually inexhaustible energy sources--nuclear, solar, or coal. The program has a five-year lifetime and seeks to look at the technology, economics, and environmental and social aspects of the development of alternative energy systems. The second global program, which we are just beginning, studies the food problem in a similar context: the evolution of national food policies and their interaction through the international food markets, and the question of how well those policies will provide for the nutritional needs of a growing world population.

The second category of international problems is what we call *universal*. These are problems that reside within national boundaries, but that all nations face--for example the design, building, operation, and maintenance of a steel industry, a health care system, or an education system. While each of these is subject to national decisionmaking, all nations share these problems, and much can be learned through the exchange of information among nations. That is one of the reasons you are here, and one of the reasons IIASA is here--to facilitate this exchange of information across national boundaries, and across social, economic, and political boundaries as well.

The second phrase in our title, *Systems Analysis*, means different things to different people. We take it to mean that, when studying problems of an international importance, we have an obligation to study them in their full breadth--not to limit our study to the way in which a Ministry or a particular discipline might approach the question, but to include all the aspects that affect the decisions to be made. So in studying the global energy future, we are not limiting ourselves to the technology or the economics of energy, but we consider also population issues: how many people will there be, what will their demand for energy be, what environmental and social factors are involved? And so on.

IIASA's research is organized in four Research Areas, each with its experts in particular aspects of knowledge necessary for systems studies. The Resources and Environment Area is concerned with the natural endowments of the earth, with water, minerals, with the environment, and so on, and it has specialists with skills and interests in those topics. The Human Settlements and Services Area, specializing in the human resources of the globe, has topographers, urban planners, health care specialists, and so forth. The third area, which is sponsoring this meeting, is Management and Technology, with specialists in organization and management matters and general technologies--at this time, particularly information technologies. And the System and Decision Sciences Area is concerned with the mathematical and computational tools for studying complex systems.

We have a residual category, as all good organizations must, that we call General Research--topics that do not fit neatly into the other Areas, some of them quite important for IIASA's work. They include a series of books on aspects of the state of the art in systems analysis. There will be, for example, a volume on computer-aided design, which draws on work initiated in the Management and Technology Area; and one on computer-aided urban traffic guidance and control.

The subject of this meeting--information technology and its impact on the economy--grows out of a study by the former Integrated Industrial Systems (IIS) project on integrated control in the steel industry. The IIS project has been combined with the former Large Organizations project to form the present Management and Technology Area.

That is the main structure of IIASA's research and management. Although I have not said much about the various studies, you can infer that it implies a large research program, one that is very ambitious for the resources available to the Institute. These consist of 70 scientists whose salaries are paid by NMO contributions, a library with good connections to other libraries around Europe, an adequate medium-sized computer system, and an annual budget of about 6 million dollars, or 110 million Austrian Schillings. But no institution with these resources could hope to achieve the program outlined if it worked only by itself. The important aspect of IIASA is that it does not aim to be, nor does it function as, a self-contained research institution. Rather, its purpose is to be the core of an international network--the visible part of an invisible international college collaborating in the programs that we ambitiously have set for ourselves.

Around this core there are two additions within IIASA. One is the presence here of guest scholars, scientists whose salary is paid by their home institutions, who work with our staff and also serve as our link to their home institutions. For example, we have had scientists here from IBM, Shell, Siemens, and Arthur Andersen. Second, we receive each year, in addition to our basic funding, about 1 million dollars of external funding from the United Nations Environment Programme, from the Ministry of Science for Research and Technology in the FRG, the Austrian National Bank, and other sources. Thus in addition to our 70 NMO-sponsored scientists, we have 10 guest scholars on average, and about 15 whose funds are provided by external resources. This makes it more feasible for us to carry out the work we want to, but even 95--or 395--is still too few for the large goals of the Institute.

The major amplification of our efforts occurs through collaborative research with particular institutions in particular countries. We have at the moment seven collaborative agreements, covering topics ranging from the development of agricultural-industrial complexes in Bulgaria, to joint work in energy, health care systems, and so on. We have agreements with the Siberian Power Institute; we have worked closely and intensively on atmospheric and climatic questions with the British Meteorological Office and the National Center for Atmospheric Research (NCAR) in the USA. Through each of these links we multiply the effort that IIASA and its NMOs can apply to a problem.

For example, we are studying the coal option as a major energy option. The two people at IIASA working on coal are the mobilizers and coordinators of an international task force from the British National Coal Board, Ruhr Coal in the FRG, and groups in Poland, the USSR, and other countries. Thus the task force has not two members, but closer to 15 or 20.

Beyond collaborative research, we have what we call catalyzed research--activities undertaken in other research institutions, not in close collaboration with IIASA, but stimulated by our concern for a particular problem. As a result of questions raised here at IIASA, other research institutions are now working intensively on the potential impact of more CO_2 burning--associated with burning increased amounts of coal--on the climate.

Finally, and I think most important for this meeting, there is the role of IIASA as an information exchange agent. We can, and frequently do, bring together representatives from institutions having common interests, but from many different countries. Through this mechanism of information exchange, IIASA is able to play an important role in facilitating joint work among institutions around the world. Thus, the main work of the Institute is achieved through this ever-increasing series of interlinkages between the Institute and the larger scientific community worldwide.

Part of that community, and one with which we are seeking closer contact, is industry. We are an applied research institute, concerned with the impact of real problems. Clearly the industry of both East and West is a major player in the solution of global and universal problems. So we are looking for ways to build up closer relations between the Institute and industry--meetings such as this one, collaborative research, joint funding of activities.

Again, welcome to IIASA; and now that you have been here, we hope that you will view yourselves as part of the extended IIASA community and continue your association with the Institute when you return to your home institutions. We hope to see you here many times in the future.

Computer Application in BOF Technology: A Systems Approach

G. Surguchov

INTRODUCTION

The development of steelmaking using the basic oxygen furnace (BOF) technology began in the early 1960s. Figure 1 illustrates this evolution from the point of view of the duration of the production cycle. The development of the open hearth technology (OHT) by means of improved organization, furnace construction, implementation of new refractory materials shortened the cycle. The first sharp decrease in production time came in the mid-1950s as a result of the development of a process for producing oxygen on a large scale. Steelmaking based on the oxygen blowing process, led to the development of the BOF, which has several advantages including high productivity and a short production cycle.

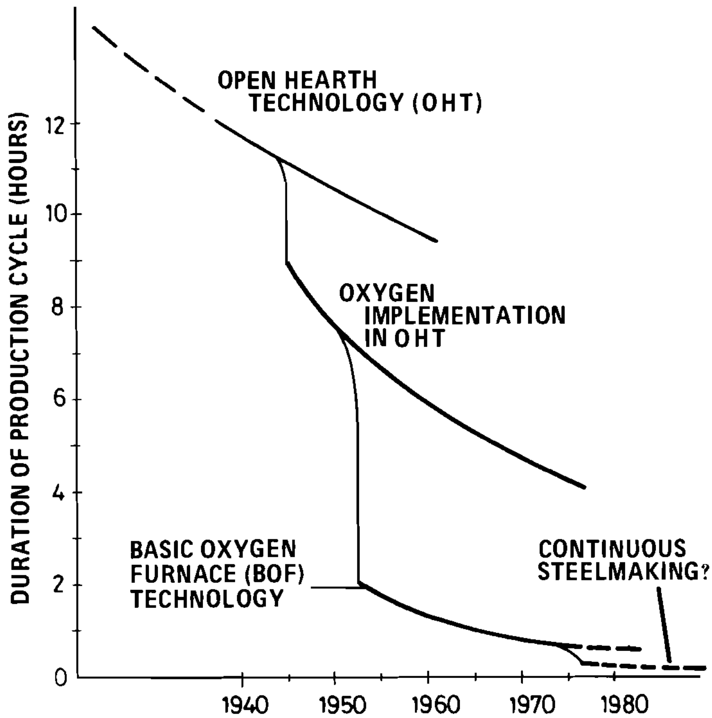


Figure 1. Development of steelmaking from viewpoint of production cycle.

Source: [8]

Steelmaking in BOFs is being increasingly used throughout the world, and is the principal technology used in most major steel producing countries. In 1975, about 390 million tons of steel, or about 53 percent of all steel produced was manufactured using this technology. At this time, there were more than 500 BOFs of different capacities in operation and about 70 under construction (see Figure 2).

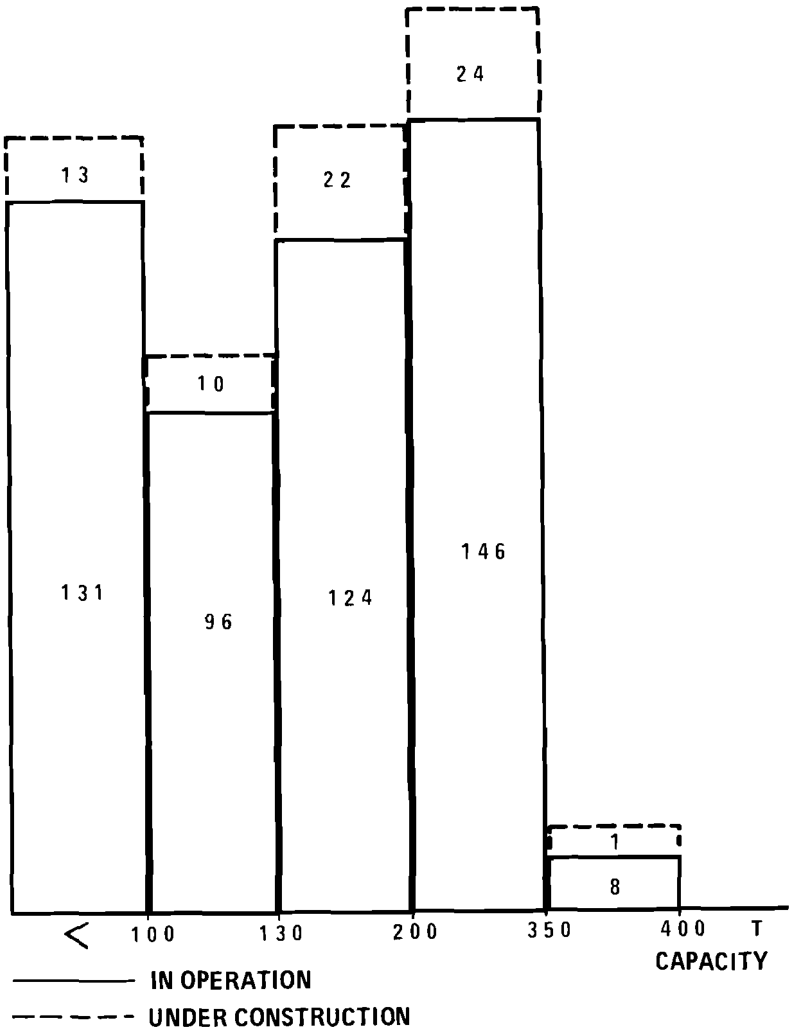


Figure 2. Basic oxygen furnaces worldwide, 1975.

After: [1]

Two properties of the BOF technology--high productivity and speed--limited for some time the possibility of producing quality steel in an optimal way. To improve this situation, BOF technology should be implemented jointly with computer-aided information systems.

The systems consideration of the joint operation of these techniques demands that both be viewed as part of a large-scale system. The BOF technology is a part of an integrated steel plant, and the computer is a part of the integrated control and management system. Moreover, the large-scale system being considered is limited by external conditions such as those imposed by the environment and by society. The system consideration demands an analysis of both the actual technology and the external factors.

Let us consider several examples of these constraints. From the point of view of absolute value, steel is the third industrial product after coal and oil. Steel manufacturing in BOFs demands a great amount of resources, e.g. raw materials, water, and energy. The average steel plant, with an annual production level of 6×10^6 tons of steel demands for operation (10^3 tons/year) 3348 coal, 8100 iron ore, 920 limestone, 8262 hot blast, 432 oxygen, 1080 scrap iron, etc. These plants demand 89.6 kl per hour of heavy oil and 2.25 billion kWh per year of electricity power [2].

The energy consumption per ton of finished steel using different steelmaking technologies is shown below in Table 1.

Table 1. Energy consumption in steelmaking [3].

Process	Consumption 10^6 kcal/t
Open-hearth ingot	11.7
BOF and continuous casting	10.3
Ideal or perfect system	1.75

The use of the BOF technology improves the efficiency of steelmaking and, in particular, reduces the amount of energy consumed as much as 12 percent. However, the BOF technology is far from being a perfect or ideal system. The improvement of the techno-economic indices for the BOF technology is an important problem that should be considered.

The steel industry, and particularly BOF, is one of the major polluters of the environment; Table 2 shows some characteristics of different kinds of pollutants [4]. About one third of the particulates are generated by steelmaking, though the cleaning system reduces this fraction considerably. Decreasing the amount of pollution is a goal that should be given a high priority.

Table 2. Pollutants resulting from the steelmaking process. After: [4]

<table>
<tr><th rowspan="3">Process</th><th colspan="4">10^3 tons/10^6 tons steel</th></tr>
<tr><th colspan="2">Particulates</th><th colspan="2">SO_x</th></tr>
<tr><th>Generated</th><th>Exhausted</th><th>Generated</th><th>Exhausted</th></tr>
<tr><td>Iron Ore</td><td>12.7
% 13.4</td><td>0.250
21.1</td><td>0.0
0.0</td><td>0.0
0.0</td></tr>
<tr><td>Sintering</td><td>28.8
% 30.5</td><td>0.750
38.0</td><td>0.517
10.1</td><td>0.098
6.8</td></tr>
<tr><td>Coke Making</td><td>9.28
% 9.8</td><td>0.100
8.5</td><td>3.330
64.9</td><td>0.61
4.30</td></tr>
<tr><td>Pig Iron Making</td><td>15.2
% 16.1</td><td>0.300
25.4</td><td rowspan="4">1.282
25.00</td><td rowspan="4">1.282
88.9</td></tr>
<tr><td>Steelmaking</td><td>26.8
% 28.4</td><td>0.067
5.4</td></tr>
<tr><td>Teeming</td><td>1.77
% 1.9</td><td>0.017
1.4</td></tr>
<tr><td>Rolling</td><td>0.0
% 0.0</td><td>0.0
0.0</td></tr>
<tr><td>TOTAL</td><td>94.55
%100.00</td><td>1.184
100.00</td><td>5.129
100.00</td><td>1.442
100.00</td></tr>
</table>

About 2.5 million people work in the steel industry under very difficult conditions [5]. If the absolute output rises without improved technology, then that number in 1980 could be as high as 3.3 million. Thus the problem of improving technology (and increasing productivity) is of great importance.

The joint development of the industrial technology and the information technology can help to solve most of these problems. In general, the overall objective of computer application in BOFs is to improve the efficiency of the technology by conserving resources, decreasing the amount of pollution, and by minimizing costs. This objective can be achieved by means of operational control and management, research and development of existing technology, and design of a new technology or technological unit (Figure 3).

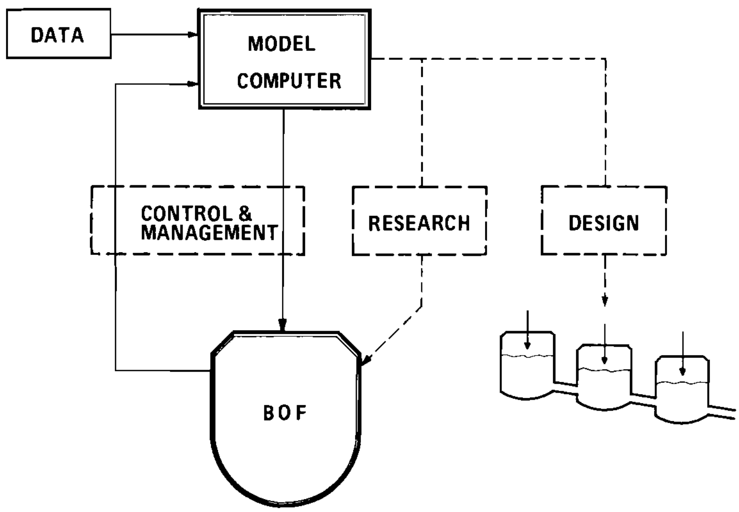


Figure 3. Computer operations in the BOF.

The existing BOF technology should be *controlled and managed operationally*. Computer-based control of BOF technology poses very serious problems. Since the BOF installation does not operate separately and is part of a large-scale production system, its control and management cannot be carried out separately. Also, the computer system installed in the BOF is generally part of other large-scale computer systems. For example, the management of a combined operation of BOFs and continuous casting machines (CCM) is one method that could lead to increased efficiency for both operations.

Every technology, and BOF in particular, should be considered a developing system whose characteristics and indices require continuous improvements. These improvements can be achieved through *research* which can be conducted on a computer application basis.

Research and development of modern technologies can provide a basis for the *design* of a new technology. For example, the continuous steelmaking process can be developed on the basis of the BOF technology. Computer application for the design of new processes, units, or large-scale industrial systems can be an effective tool. Let us now consider the application of computers for these three activities using as an example the development and use of mathematical models. For each of these activities, the models will differ in complexity, detail, and aggregation.

MODEL DEVELOPMENT

Data about the system to be modeled (off-line or on-line) are needed to develop a mathematical model. We will consider the system, objective-oriented approach in discussing the development and use of mathematical models.

Figure 4 shows the hierarchy of different types of models. There are *models for process control* which are solved on line in accordance with the process cycle. These include a set of coordinating models for coordinating the production processing of different units, and a planning and scheduling model solved in accordance with the planning and scheduling cycle. *Research models* are used periodically. Optimizing the technological processes by changing the conditions (different raw materials, units of construction, etc.) can be carried out using an off-line solution of research models. Finally, *special purpose models* are used for designing new processes.

The general procedure for developing mathematical models is shown in Figure 5. A study of the real system may show that the model as developed originally cannot solve the problem, thus requiring a more accurate redefinition of the goals of the modeling exercise. Also, after verifying the model on the basis of real data, it may be necessary to adjust the model, e.g., by changing the structure or by making the coefficients of the model more precise. The utilization of the model should improve the existing system or contribute to the development of a new one.

Various methods exist for developing the model from the information viewpoint (Figure 6). An *analytical model* (often called a physical model, see A in Figure 6) can be developed on the bases of modern science, theoretical knowledge, and experience in the field under consideration. An *experimental model* (often called a statistical model, see B in Figure 6) can be developed using the black-box principle, taking into consideration the behavior of the input and output parameters.

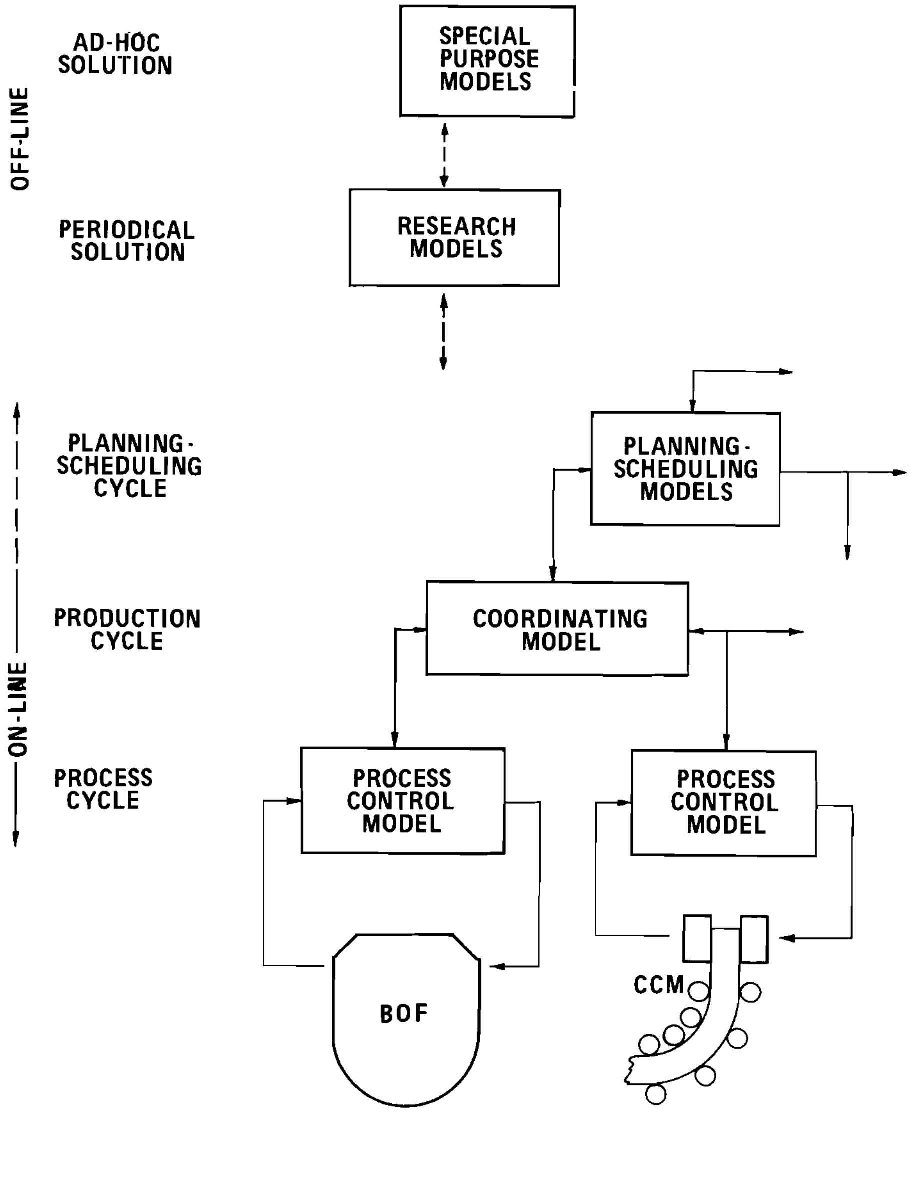

AD-HOC SOLUTION
SPECIAL PURPOSE MODELS
OFF-LINE
PERIODICAL SOLUTION
RESEARCH MODELS
PLANNING-SCHEDULING CYCLE
PLANNING-SCHEDULING MODELS
PRODUCTION CYCLE
COORDINATING MODEL
ON-LINE
PROCESS CYCLE
PROCESS CONTROL MODEL
PROCESS CONTROL MODEL
BOF
CCM

Figure 4.

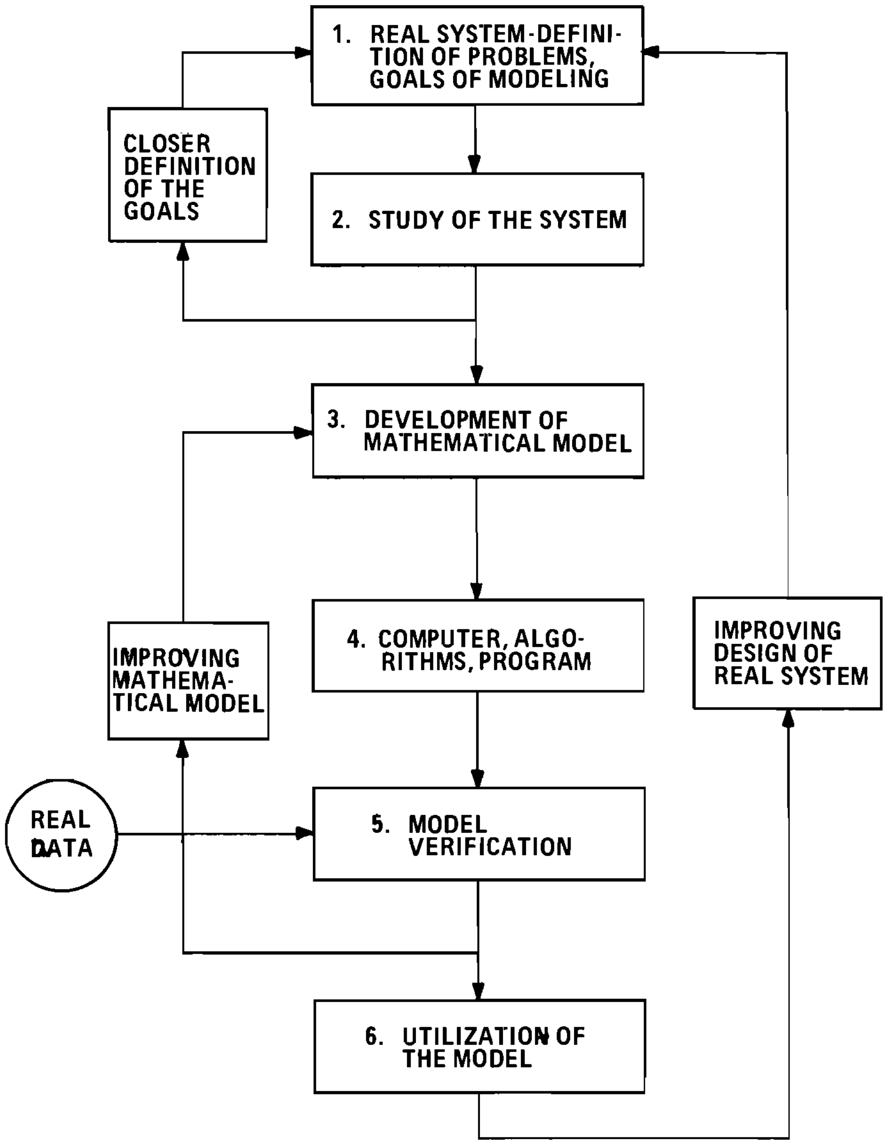


Figure 5.

Source: [8]

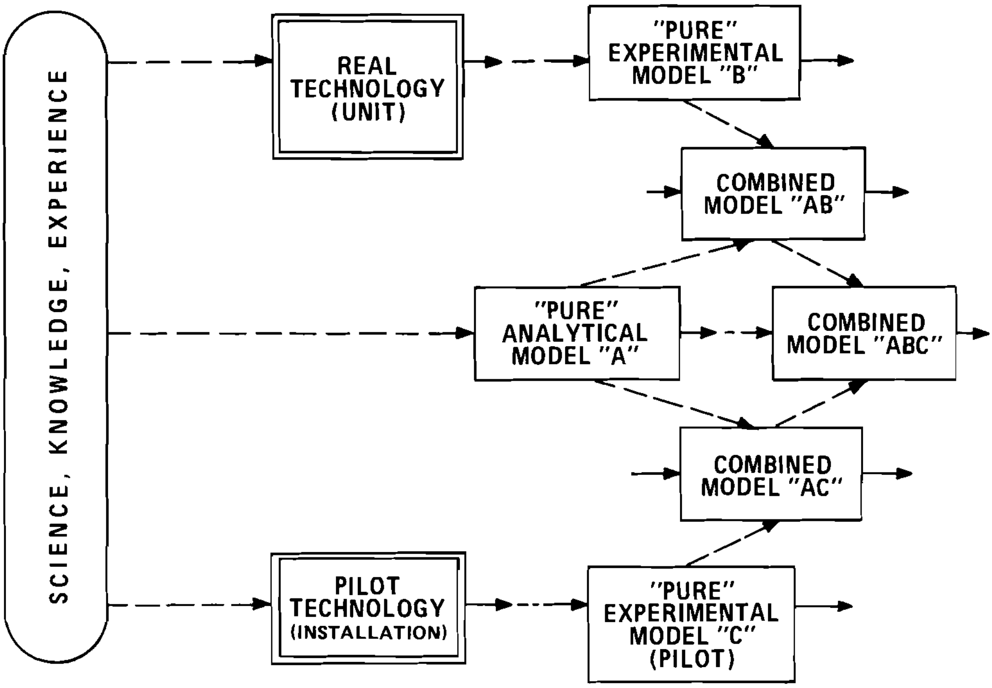


Figure 6.
Source: [8]

Another way to develop a mathematical model is to conduct a study of a pilot technology (see C in Figure 6). The study can be conducted in special pilot units or in installations, with a view to identifying separate processes in the technology, to designing a new technology, etc. The results of these investigations can be used for developing the mathematical model on an experimental basis.

The advantages and disadvantages of analytical and experimental approaches are well known. Applying a combination of both types of models is even more advantageous (see AB, AC, ABC in Figure 6). These combined models use classical laws and experimental data (e.g., coefficients and equations), and are most widely used in technological fields.

Table 3 shows some features of model development for different purposes. A number of factors must be considered when studying the system from a modeling viewpoint. For identifying operational (management and control) and research problems, data exist on the technological system that can be used for model development. As for the development of models for designing

Table 3 [8].

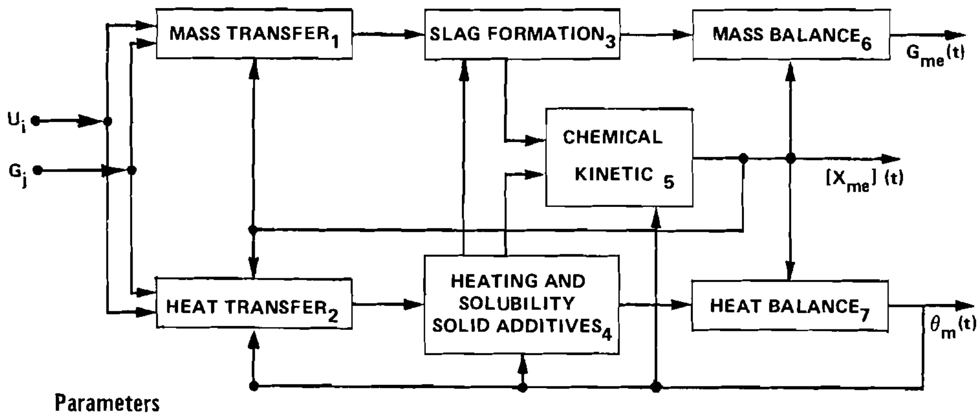
Steps \ Problems	Operational Control and Management	Research	Design
Problems formulation	Improvement of indices in technology in operation by means of operational control and management	Improvement of indices of up-to-date technology by means of research and development	Design of advanced (new) technology
Special features of the study of the system under modeling	Knowledge and data available. Implementation of special methods of study: experimental statistical, etc.	Knowledge and data available. Implementation of special methods of study: experimental, statistical, etc.	Not enough knowledge and data about the existing system
Method of developing mathematical model	- Analytical - Experimental - Combined	- Analytical - Experimental - Combined	- Analytical - Combined
Model's size/complexity	Limited	Any complexity	Any complexity
Computer	Universal	Analog/Universal	Analog/Universal
Solution	On-line	Off-Line	Off-line
Data availability	Necessary comparative data available	Possible comparative data available	Difficult - no comparative data
Possible or necessary accuracy	High	Middle/high	Low

new technologies, there is often some delay or the model description is not precise owing to a lack of real data. In the latter case, previous experience could be used or an analog technological system could be studied. Nevertheless, there may still be insufficient information for developing the verifying design models since data are needed for applying the statistical method to the development of these models.

Operational models should be solved on line in accordance with the technological cycle and have a high accuracy level; the latter determines the properties of models such as limited size, and universal computer implementation.

In discussing model development and data selection with respect to computer application in BOFs, it is necessary to stress that one of the elements of a systems approach should be concerned with problem orientation for all procedures and techniques.

The study of a simulated system includes identifying the main input and output parameters, grouping the similar processes, and dividing the system into several elementary subsystems (see Figure 7). The BOF technology can also be considered a complete entity. In this case the connection between input and output parameters can be found without taking into consideration the elementary subprocesses.



Parameters

U_{oxi} . oxygen and fuel rate

X_{me} : carbon concentration

G_i : metal flow

$\Theta_m(t)$: reaction constant

Figure 7.
Source: [8]

MODELS FOR OFF-LINE COMPUTER APPLICATION

Let us start with an example of computer application for the *design* of a new technology. The development of new processes demands the solution to many problems, for example, the identification of conditions for stabilizing the on going processes in the continuous steelmaking technology. The stability of these processes depends on furnace capability, productivity, storage, etc. Figure 8 shows the scheme of a continuous steelmaking installation. The ongoing processes in each of the furnaces are typical of the BOF technology. The need to coordinate the combined output of all the furnaces should be taken into consideration in designing the new technology.

The main purposes of the model are to describe the dynamic behavior of the process parameters, and to identify the optimal conditions for operational control of all furnaces.

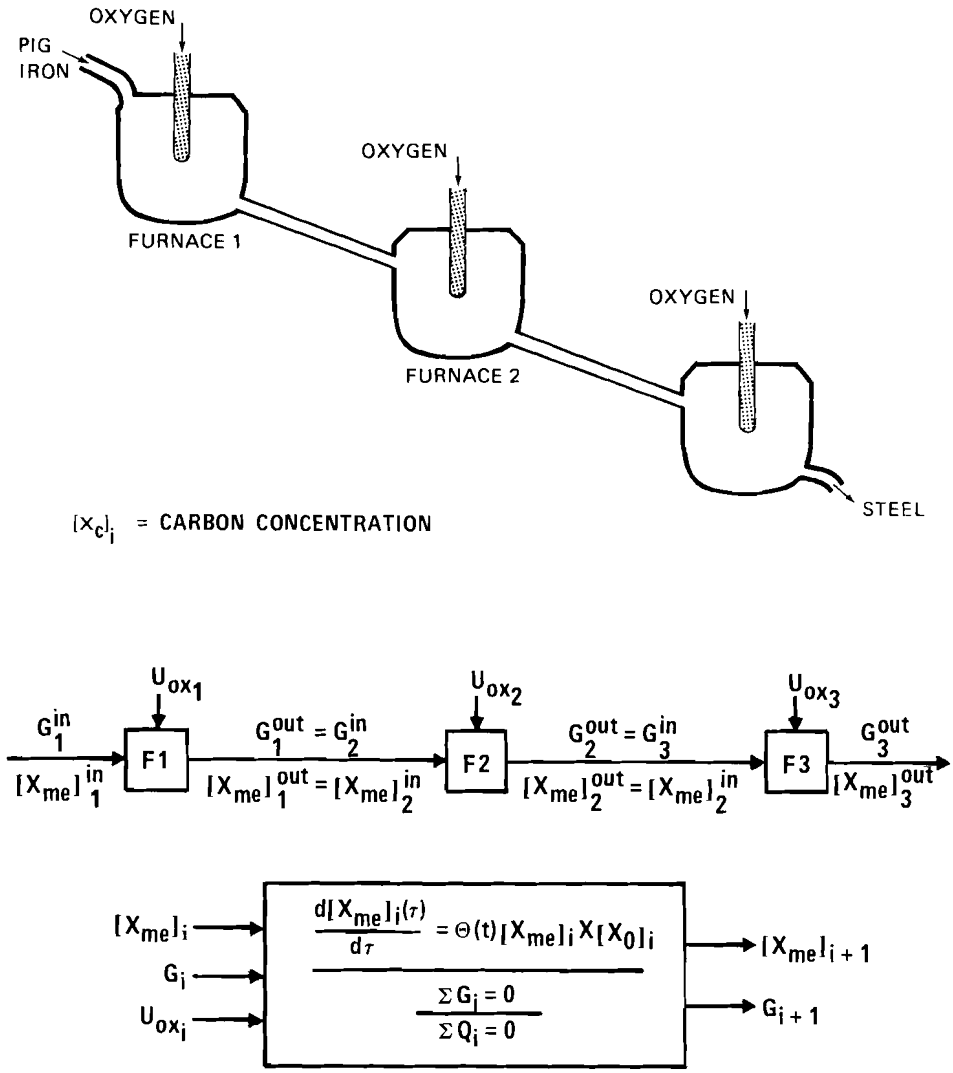
For the model's input parameters, the oxygen and fuel rate, U_{oxi}, have been considered. The controllable quantities (output parameters) are the carbon concentration X_{me}, and the temperature. A special characteristic of this new technology which was taken into account by the model builders, is the metal flow G_i from one furnace to another.

A block diagram of the mathematical model is given in Figure 8. The model is composed of three blocks; each describes the process in one furnace, based on the basic laws of mass action and mass and heat conservation.

Approximately 20 equations, including 10 nonlinear differential equations, are contained in the model. An analog computer was used to simulate the model. No data exist for developing and verifying the model because the modeling technology does not exist. Valuable information can be acquired on the simulation process, that may be used in developing a new technology.

Many static and dynamic characteristics have been acquired as a result of mathematical modeling; one example is the dynamics of carbon concentration in each of the furnaces (Figure 9). The practical results of this modeling exercise include the identification of a number of alternatives for the design of the new technology and recommendations for the operation of a pilot installation.

Off-line computer application is useful for improving the techno-economic indices of BOFs, in particular for increasing the metal yield from a charge, based on the optimization of the process parameters.



Parameters

U_{oxi} : oxygen and fuel rate

X_{me} : carbon concentration

G_i : metal flow

$\Theta_m(t)$: reaction constant

τ : time

Figure 8.
Source: [8]

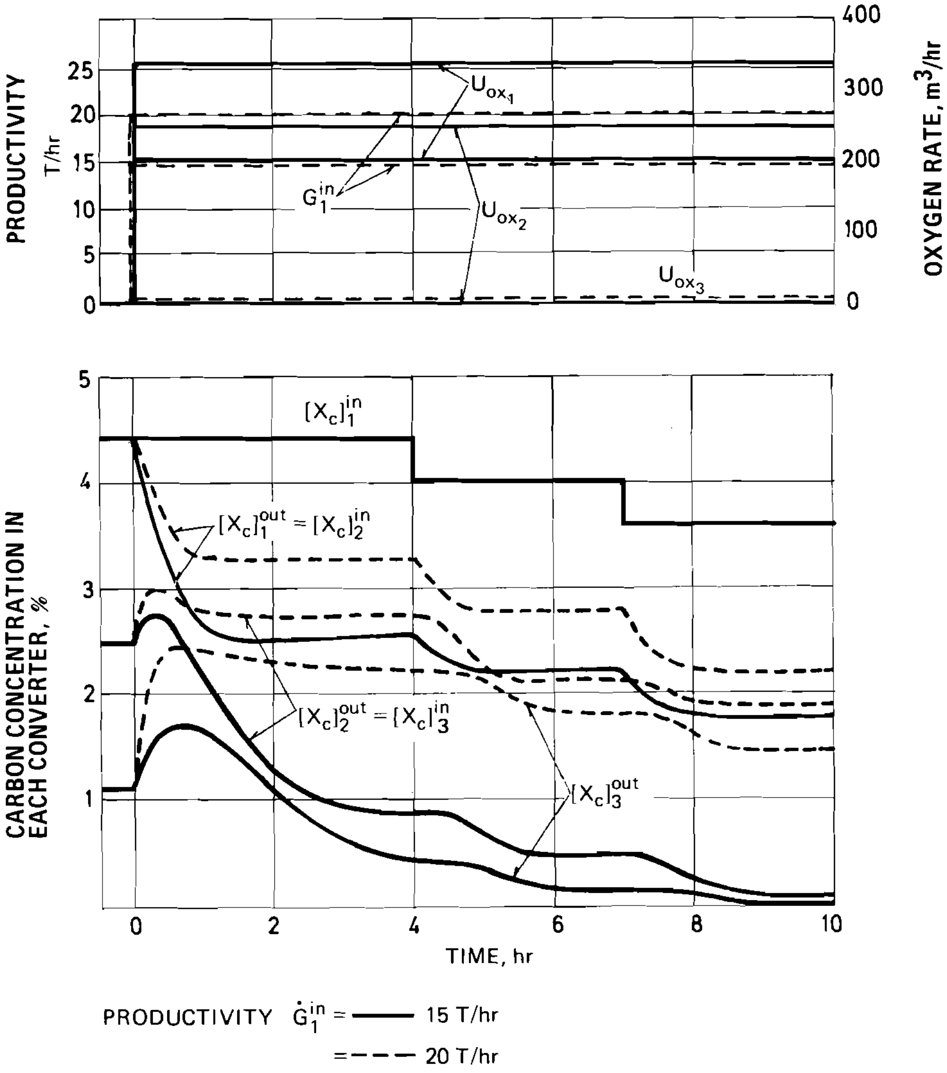


Figure 9.
Source: [8]

For this purpose the model can be solved off-line, and can have any complexity; process data can be made available for model adaptation; solution time is unlimited; demand for model accuracy is not high. Taking these constraints into consideration, the combined experimental and analytical approach can be used to develop the mathematical model (see AB in Figure 6). Figure 10 shows the scheme of the model.

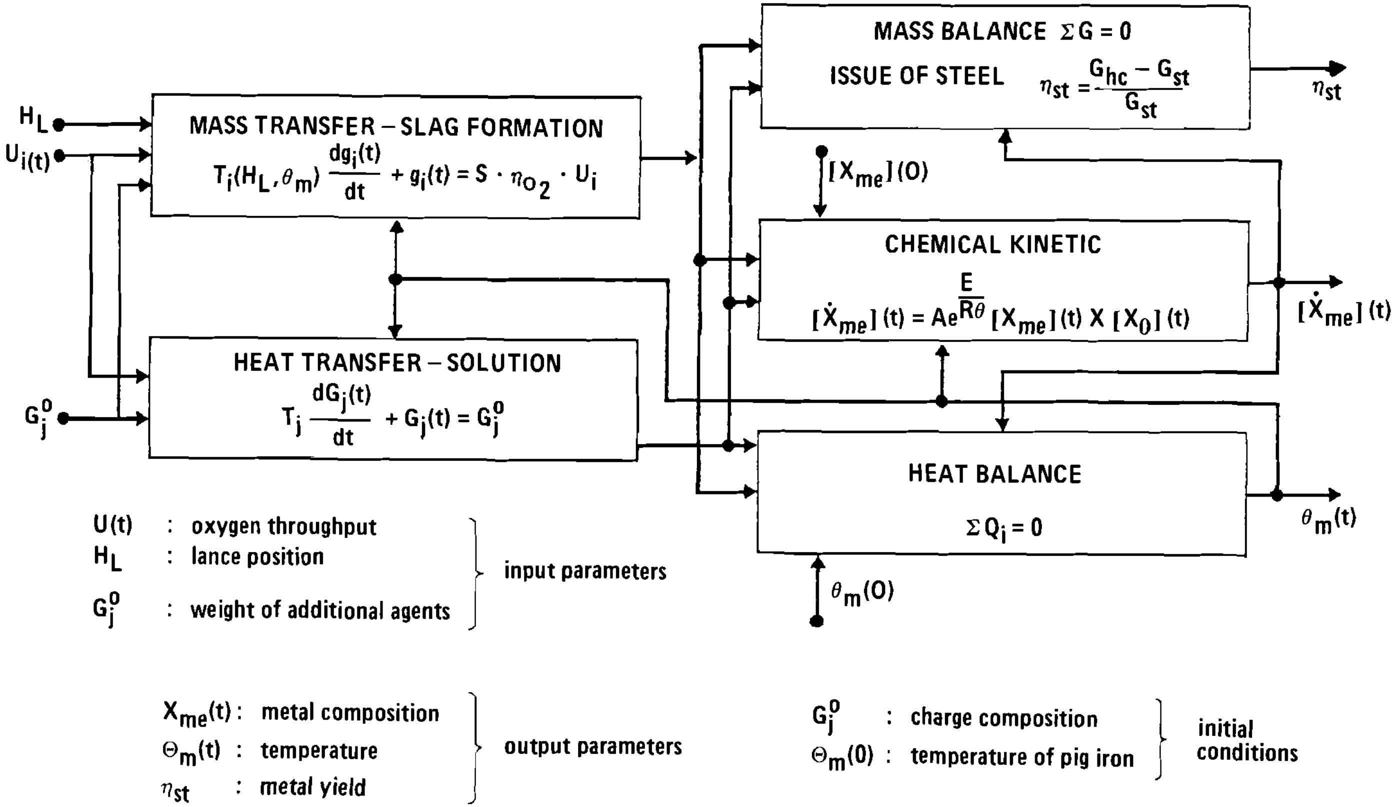


Figure 10.
Source: [8]

The model is a system of 48 linear and nonlinear equations including 13 differential equations. Two types of computers have been used for solving this model: an analog computer for the structural identification of the preliminary model, and a universal computer for detailed simulation of different types of technology.

Figure 11 shows one result of this investigation. The modern trend in BOF technology is to increase the specific oxygen consumption from 2 to 6-7 $m^3/t/min$ in order to increase

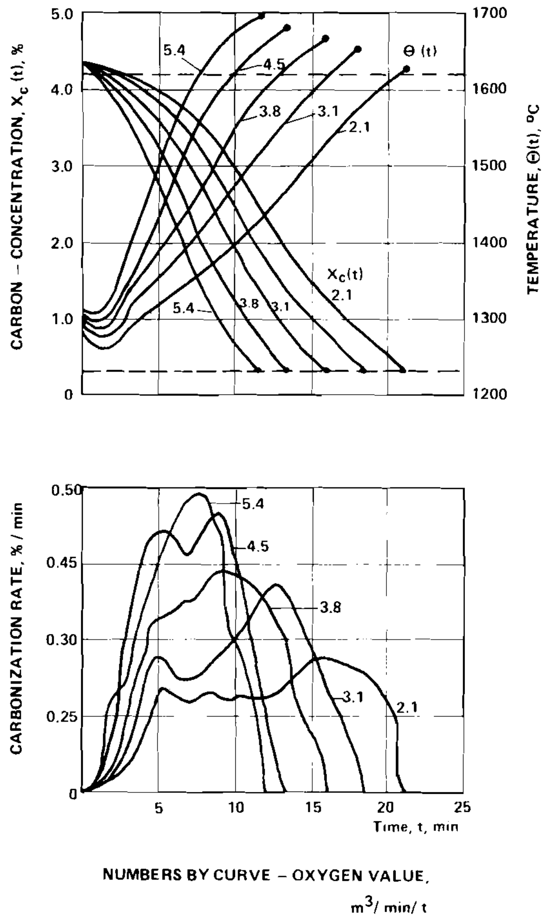


Figure 11.

productivity. This increase has a number of consequences; for example, by increasing the oxygen consumption the metals reach the end-point temperature at a much faster rate than the carbon concentration. The carburization rate may reach 0.60 percent per minute. These data are very important for constructing an exhaust system.

The influence of different parameters on the metal yield has also been investigated. Figure 12 shows the influence of the fraction of scrap in the charge; the maximum yield is obtained with about 25 percent scrap in the charge.

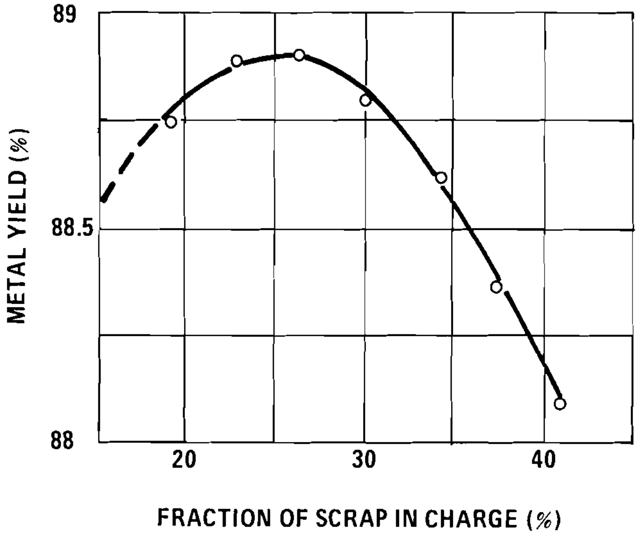
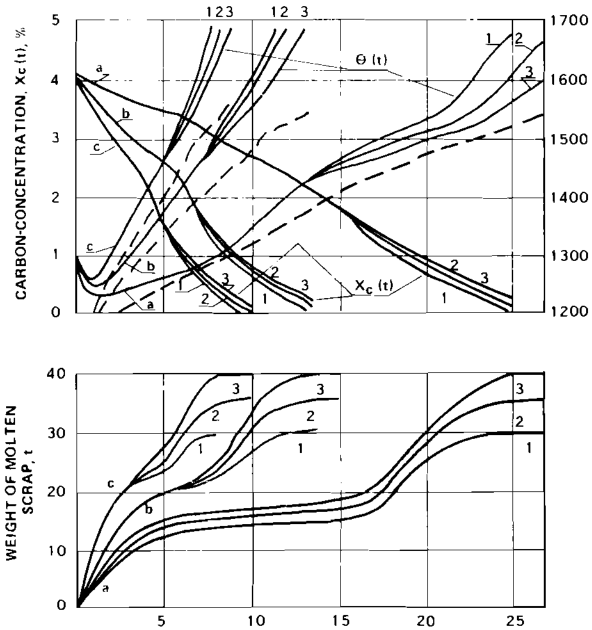


Figure 12.
Source: [8]

Computer application and modeling allows one to study the macroprocesses and the microphysical-chemical processes of BOFs. For this purpose, a detailed model including about 50 linear and nonlinear differential equations was developed on an analytical basis. The practical data have been used for verifying the model.

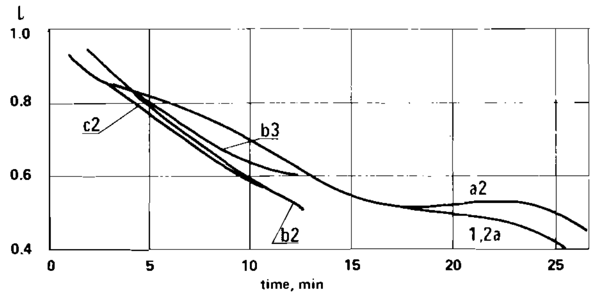
Figure 13 shows the dynamics of carbon oxidation, heating and scrap solution using different oxygen throughputs and the fraction of scrap in the charge. Figure 14 shows the fraction of direct decarburization (in the reaction C + O = CO) in total decarburization. This type of information is very difficult to obtain from other methods (e.g. experimental).



OXYGEN THROUGHPUT, m^3/t min — a-2,1; b-5,0; c-7,0

WEIGHT OF SCRAP IN CHARGE, t (FOR 13t BOF) MELTING POINTS — 1-30,0; 2-35,0; 3-40,0

Figure 13.



OXYGEN THROUGHPUT, m^3/t min — a-2,1; b-5,0; c-7,0

WEIGHT OF SCRAP IN CHARGE, t (FOR 130t BOF) — 1-30,0; 2-35,0; 3-40,0

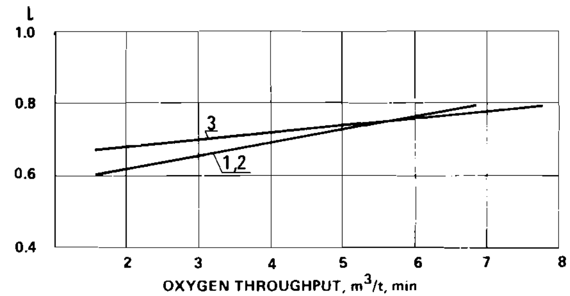


Figure 14.

MODELS FOR ON-LINE COMPUTER APPLICATION

Computer application for *operational control and management* is a broad field that has received attention in the literature (e.g. [6]).

About 80 computer systems are operating in BOFs around the world, based mostly on static models, some (about 20) having also dynamic elements. While there is no doubt that computer application for operational control is economically efficient, only about 15 to 20 percent of all BOFs with a capacity of more than 100 t are controlled by computers. There are several reasons for this including traditional investment difficulties, and technical problems. For example, the lack of sensitivity elements, imperfect models, and the inaccuracy of indirect information make the broad use of computers difficult.

There are several ways to improve the efficiency of computer application for BOF control. The prediction of end-point conditions using the static model and computers makes it possible to improve the techno-economical indices. The extremely dynamic properties of the BOF technology have been taken into consideration in the model.

A dynamic model based on differential equations had been used to predict the behavior and final stage of the process parameters [7,8]. Three kinds of dynamic processes are considered in this model: slag building, oxygen processes, and heat and material balance. The input parameters considered are the oxygen throughput and the amount of any additional resources. The output parameters are the temperature and the composition of the metals. The model is a system of 8th order differential equations. The general structure of the model is shown in Figure 10. There are several unknown coefficients in the model which have to be identified. Because the BOF technology is stocastic and experience plays an important role in this technology, the identification procedure is repeated in each of the production cycles. The data for several previous production cycles may be used for determining the coefficients. With the newly identified coefficients, the subsequent production cycle can then be predicted on the basis of this model.

The model and adaptation algorithm was solved on a universal computer and the time required for this solution was 0.5 minutes, which is acceptable for a given production cycle. The dynamic model is more accurate in this case.

Since the BOF is an integrate part of large-scale industrial complexes, one purpose of operational control is to coordinate the operations of BOFs and other complexes. For example, let us consider the coordination of BOFs and CCMs. The duration of the BOF and the CCM cycles differ. To achieve optimal results (e.g., maximizing productivity), the frequency of the heat preparation in the oxygen converter complex should correspond to the productivity of the CCM. This is possible to achieve by means of scheduling. The coordinating model and the corresponding algorithm have been developed for scheduling in these complexes [9].

The production cycle being considered consists of three tasks: melting in the BOF, preparing for casting, and casting. The very complex BOF technology is considered a single task within the overall system and simple models can be used to describe this and other tasks in this production cycle.

The number of BOFs and CCMs are considered resources. The objective function is the completion time for all production cycles--e.g., melting, preparation, casting. The model is a relatively easy system of dynamic finite-difference equations.

The algorithm used for solving this problem is based on the successive approximation method and standard procedures. These scheduled models should also be solved in real time in order to predict the actual state of the complexes.

The results of this simulation using real data have been written in the form of a Ghand diagram (see Figure 15). Figure 15 shows the sequence of the tasks for five production cycles of the three BOFs and CCMs studied. The model and the algorithm can be used both for the operational management of the industrial complexes and for design purposes. The optimal number of BOFs and CCMs can be chosen to achieve the required productivity.

PROBLEMS OF INTEGRATION

Developing and implementing an integrated management system is a very difficult problem, especially for integrating existing subsystems that were developed and installed at different times and under different conditions and which are still in operation at the present time. This situation is typical for most steel companies. In some cases there is a tendency to delay integration and to develop only special subsystems.

The integration of subsystems is difficult for a number of reasons: different kinds of tasks requiring solutions at different control and managerial levels, different production shops, etc. The integration of the system, viewed as a large project, cannot be developed and installed in one step. Also, the rapid development of computer techniques makes the subsystems installed initially obsolete. Generally, this is a financial problem which many firms give a low investment priority.

The concept of integrated management systems is well developed in a number of steel firms and also in some non-steel organizations. The state-of-the-art review of integrated control systems for the steel industry was prepared by IIASA, based on a study of international experience [2]. As a result of this

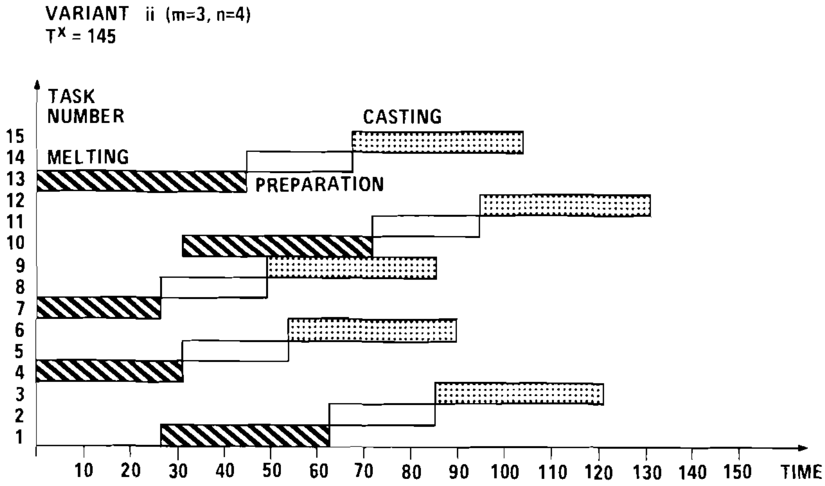


Figure 15a

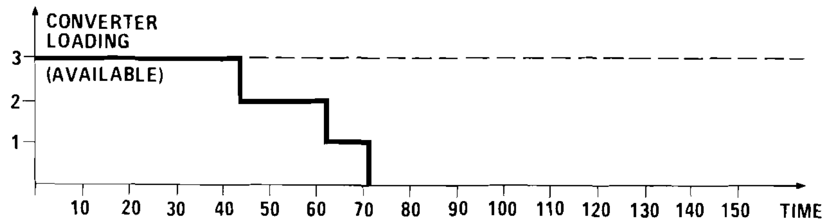


Figure 15b

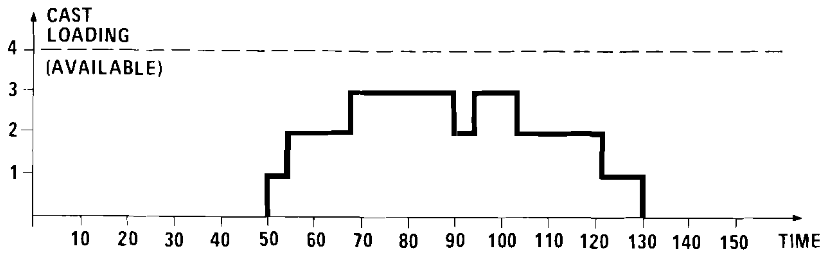
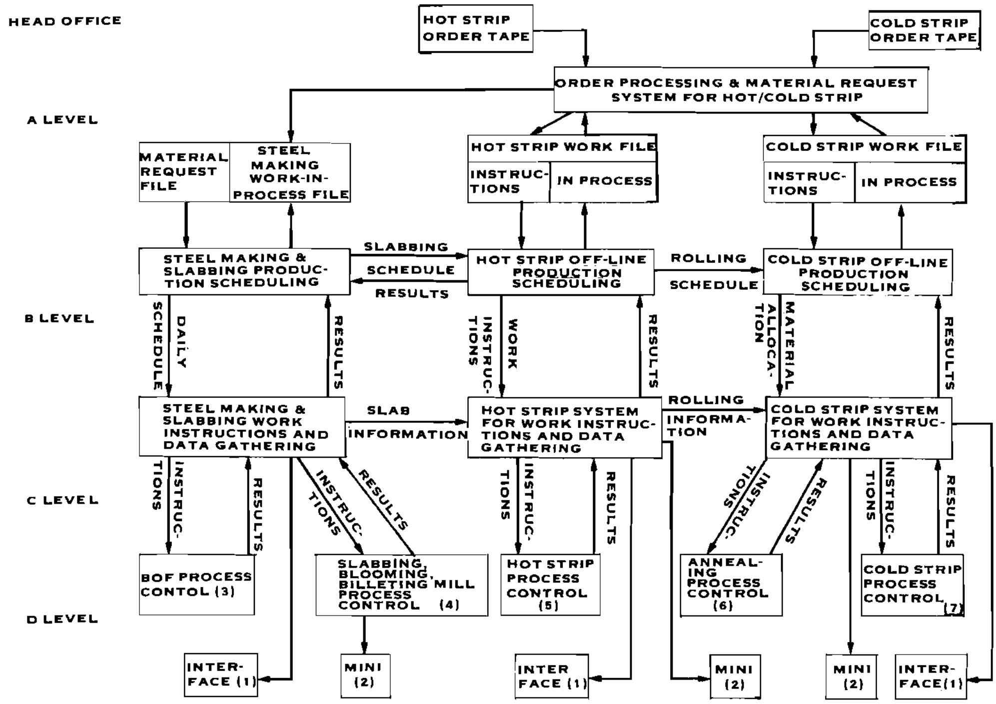


Figure 15c

Source: [8]

study the functional structure of an idealized computer-based integrated system has been developed. An example of such a system is presented in Figure 16. As a rule such systems are organized at three or four levels.



Legend for Figure

(1) Man-machine interface:
includes keyboard, printer display panel, auto I/O signal, etc.

(2) Minicomputer:
Positioning control
Sequence control

(3) BOF control:
End-point control
Charge calculations
Operating instructions
Production control information
technical report

(4) Slabbing, blooming, billeting mill control:
Scheduling
Combustion control
Mill setting and sequence control
Production control information

(5) Hot strip mill control:
Reheat furnace control
Mill pacing
Mill setting
Adaptive control
Spray control
Coiler setup
Technical report

(6) Annealing process control:
Combustion control
Timing control
Production control information
Technical report

(7) Cold strip mill control:
Mill setup
Adaptive control
Tension control
Automatic sequence control
Technical report

Figure 16. Computerized control system for modern steelworks.

Source: [2]

There are several characteristics of the system worth noting here.

The system is hardware oriented; each block denotes the functions carried out by a separate computer. There is an ordering with respect to the size and number of computers employed at each level; i.e., there tends to be fewer separate computers but of progressively larger size as we proceed up the hierarchy. Indeed, at the lowest level, there are a number of minicomputers assigned to special purpose tasks.

The consideration of hardware has not been a dominant factor in the hierarchical structure developed here, and is not explicit in the formulation.

The information flow follows the general pattern of the hierarchical structure: decision and control actions proceed from supremal to inferior control units, and there is information feedback on the results of prior actions. Information also flows horizontally whereby interacting units at the same level receive information on decisions of other units that affect their decisionmaking.

The man-machine interfaces are a very explicit and important part of the integrated system. This again reflects the hardware orientation; in our formulation of the system, the operator-computer communication requirements are implied through the information processing functions.

Other aspects of the system structure (e.g., consideration of the effects of disturbances and contingency events, coordi nating control of interacting production units, and an ordering of decisionmaking according to a time scale) are not shown explicitly on the diagram; however, most of these appear to be an integral part of the functions listed.

Within the framework of IIASA's work on computer application in the steel industry, levels of computerization were analyzed [2]. Eighteen steel firms with about the same annual sales per employee (US $38,000-48,000 per employee) were studied. The level of computerization, expressed as a core memory of installed computers per employee was found to be equal--namely, 73 to 88 bytes/employee, independent of size of plant or firm. For a number of firms or plants this index is higher than average--e.g., Kogevence Estel in the Netherlands and in the FRG with 160 bytes/employee; Kimitzu NSC in Japan with 150 bytes/employee. It is interesting that this index has approximately the same value in other industrial sectors: e.g., chemicals 25 to 120 bytes/employee; machine building 73 to 95 bytes/employee. This technical index does not characterize the socio-economic aspects of computer application.

The level of computerization of the steel industry as a whole can also be described in terms of the cost of the computer installation per million tons of steel produced annually. Table 4 gives these indices for different regions and countries.

Table 4. Cost of computer installation per million tons of steel (in 1000 US $) [10].

Region/Country	Cost
Western Europe	540
USA	520
Japan	790

The Japanese steel industry has a much higher level of computerization as compared to that of Western Europe and the USA for a number of reasons that are connected with special features of the development of this industry in Japan and of the Japanese economy as a whole.

The IIASA study revealed that a completely integrated computer-based management system, designed partly and developed jointly with *new* steel plants, exists only in Japan.

CONCLUSIONS

Computer application in BOFs improves the operational control and the research and development of the existing technology, and aids in the design of a new technology based on BOFs. The systems approach involves formulating the objectives and applying computers for model development, data selection, etc. The consideration of which models may be used for other purposes depends greatly on the objectives achieved.

The task of developing integrated computer based control and management systems, including BOF control subsystems, has been solved only to a very limited degree. Most of the steel firms have an equal level of computerization represented in terms of a core memory capacity in byte per employee.

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Discussion

The discussion opened with a question about how to determine the structure of dynamic models and the type of input-output model information needed. Surguchov gave additional information, stating that the models that are used for operating purposes are the static and the dynamic models. Although the dynamic model may use information about waste gas analysis, the model presented does not. The static model can determine the end-point temperature but not the behavior of temperature and the carbon content during blowing time. The dynamic predicted model presented in this paper makes it possible to calculate the oxygen value, additives, etc. and the behavior and temperature of the carbon content during blowing time, on the basis of the same information used for the classical static model. This is achieved by means of the model structure which is based on nonlinear differential equations; this approach seems to reflect more accurately the dynamic nature of BOFs. More information about the structure of the models can be found in references [7,8] of the Surguchov paper.

Attention then focused on the implementation of the model and its accuracy. The model was not tested on line. The data on about 500 melts that had been previously produced were selected for verification of the model, and a special adaptation algorithm was developed. The number of previously produced melts that could be used for model adaptation was found purely by experimenting, in this particular case four melts is the required amount. The accuracy achieved has been shown in Figure 14. The accuracy of other types of models has been tested only theoretically.

Dynamic and static models can have an error rate of up to 10 percent because of errors in input information. As a result it is impossible to predict the end point without periodic model adaptation. Practically the same adaptation methods were used for controlling the process described in Surguchov's paper.

The participants then turned their attention to the energy consumption of different steelmaking techniques. The rate of consumption depends on the calculation methods used and whether, for example, the blast furnace has been taken into account.

MATHEMATICAL MODELS AND CONTROL SYSTEMS IN BASIC OXYGEN FURNACES

Thermal Considerations in Modeling the LD Process

J. Weniger

INTRODUCTION

VÖEST Alpine has developed a group of models for Linz-Donau (LD) processing that are operating satisfactorily in the plant. A short summary of possible applications of the available models is given here, together with their functions and starting points in relation to the process phases. A fundamental problem of the process modeling has been to understand the thermal behavior of the vessel thoroughly and describe it correctly. With the computer program developed, one can also study the melting of scrap in the vessel. Results of the models are compared with the results of manual handling by the vessel crew.

THE CONCEPT OF LD MODELS

A simplified concept of the operation of the LD models is given by means of an example: Model STAT 1 calculates hot iron weight and scrap weight. This could be changed in the following manner: Model STAT 1a selects from prepared scrap (in the scrap yard) the most convenient combination for this heat, and model STAT 1b calculates the best matched hot iron weight and ore buffer for reaching the desired end-point temperature.

Figure 1 shows the starting points of the models in relation to the actual process phases. The functions of the models are shown in block diagram form in Figures 2 to 4.

THERMAL PROPERTY OF THE VESSEL

A great problem in the development of the process models was to describe the thermal behavior of the vessel in a satisfactory mathematical form. Especially when starting with a cold vessel, the stagnation times between several heating periods (some hours) and other factors have to be respected and calculable from the model. A satisfactory computer program (method of finite elements) has been developed for this purpose.

The following examples show the behavior of the 130 t vessel of the steel plant LD III with the following dimensions:

- outer diameter of the vessel: 6.0 m,
- height of the vessel: 7.0 m,
- vessel mouth diameter: 2.8 m.

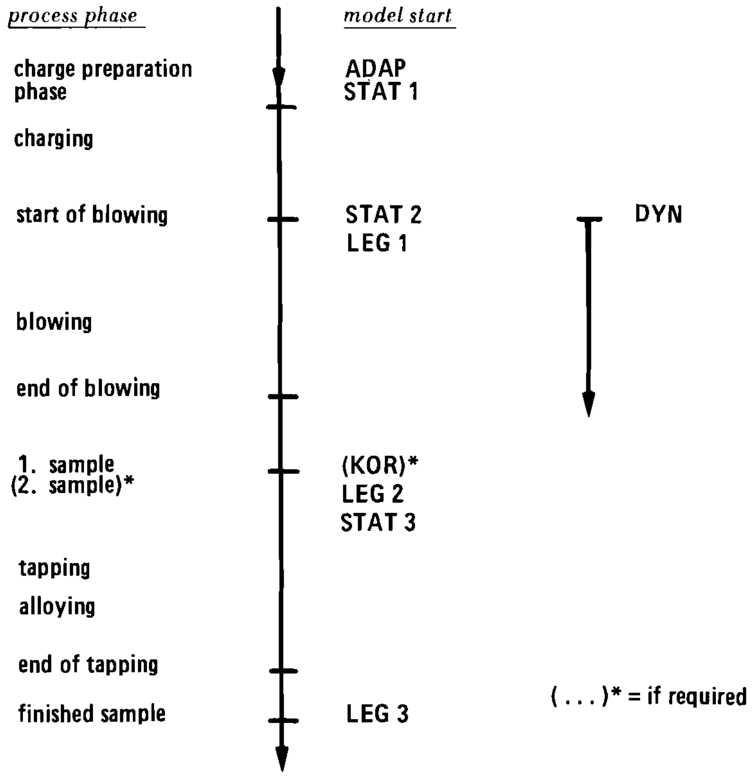


Figure 1. Process phases and model starting points.

During a vessel campaign the wall thickness changes because of burn down of the refractory, and so studies were carried out for wall thicknesses of 400, 500, 600, and 700 mm.

The following boundary conditions were used:

- Vessel outer wall: Free convection and radiation to the surroundings. Coefficients of thermal conductivity for the outer wall are given in Table 1a.

- Vessel inside wall: During the heating period, the vessel inside wall temperature was taken to be a constant 1400 °C. During the cooling period the vessel inside wall temperature was calculated from the radiation and free convection. As all the heat from the inside wall has to leave as radiation through the converter mouth, the coefficients of thermal conduction were calculated from the ratio of the vessel mouth area to the vessel wall area. Coefficients of thermal conductivity of the vessel inside wall are given in Table 1b.

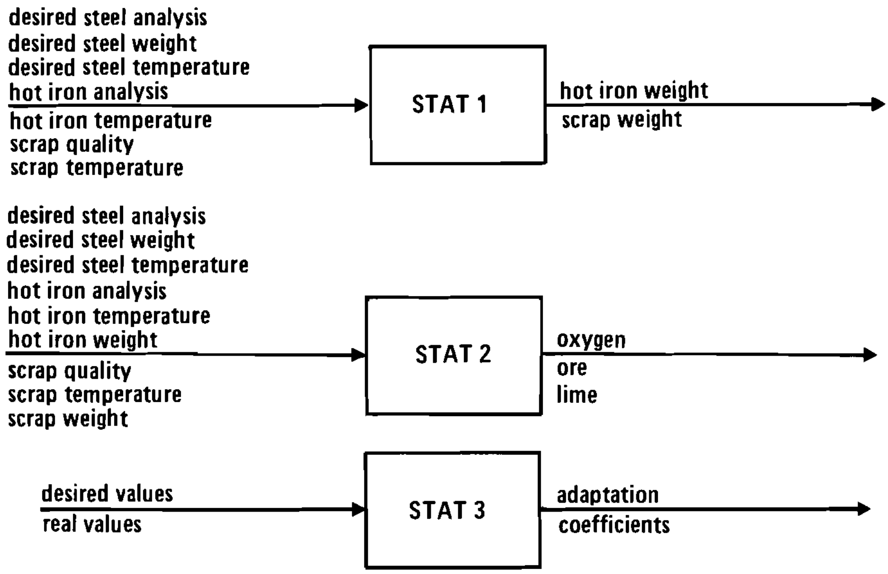


Figure 2. The models as a block diagram.

In the calculation of the thermal coefficients only the magnesite wall material was considered, because the steel part of the wall contributes only slightly to the thermal behavior of the vessel due to its high thermal conductivity. Thermal coefficients for stones of magnesite are given in Table 2a.

Results

The Steady State

The temperature gradients through the wall are shown by the curves plotted in Figures 5 to 8 for various times. The temperature-dependent thermal coefficients result in the weakly curved plot. Some values for wall temperature and heat flow in the stationary state are given in Table 2b.

Cooling From the Steady State

The cooling results from radiation and convection from the inside and outside walls. The thermal behavior was calculated over a period of 48 h. The initial condition was the calculated steady state. The temperature curves are shown in Figures 5 to 8; the amount of heat and the heat flow density are shown in Figures 9 and 10.

At the beginning, the cooling takes place mainly through the vessel mouth (inside wall). After one to three hours (depending on the wall thickness) heat flow through the outside wall predominates.

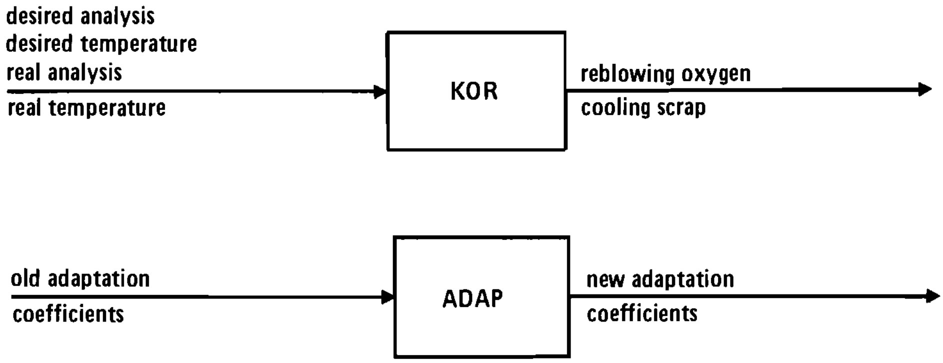


Figure 3. The models as a block diagram.

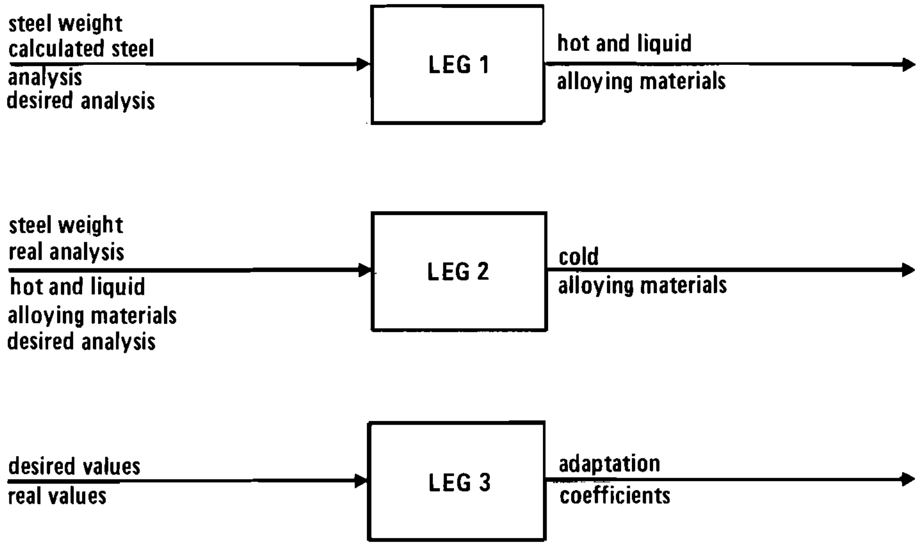


Figure 4. The models as a block diagram.

Table 1. Coefficients of thermal conductivity.

(a) outer wall

wall temperature (°C)	0.0	200	400	800	1100	1400
α (W/m² °C)	8.0	19	35	80	155	260

(b) inside

$$\alpha_{radiation} = \frac{\varepsilon * \sigma * (T_W^4 - T_L^4)}{T_W - T_L} \qquad \frac{W}{m^2\ ^oC}$$

$$\sigma = 5.8 \times 10^{-8} \quad W/m^2\ ^oC^4$$

$$\varepsilon = 0.75$$

$$T_L = 300\ K\ (27\ ^oC)$$

$$\alpha_{convection} = 20 \quad W/m^2\ ^oC$$

$$\alpha = \alpha_{radiation} + \alpha_{convection}$$

wall temperature (°C)	200	400	800	1100	1400
α (W/m² °C)	1.7	2.3	5.1	8.9	14.5

Table 2. (a) Thermal coefficients for magnesite.

Temperature (°C)	0	500	900	1100	1500
Thermal Conductivity λ (W/m°C)	5.5	3.75	2.6	2.2	1.64
Specific Heat Capacity (J/kg °C)	840	1080	1220	1210	1170

density = 2000 kg/m³

(b) Wall temperature and heat flow in the stationary state.

Thickness wall (mm)		700	600	500	400
Wall Temperature (°C)	inside	1400	1400	1400	1400
	outside	244	261	282	309
Heat Flow	(kW)	533	605	704	847
	(kcal/h)	458,300	520,200	605,300	728,300

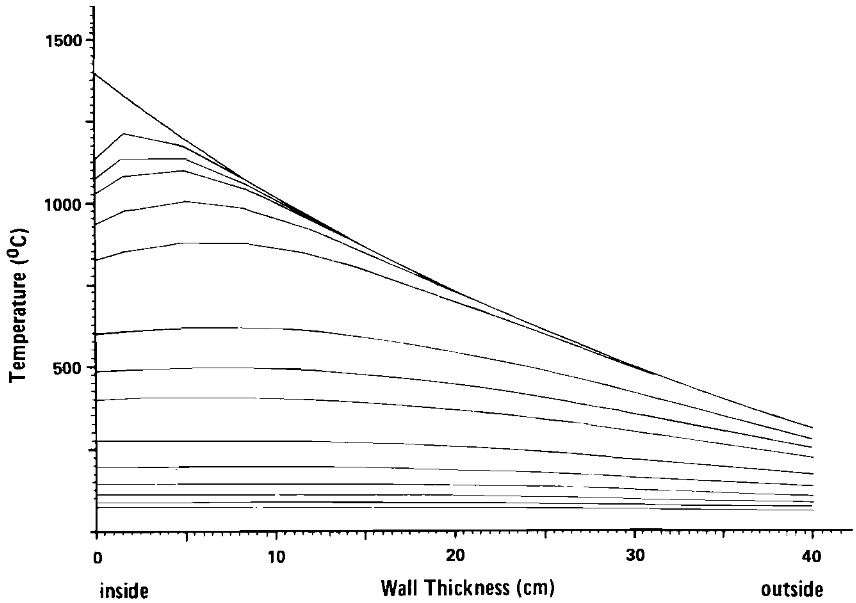


Figure 5. LD - Converter, cooling down from the steady state; wall thickness = 400 mm.

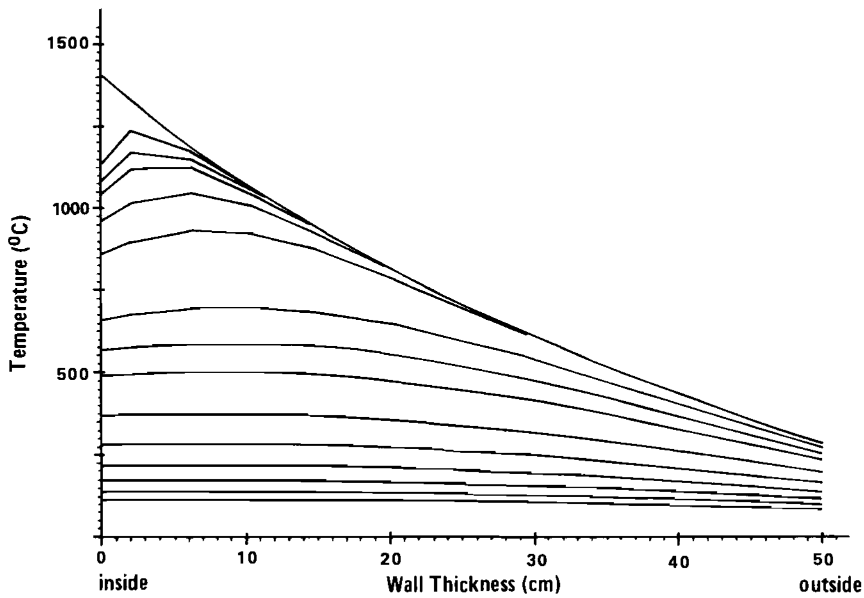


Figure 6. LD - Converter, cooling down from the steady state; wall thickness = 500 mm.

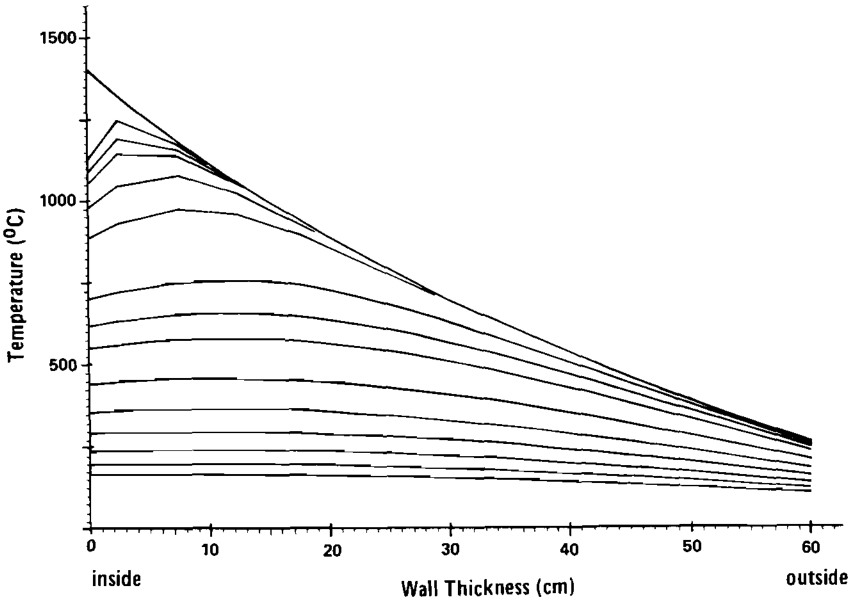


Figure 7. LD - Converter, cooling down from the steady state; wall thickness = 600 mm.

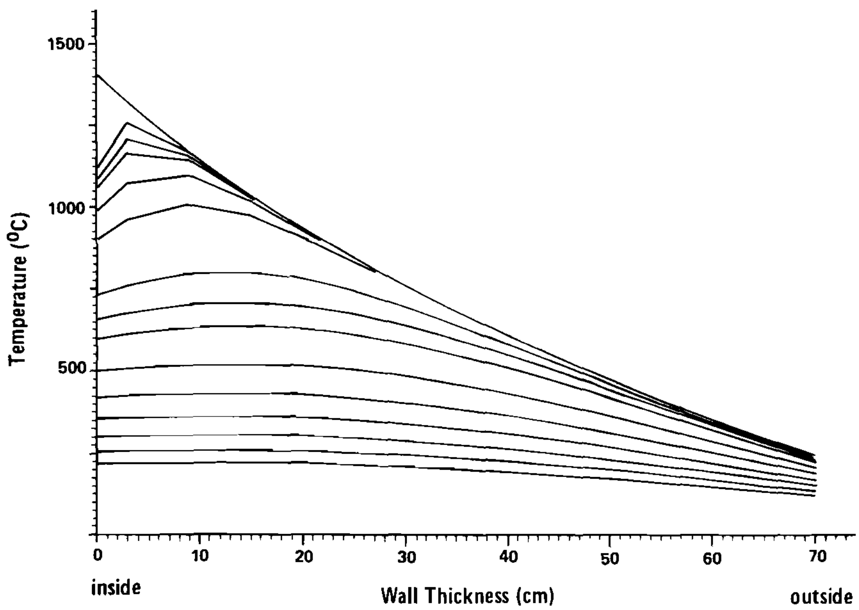


Figure 8. LD - Converter, cooling down from the steady state; wall thickness = 700 mm.

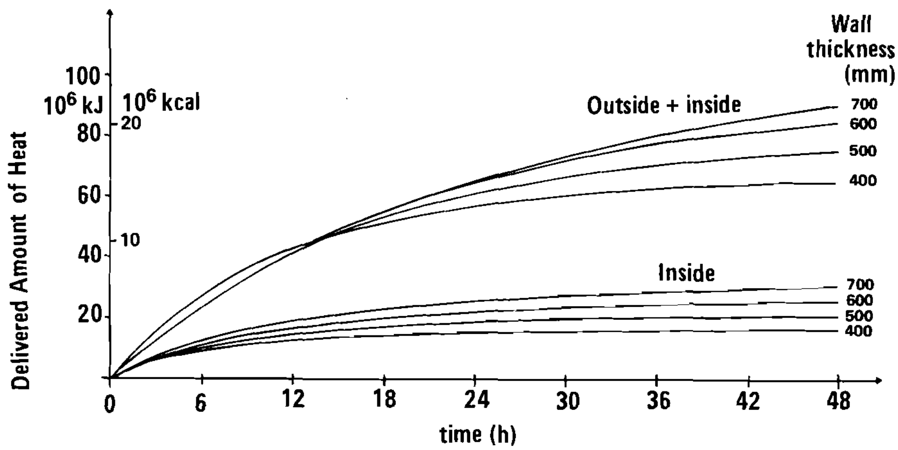


Figure 9. Cooling down from the steady state: LD-Converter.

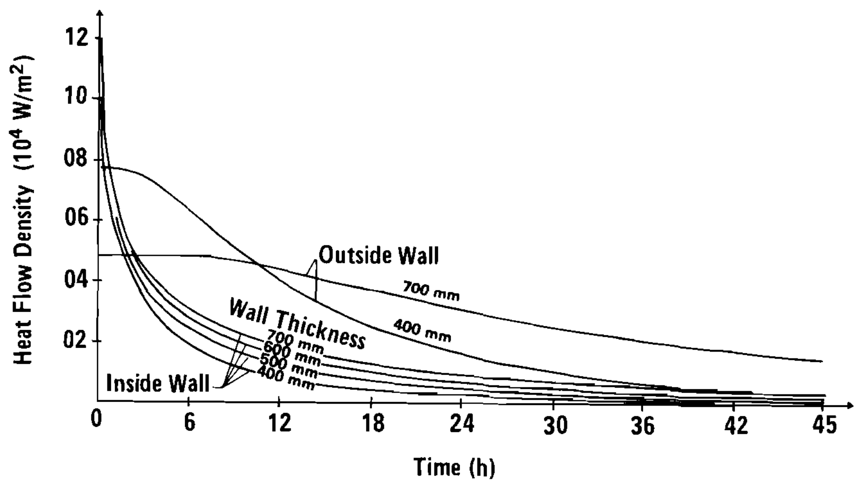


Figure 10. Cooling down from the steady state: heat flow through the vessel wall.

Heating After a Stop of 48 Hours

The initial condition is the final state calculated above. The heating is performed up to a determined vessel inside wall temperature of 1400 °C. The temperature gradients are plotted in Figures 11 to 14. Heat flow density and amount of heat are shown in Figures 15 and 16.

At the beginning of the heating process the energy is stored in the converter wall; when the steady state is reached, i.e. after 24 h for a wall thickness of 400 mm, constant heat emission takes place.

Of course, all possible cases can be simulated with this program, e.g. other wall temperatures, heating up after a stop of various durations, other vessel dimensions, etc.

Now we incorporate the results discussed above in various ways into the process models. Equations (1) to (3) show a simple example.

$$Q_w = \frac{Q_A}{Q_B} + \frac{Q_C\left(T_A+T_B+T_C\right)}{Q_D} + \frac{Q_E\ T_A}{\left(T_A+Q_F\right)\sqrt{Q_D}} + \frac{Q_G\ T_C}{\sqrt{Q_D}} \qquad (1)$$

$$Q_D = 1 - \frac{Q_I}{Q_H}\left(1 - Q_J\right) \qquad (2)$$

$$Q_U = \left(T_S - T_E\right) C_K \qquad (3)$$

The terms are defined as follows:

Q_w , heat loss from the vessel;

Q_A , starting correction for a cold vessel;

Q_B , number of heatings after the start with a cold vessel;

Q_C , mean loss of heat by conduction through the wall of the new vessel;

Q_D , wall thickness;

Q_E, Q_F, Q_G , radiation constants;

Q_H , mean number of heats per vessel campaign;

Q_I , actual number of heats in the vessel campaign;

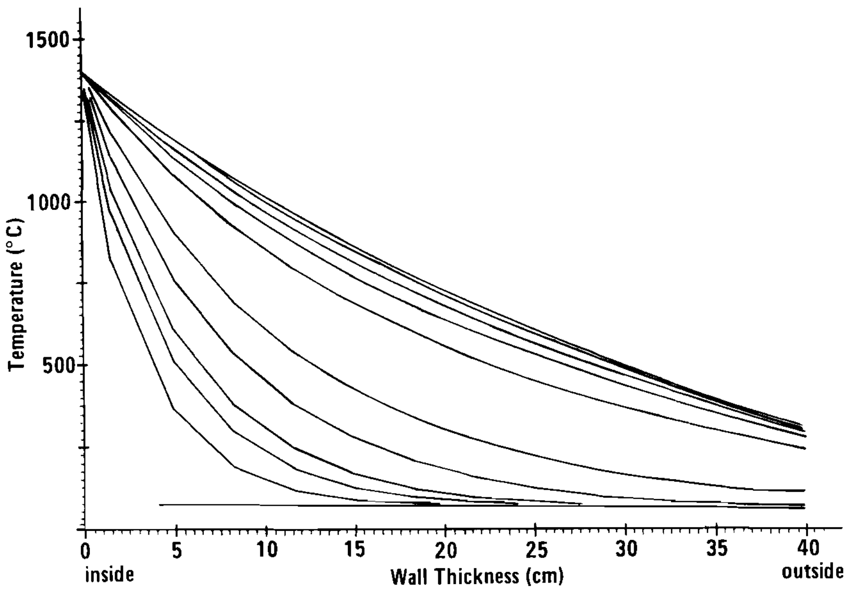


Figure 11. LD-Converter, heating up after a stop of 48 hours; wall thickness = 400 mm

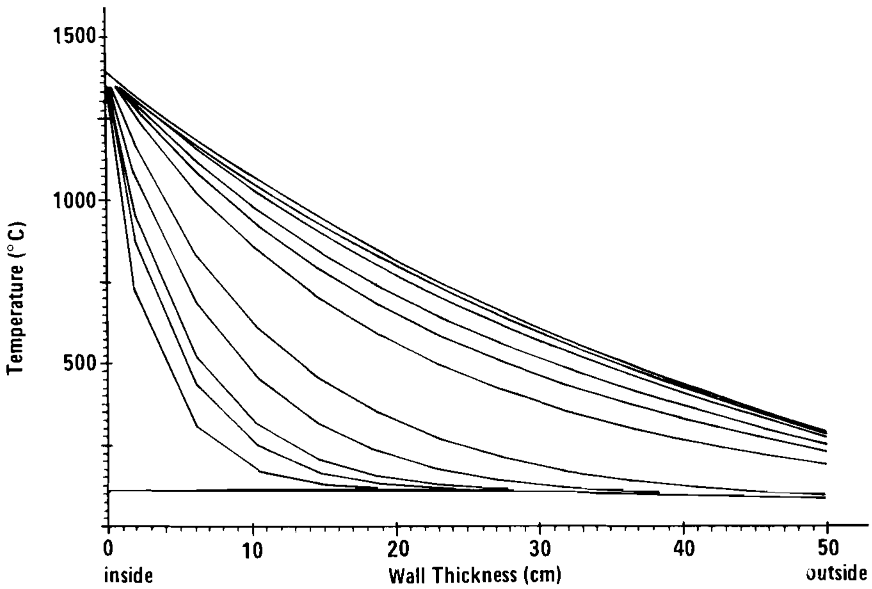


Figure 12. LD-Converter, heating up after a stop of 48 hours; wall thickness = 500 mm.

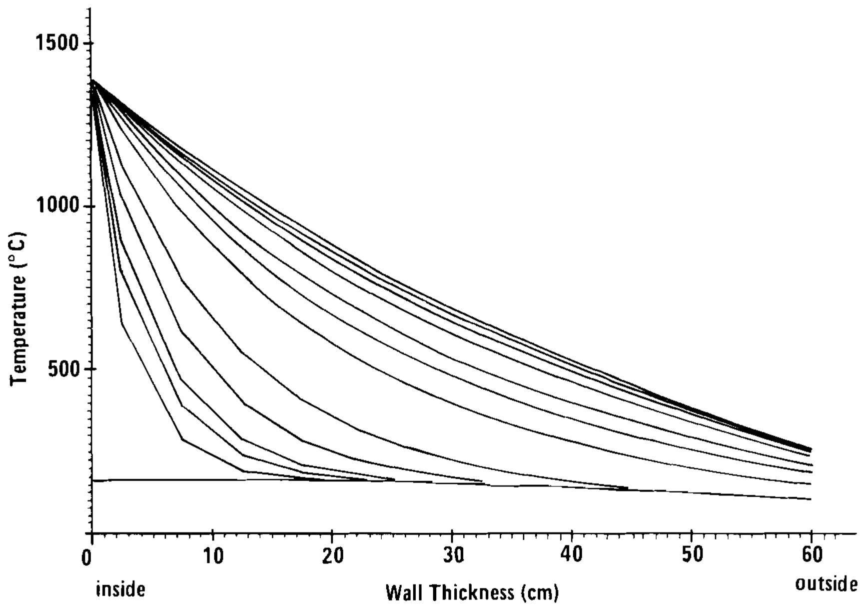


Figure 13. LD-Converter, heating up after a stop of 48 hours; wall thickness = 600 mm.

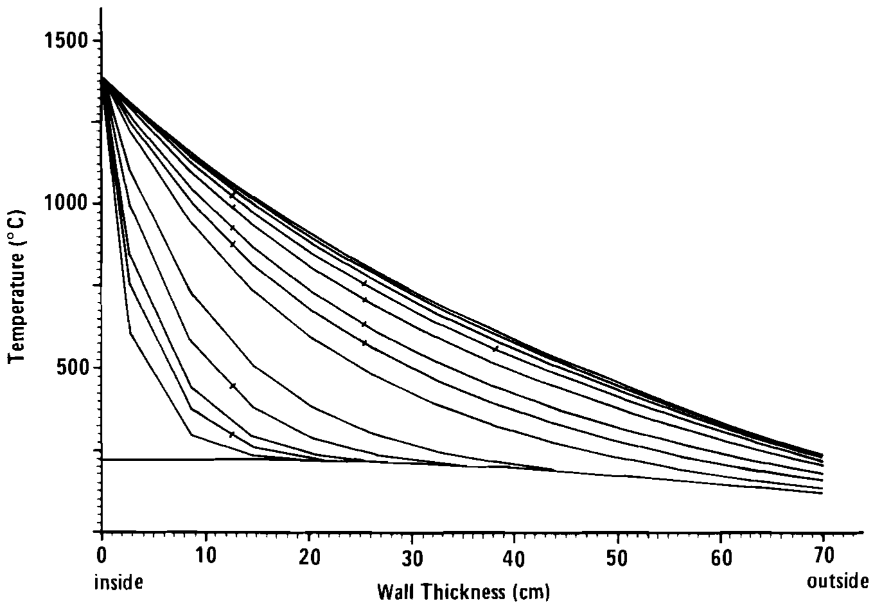


Figure 14. LD-Converter, heating up after a stop of 48 hours; wall thickness = 700 mm.

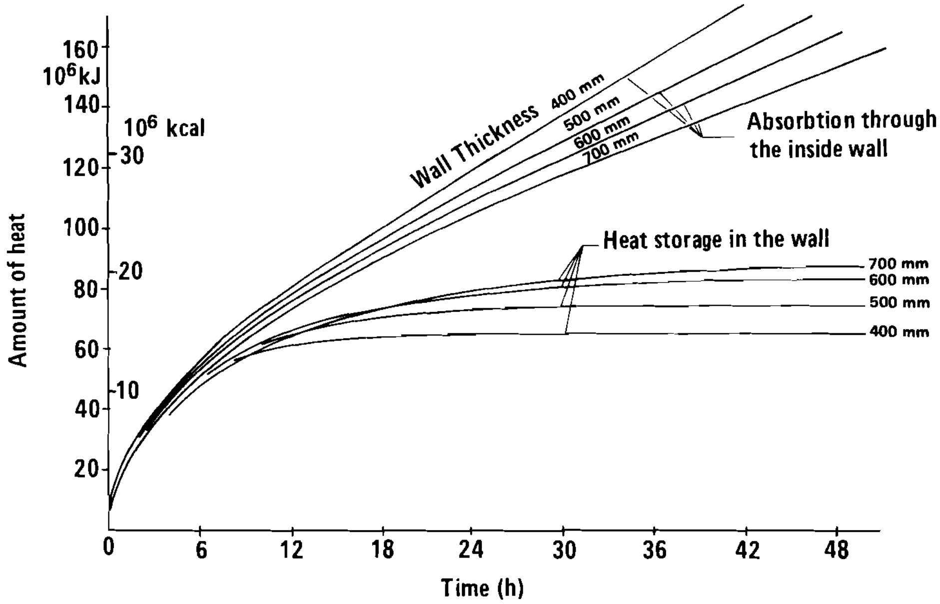


Figure 15. Heating up after a stop of 48 hours: LD-Converter.

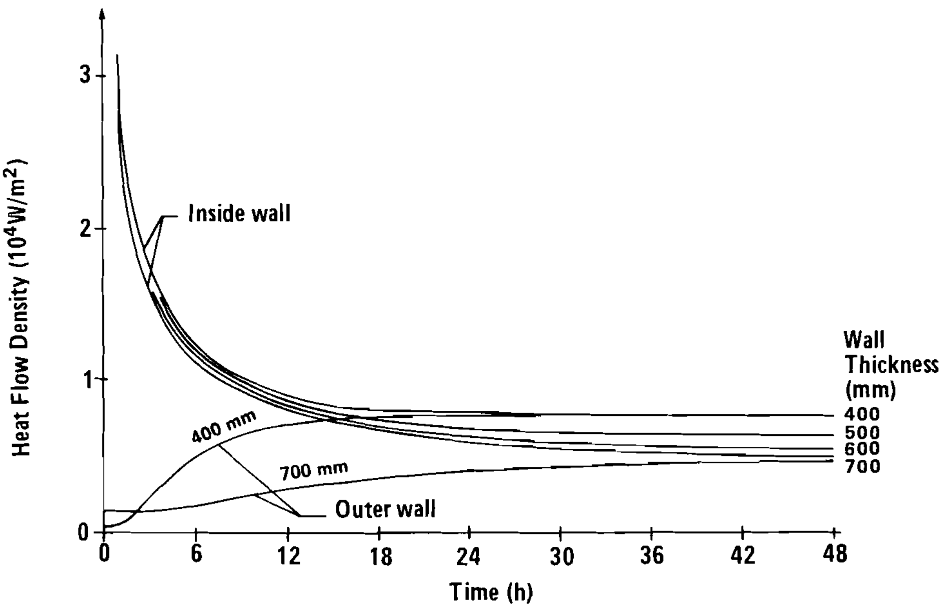


Figure 16. Heating up after a stop of 48 hours: heat flow through the vessel wall.

Q_J , wall thickness at the end of a campaign as a percentage of the starting wall thickness;

T_A , time between the end of tapping and the start of blowing;

T_B , blowing time;

T_C , time between the end of blowing and the temperature measurement;

C_K , specific heat capacity of the thermally active part of the vessel wall;

Q_U , heat transferred from heat n - 1 to heat n;

T_E , end temperature of heat n - 1;

T_S , desired temperature of heat n.

MELTING SCRAP IN THE BATH

A further problem consists of the melting of scrap in the bath during the blowing period. Particular difficulties occur with catch charges with high carbon content. In fact, since scrap melting is a function of time, the blowing period must be as long as the scrap needs for melting; alternatively one must restrict the quantity of scrap in proportion to length of the blowing period.

The melting of a scrap plate 15 cm thick is illustrated in Figures 17 and 18. The boundary conditions have been chosen such that complete melting of this scrap plate takes place within about 15 min. Figure 19 shows the specific heat capacity of the scrap and Figure 20 the heat conduction used. The phase transitions and the region of crystalline transformation of the scrap during the whole blowing period can be seen distinctly.

Next, the behavior of a scrap wheel was computed for the same boundary conditions. The results are shown in Figures 21 and 22.

Figures 23 and 24 show the melting of the surfaces as a function of time for the plate and the wheel, respectively.

THE RESULTS OF A NINE DAY TEST PERIOD

Last year in steel plant LD III we had a nine day test period to compare the end-point temperature reached manually by a well-trained vessel crew and that computed with the newly developed process models. Only steels with low carbon content (about 0.05 % C) were produced.

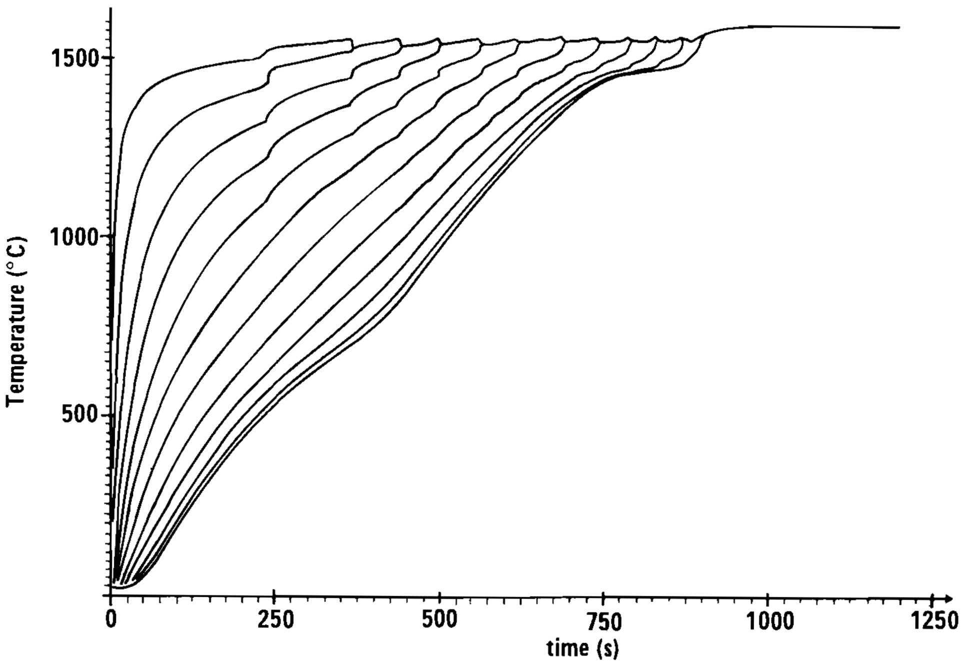


Figure 17. Melting of a 150 mm thick scrap plate: temperature distribution.

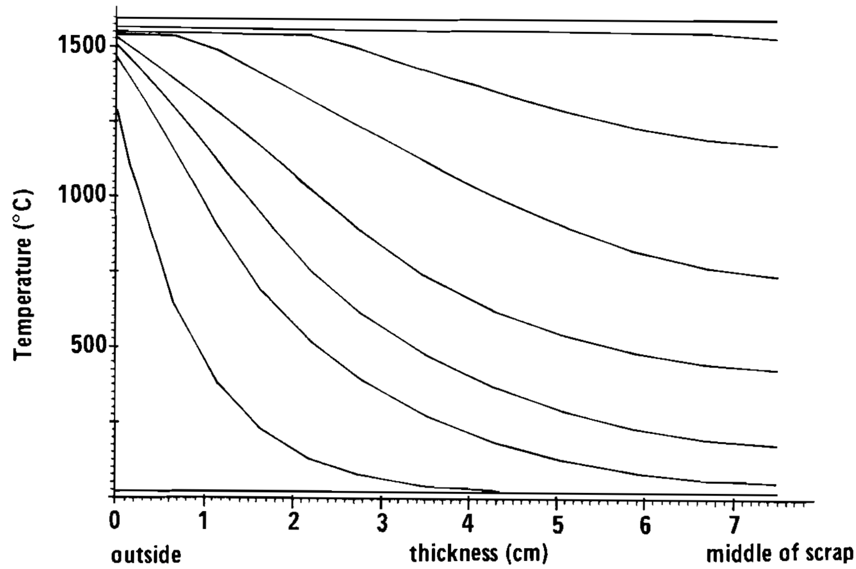


Figure 18. Melting of a 150 mm scrap plate: temperature distribution.

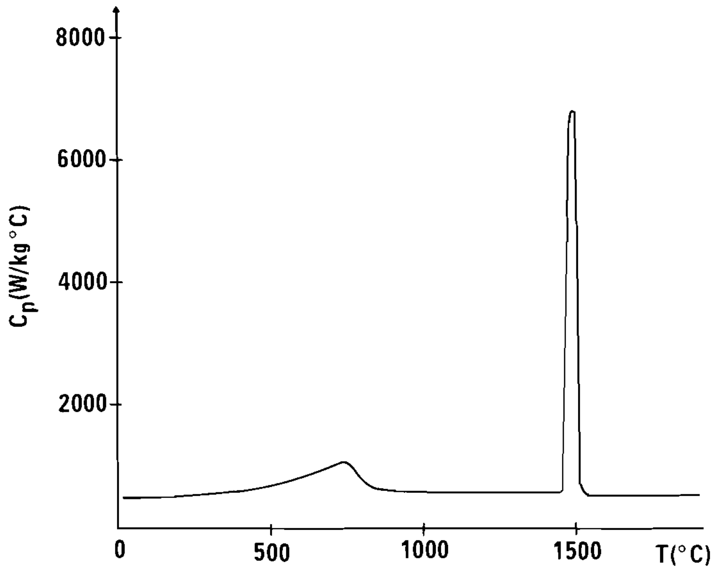


Figure 19. Specific heat capacity.

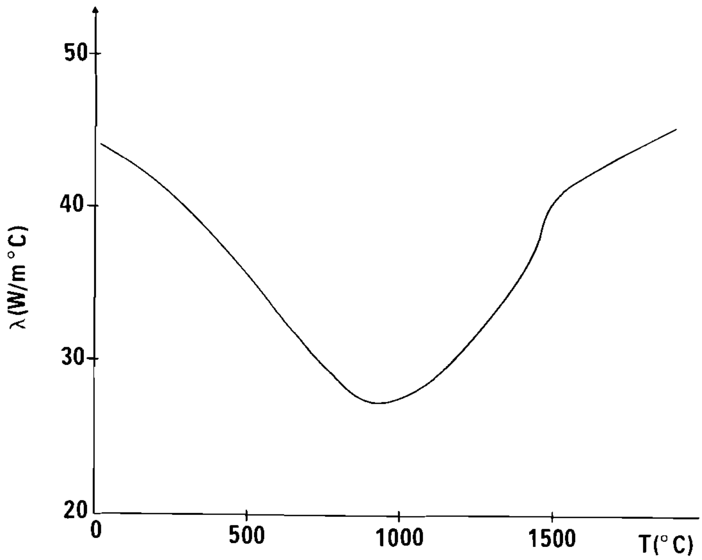


Figure 20. Heat conduction.

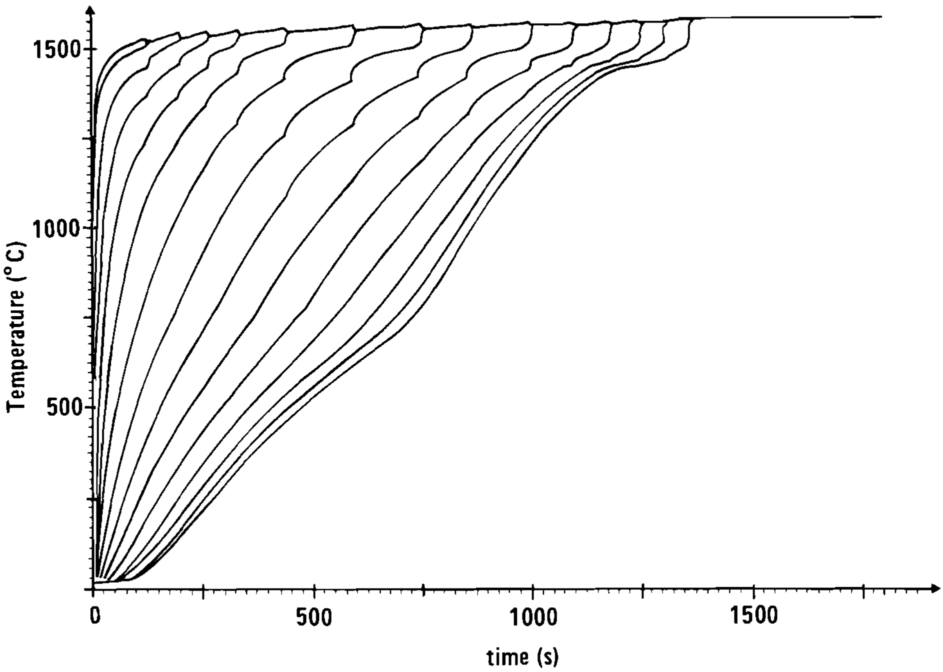


Figure 21. Melting of a scrap wheel of diameter: 300 mm: temperature distribution.

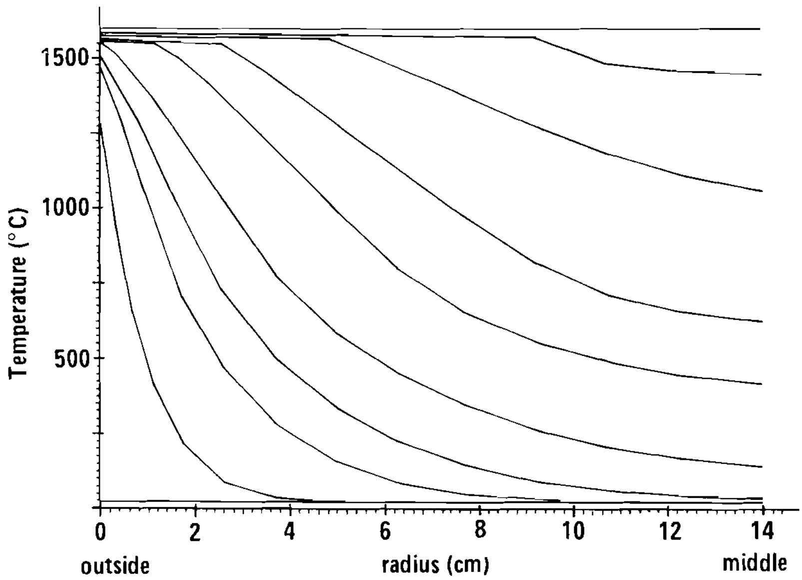


Figure 22. Melting of a scrap wheel of diameter: 300 mm: temperature distribution.

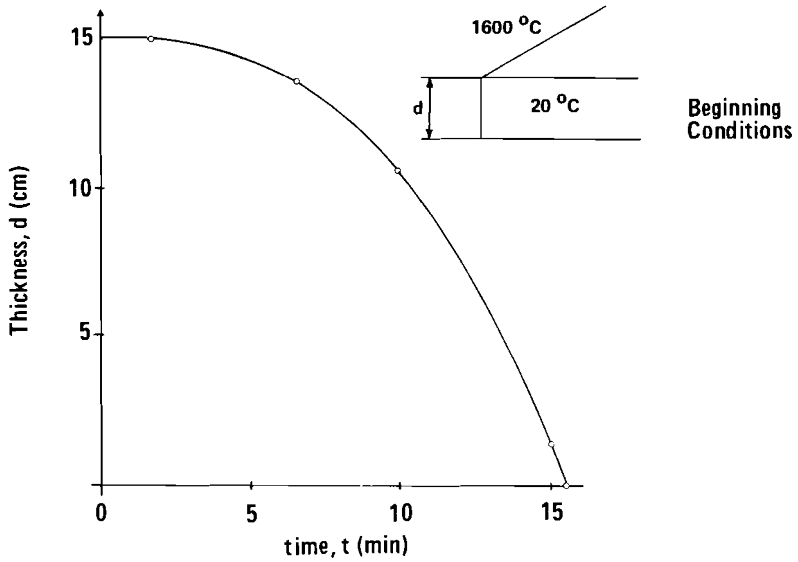


Figure 23. Melting of a scrap plate.

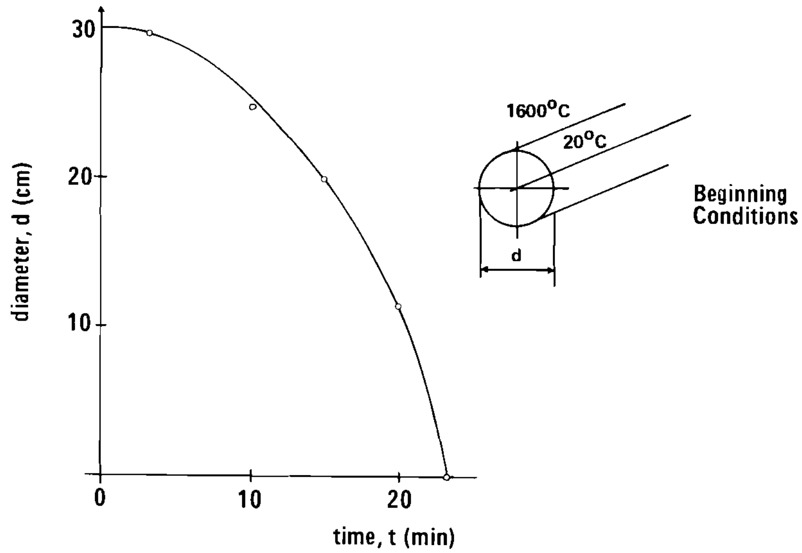


Figure 24. Melting of a scrap wheel.

For the first six days of the test, the adaptation model was not used, because we wanted to control the stability of the model; it was only used for the last three days. The process model calculated the quantities of hot iron, scrap, ore, and lime to insert, while the vessel crew fixed these quantities by their own methods without considering the computed values. The model calculated for these inputs the probable temperature obtained if the amount of oxygen calculated from the model was blown. The standard deviations of the several days were calculated as follows:

$$\Delta T_{hand} = T_{real} - T_{desired} \quad ,$$

$$\Delta T_{model} = T_{real} - T_{model} \quad ,$$

$$\bar{x} = \frac{1}{n} \sum \Delta T,$$

$$S = \sqrt{\frac{1}{n-1} \sum_i (x_i - \bar{x})^2} \quad .$$

The results are shown in Figure 25. The similar behavior of the standard deviation curves of temperature are probably

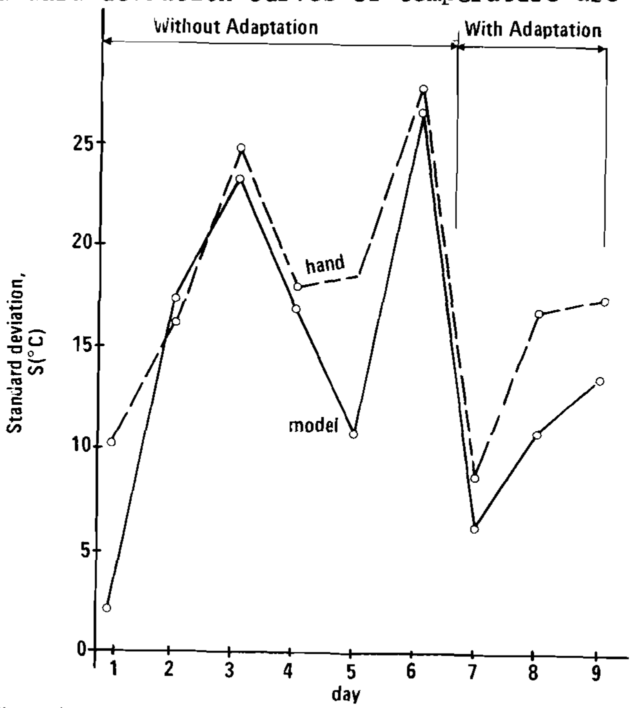


Figure 25. Temperature standard deviation comparison: model and hand.

caused by measurement errors (hot iron analysis, hot iron temperature), unknown scrap composition, etc. Unless these measurement errors can be reduced, greater efforts in trying to improve the accuracy of the process models will not give better results.

Discussion

Heat loss from the vessels is very important from the control and investigations points of view. Several issues were raised about the decrease in temperature during the time the converter is inoperative. It was pointed out that the model discussed in the previous paper takes into consideration a number of factors that affect the temperature behavior of the converter when inoperative. The most important factor influencing temperature decrease is the wall thickness which, for example, can vary from 40 to 70 cm.

Discussion also centered on factors affecting the end-point temperature. It was pointed out that, from Mannesmann's calculation, the most important factor is the amount of silicon, the second most important is that of carbon, and the third is that of scrap. The calculations by British Steel Corporation (BSC) show that the most important factor is the error in silicon analysis, the second that in carbon analysis and the third that of the hot metal weight. For VÖEST-Alpine, the most important factor is analysis and the second is hot metal temperature. The end-point error depends on the standard deviation of the input factors.

Another important issue discussed was the choice of a representative point for temperature measurement of hot melted scrap. Non-melted scrap makes this temperature measurement difficult. Boundary conditions are a real problem for scrap metal studies. Figures 19 and 20 in the paper by Weniger present specific heat capacity and amount of convection to be used for the calculation. Other boundary conditions concerned scrap configuration. For example, with a thickness of 15 cm, scrap could melt in 15 min. The model makes it possible to calculate the largest scrap dimensions that can be melted within the short blowing time associated with a high oxygen blow. It was pointed out that the model calculation of scrap melting made it possible to correct the measured temperature, however measured; this is of great practical importance.

The Dynamic Control of Basic Oxygen Furnaces

T. Kuwabara

INTRODUCTION

The greatest problem in the basic oxygen furnace (BOF) operation is how to attain the desired steel temperature and carbon content at the end of blowing simultaneously. Various methods have been tried to improve the rate of successful heats. For example, studies on computer static control were started in 1961 at the Yawata and Hirohata Works of Nippon Steel, but this method proved incapable of following the complex reactions involved during blowing in the basic oxygen process. So study started in 1963 on several dynamic control methods.

Since 1968, emphasis has been on the sublance method, which can measure representative values with the highest accuracy. Success was first achieved in temperature control at Muroran Works--the desired temperature was attained with a success rate of 85 percent, compared with the previous 60 to 70 percent. Then, a number of improvements and developments, in both hardware and software, were made to this technique, and eventually Nagoya Works achieved a successful heat rate of more than 90 percent.

The system is a completely closed-loop dynamic control one by which all steps of the BOF process are automatically carried out at the push of a button. It is referred to as the controlled quick tap (CQT) system and this paper now describes the CQT system as it operates at the Nagoya and Kimitsu Works.

THE PRINCIPLE OF THE CQT SYSTEM

The BOF process makes it possible to obtain steels of high temperature and low carbon content through the heat evolved when oxygen is blown into a low-temperature and high carbon content molten bath (comprising scrap and hot pig iron) containing inflammables such as carbon and silicon. As the solid line in Figure 1 shows, the conditions of the bath vary during this operation, i.e. its temperature rises gradually from the initial stage, while its carbon content lowers sufficiently to meet the aimed specifications of the steel. However, owing to factors that cannot be easily controlled, such as fine elements in molten pig iron, partial dissolution of the vessel lining, and the shape of the scrap, the condition of the molten steel at the end of the blowing can vary greatly. As a result, the attainment rate for aimed ranges is as low as about 50 percent. As shown by the dashed curve in Figure 1, dynamic control is a system where, by measurement of the carbon content and temperature with a sensor lowered into the bath during the course of blowing, the amount of oxygen blown in and of iron ore charged can be adjusted so as to attain final conditions of the bath within the aimed range. This system is more or less analogous to that of a moon rocket launched from the Earth (corresponding to the first bath) whose course is adjusted from knowledge of its exact position when it approaches the moon (corresponding to the bath condition at the end of blowing).

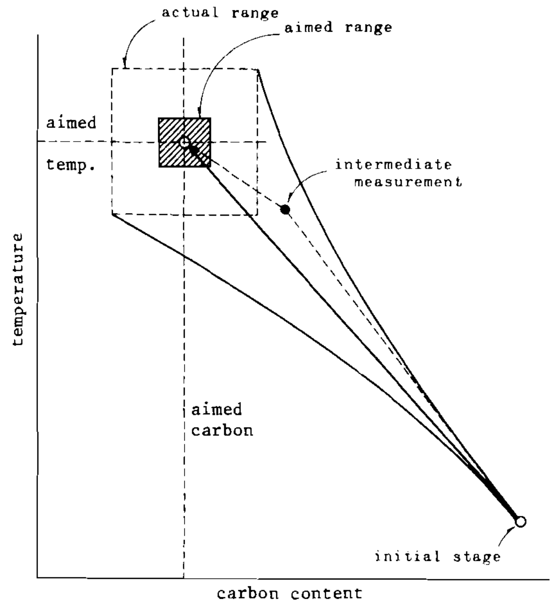


Figure 1. Principle of dynamic control.

THE TECHNIQUES TO BE DEVELOPED

The BOF dynamic control system comprises four items:

- A technique to measure representative values,
- A highly accurate sensor,
- Reliable sublance equipment (to transmit the signal from the sensor to the computer), and
- A good dynamic control model.

A Technique to Measure Representative Values

If the measured values of the molten both are not representative of the entire heat, accurate control cannot be achieved. At the time of intermediate measurement, oxygen is being blown and reactions are proceeding. Accordingly, the following special considerations have to be given to securing representative values.

The Timing of the Measurement

The timing of the measurement must be good. When molten steel is below 1540 °C (2815 °F), the measured values cannot be regarded as representative, since scrap may not have melted completely. On the other hand, if the measurement is carried out too late, carbon in the molten steel is so, reduced that the boiling action stops with a resultant lack of thermal uniformity in the bath. The best time to perform the intermediate measurement is when the carbon content in the molten bath is between 0.3 and 1 percent.

The Measuring Position

In determining the measuring position, care must be taken to locate the sublance on the appropriate horizontal and vertical axes, as shown in Figure 2. Horizontally, if the measurement is done in a jet stream of oxygen supplied from the main lance, the measuring sensor will probably be either shocked or instantaneously burnt out. So this critical area must be avoided. Vertically, there exists a considerable temperature and carbon content gradient through the molten bath. So the most representative position must be selected depending on the capacity of the furnace.

The Sensor

The functions of the sensor are:

- detection of temperature,
- detection of carbon content (by measuring solidification temperature), and
- taking of samples for chemical analysis (to check Mn, P, S, etc. content).

As the dynamic control system is dependent on accurate intermediate measurement, the sensor is required to have high sensitivity and reliability. It took more than five years to develop a sensor capable of measuring the carbon content correctly: in order to detect carbon content to the necessary tolerances, an accuracy of solidification temperature, i.e. accuracy of electromotive-force, shown in Table 1, is needed. The accuracy of the thermocouple used in the sensor is maintained at a high level, i.e. -0 to +1 °C at 1600 °C. The solidification curve obtained by the sensor is much affected by the construction of the sensor and so a number of sensors have been tested. A cross-section of our sensor, and curves recorded during blowing are shown in Figure 3.

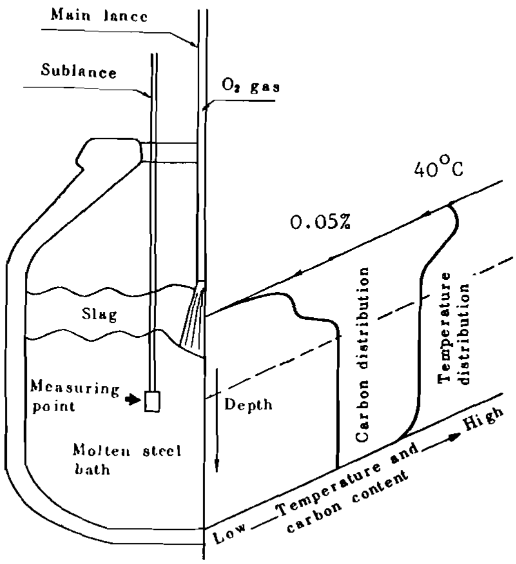
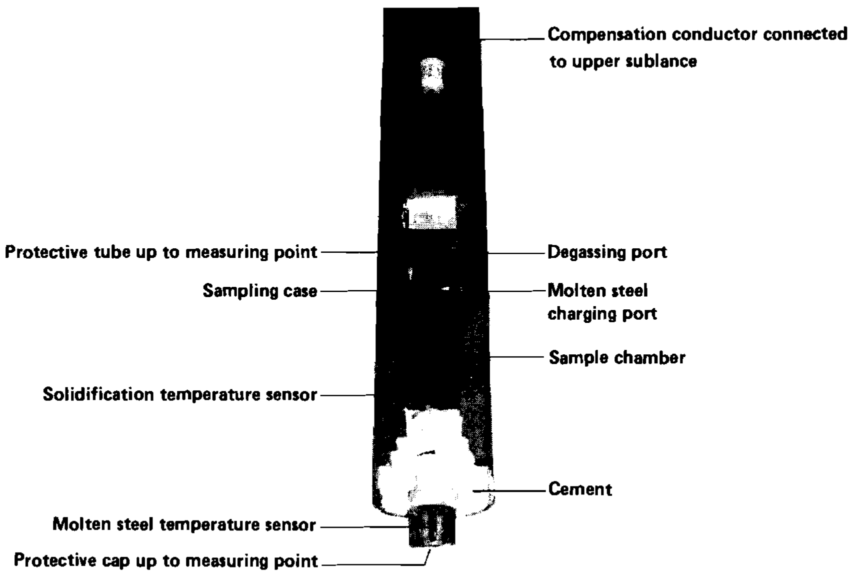


Figure 2. The temperature and carbon distributions and the measuring point.

Table 1. Measurement accuracies required of the sensor.

Measurement Range (Carbon Content in Molten Steel)	Accuracy of Carbon Content	Accuracy of Solidification Temperature	Accuracy of Electromotive Force
1.0% or above	±0.04%	±4 °C	±0.04 mV
About 0.5%	±0.02%	±2 °C	±0.02 mV
0.1% or under	±0.01%	±1 °C	±0.01 mV

(1) Cross section of NSC type sensor



(2) Example of recorded curves during blowing

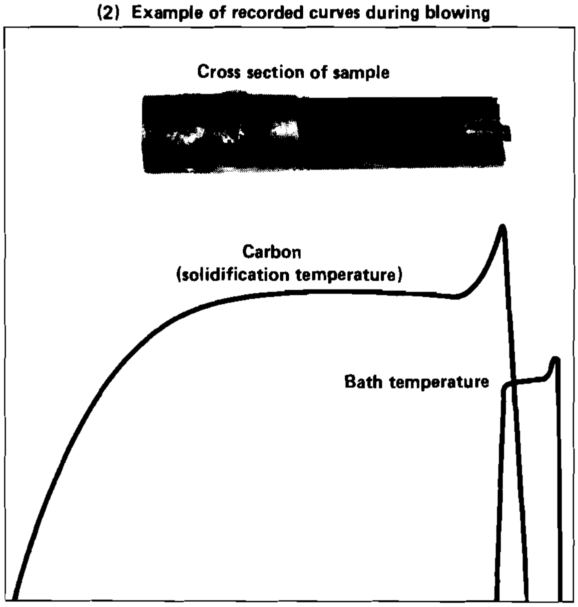


Figure 3. NSC type sensor for CQT.

The Sublance Equipment

The sublance equipment has to be installed in an unfavorable location in the limited space above the vessel where auxiliary facilities are arranged. Nevertheless, as a measuring instrument for control use, the sublance is required to have high reliability and fully automatic operation: measurement is possible only once during blowing. The sublance must operate the moment the computer demands the information. It must reach its measuring position quickly, and stop precisely at that position. In addition, owing to the unfavorable location of the equipment, all operations--from the extension of the sensor to removing samples for chemical analysis--are required to be automatically performed by remote control.

We started developing such equipment and techniques in 1964. After several modifications, two types of sublance, a rotary type and a fixed type, were completed. The rotary type installed at Nagoya No. 2 BOF is shown in Figure 4.

The rotary type is appropriate for existing BOF plants where space is limited, particularly in height, and is installed so that the attaching and detaching position of the sensor and the measuring position is reached by means of a rotary movement. The fixed type is for use in newly constructed BOF plants where there is sufficient space over the furnace for installation so that the attaching and detaching position of the sensor is vertically above its measuring position in the vessel, resulting in the measuring time being slightly shorter than that of the rotary type. We are contemplating the installation of this fixed type of sublance in the No. 3 BOF of our Muroran Works and in the Kimitsu No. 2 BOF.

Table 2 gives the main specifications of examples of the rotary type and the fixed type of sublances that we are adopting.

The Dynamic Control Models

The intermediate values measured by the sublance show the deviations of the actual furnace conditions from the results of the computation. To correct such deviations during the time between the intermediate measurement and the end point, the following control models are needed:

- decarburization rate model,
- temperature increase rate model, and
- controlled coolant model.

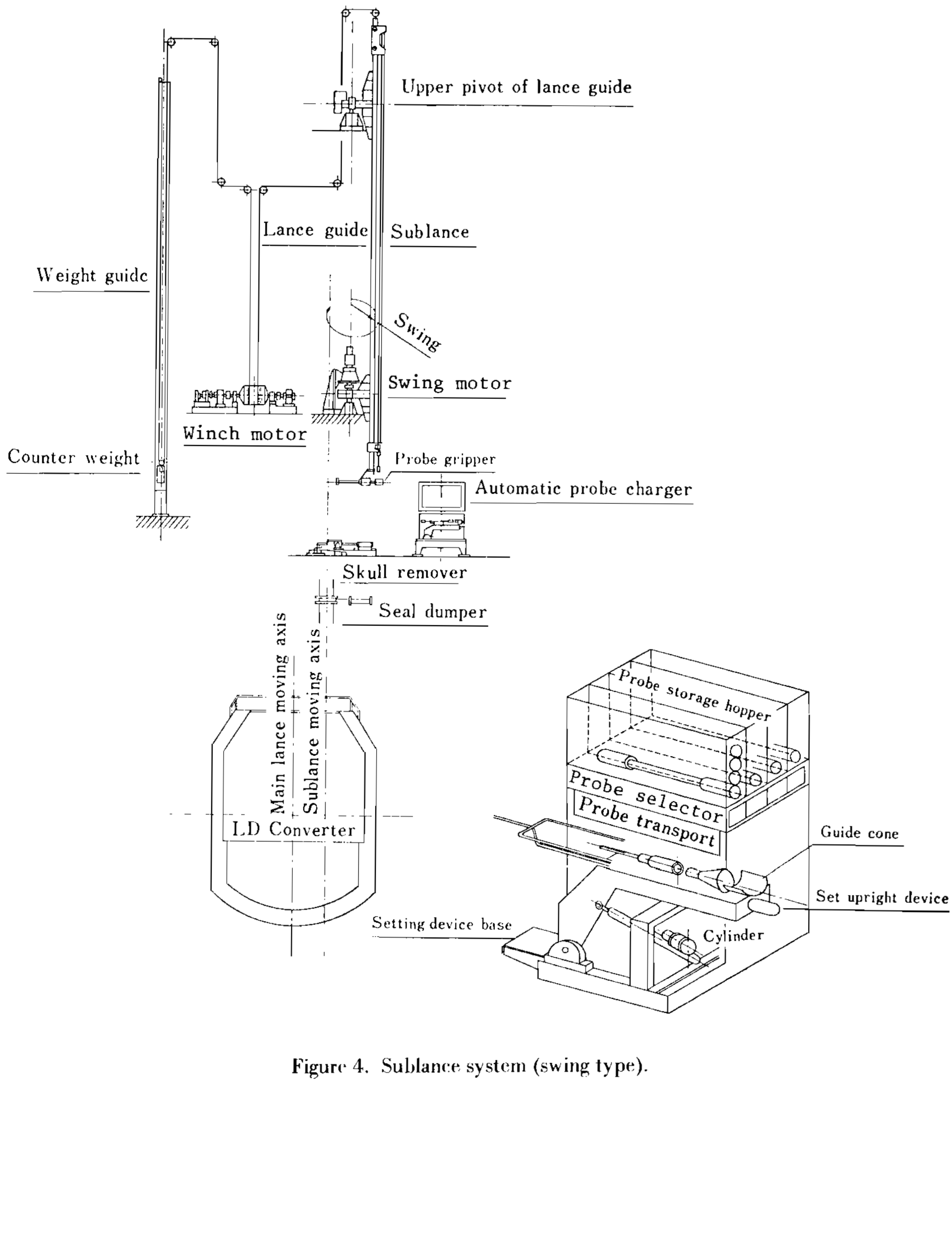


Figure 4. Sublance system (swing type).

Table 2. Particulars of the sublance equipment.

Type of Sublance	Rotary	Fixed
Name of shop	Nagoya No. 2	Kimitsu No. 2
Elevation speed (max)	120 m/min	150 m/min
Elevation speed (min)	5 m/min	6 m/min
Vertical stopping accuracy	±10 mm	±20 mm
Horizontal stopping accuracy	±30 mm	±30 mm
Rotary angle	140°	-
Rotating speed	2.5 rev/min	-
Measuring cycle time	108 s	90 s
Probe attachment	Fully automatic	Fully automatic

THE STRUCTURE OF THE CQT SYSTEM

Figure 5 shows the operational flow of the fully automatic CQT system. It functions as follows:

- As shown in Block-1, the computer using a static model first calculates and determines (a) the lance pattern, (b) the oxygen blowing pattern, (c) the amount of fluxes and ore to be added, (d) the flux and ore charging pattern, (e) the amount of oxygen to be blown, and (f) the intermediate measuring time.

- For dynamic control, the decarburizing pattern and the revised temperature increase rate to be followed after the intermediate measurement are automatically determined by the computer, as shown in Block-3 and Block-4.

- When the blow start button is pushed, all the operations shown in Block-2 as well as the intermediate measurement are performed automatically.

- Based on the results of the intermediate measurement, the computer decides the amount of coolant and oxygen, and the necessary amount of coolant is automatically supplied and the revised amount of oxygen blown until the blow automatically comes to an end.

The samples taken for intermediate determination of carbon content are analyzed immediately to obtain reference values that will suggest the end-point contents of elements other than carbon.

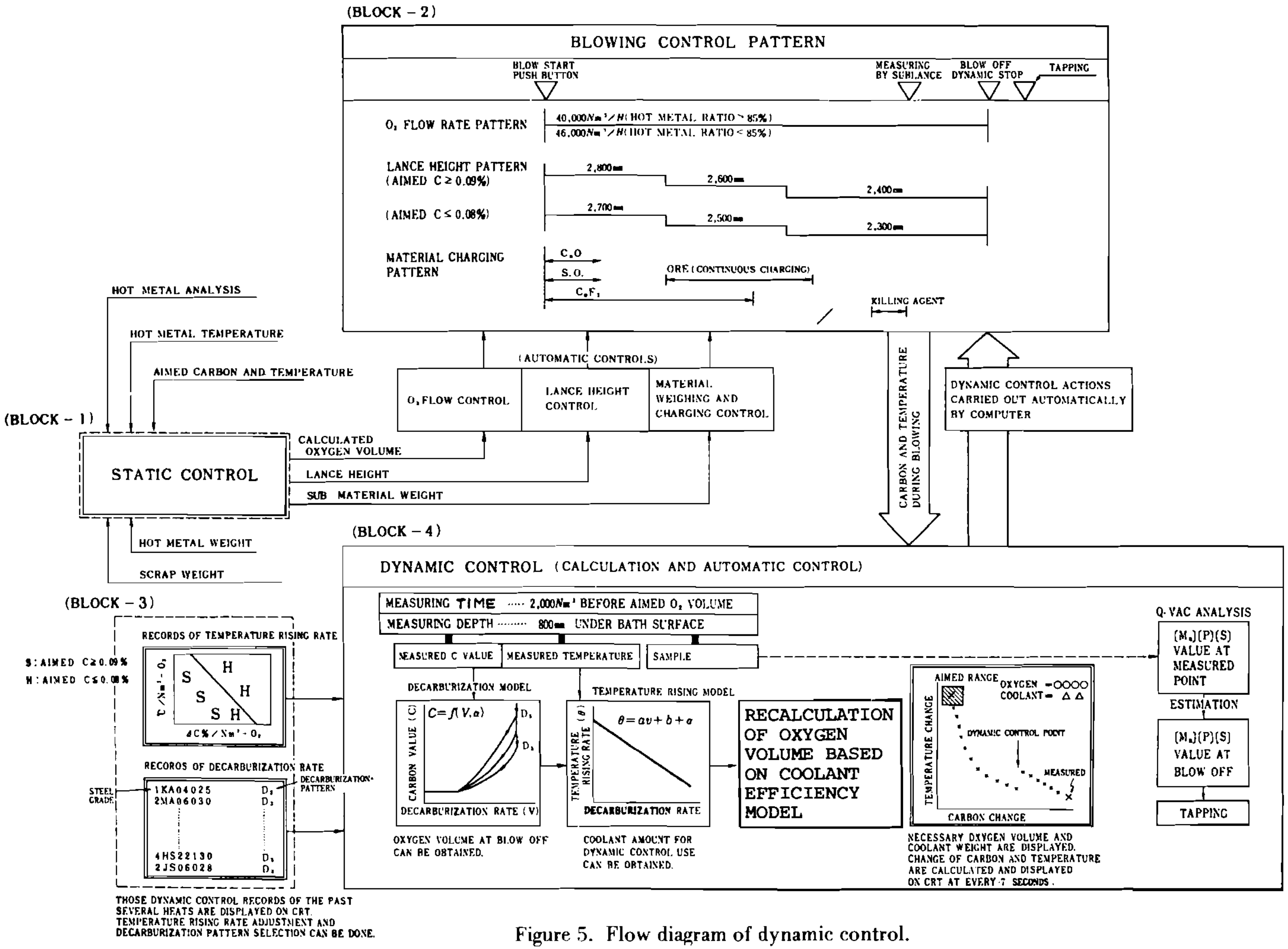


Figure 5. Flow diagram of dynamic control.

OPERATIONAL PERFORMANCE

In order to give examples of the CQT system in operation, that at No. 2 steelmaking plant of Nagoya Works is first described, since this plant was the first to adopt the system on a commercial basis. It has two 250t BOFs producing 240,000 t per month, half of which is for ingot casting and half for continuous casting. As shown in Table 3, more than a half of the many types of steel produced there contain less than 0.1 percent carbon. Even steel with the highest content has only 0.3 percent carbon, so the Works is in rather a good position to benefit from the CQT system. Many improvements have been made to the system since the installation of the sublance in August 1974 and for about a year it has reached the desired carbon content and temperature more than 90 percent of the time, as shown in Figure 6. Carbon and temperature are controlled in the Works to tolerances of ± 0.02 percent and ± 12 $^{\circ}C$, respectively.

Table 3. The steel grade at No. 2 BOF shop of the Nagoya Works.

Casting	Application	Carbon Content (%)	Ratio (%)
Ingot Casting (120,000 t/month)	CR sheet	0.04 - 0.12	21.0
	Deep-drawing sheet	0.04 - 0.10	16.1
	Plate	0.15 - 0.25	6.0
	High-strength steel plate	0.13 - 0.20	6.9
Continuous Casting (120,000 t/month)	Deep-drawing sheet	0.03 - 0.10	20.0
	High-strength steel plate	0.13 - 0.30	30.0
240,000 t/month			100.0

A second example is the system installed at the No. 2 steelmaking plant of Kimitsu Works. Compared with that at Nagoya Works, the Kimitsu Works system has a shorter operational record, but its production covers a wider range of steel types. The plant has two 300t BOFs, producing 300,000 t per month, details of which are shown in Table 4. All the output is for ingot casting ranging from low-carbon steel to high-carbon steel with a carbon content of 0.80 percent. Temperature is controlled to a tolerance of ± 12 $^{\circ}C$, while carbon is controlled to a tolerance of ± 0.02 percent for steel with a carbon content of less than 0.15 percent, ± 0.03 percent for steel with a carbon content of 0.16-0.5 percent, and to ± 0.05 percent for steel with a carbon content of more than

0.5 percent. As shown in Figure 7, the rate of achieving successful heats by the system has been improved from 80 to over 90 percent. The success rate for low-carbon steels has reached almost 95 percent, that for middle- and high-carbon steels has jumped from 70 to over 80 percent.

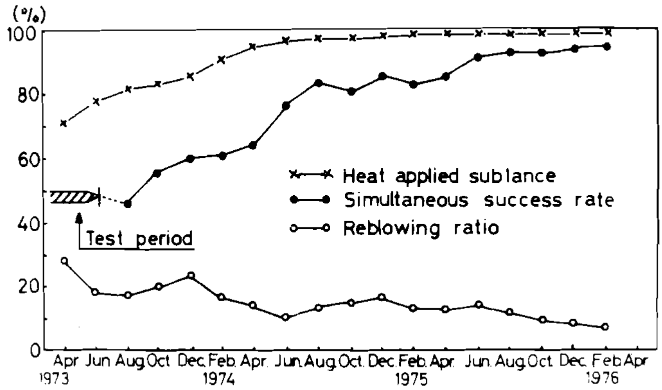


Figure 6. Progress of dynamic control at Nagoya works.

Table 4. Steel grades at No. 2 BOF shop of Kimitsu Works.

(300t/heat × 1/2)

Production Capacity	Application	Carbon Content (%)	Ratio (%)
For Slabbing 180,000 t/month	Cold rolled sheet	0.04 - 0.14	37
	Deep-drawing sheet	0.04 - 0.07	5
	Hot rolled sheet	0.05 - 0.25	4
	Plate	0.12 - 0.25	14
For Blooming 120,000 t/month	Low carbon wire rod	0.05 - 0.25	9
	High carbon wire rod	0.25 - 0.85	14
	Tube	0.08 - 0.40	4
	Shape	0.15 - 0.35	13
300,000 t/month			100

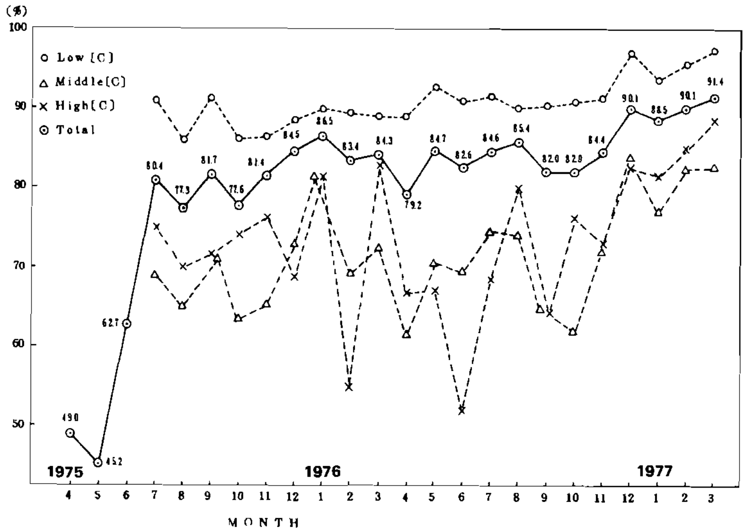


Figure 7. Progress of dynamic control at Kimitsu works.

Table 5 shows the improvements in operational performance brought about by CQT at the No. 2 BOF of Nagoya Works. The reblowing rate is due only to deviations in carbon content and temperature at the end point.

The following benefits were obtained as a result of these marked improvements in operational performance of the plant:

<u>Materials Merits</u>

- Reduction in consumption of furnace refractories because of the reduced sampling time and reblowing and overblowing rate: 2.87 kg/t ——>1.78 kg/t.

- Reduction in consumption of deoxidizer because of the reduced amount of oxygen in steel (consumption of aluminum). Low-carbon aluminum-killed steel: 2.57 kg/t——>1.85 kg/t. Al-Si killed steel for heavy plate: 0.93 kg/t——>0.74 kg/t.

- Improvement in iron yield because of the reduced reblowing rate and overblowing rate: 97.5——>98.0%.

Table 5. Improvements in operational performance brought about by CQT.

(1)	Improvement in simultaneous attainment of desired carbon content and temperature at end point	45% ⟶ 90%
	- Carbon content	65% ⟶ 92%
	- Temperature	65% ⟶ 95%
(2)	Reduction in variation of end-point temperature	= 11.7 °C ⟶ 6.0 °C
(3)	Reduction in variation of end-point carbon content	
	- Target content ≥ 0.09%:	σ = 0.038% ⟶ 0.012%
	- Target content ≤ 0.08%	σ = 0.019% ⟶ 0.011%
(4)	Reduction in reblowing rate	17% ⟶ 4%

Production Merits

- Reduction in steelmaking hours (improvement in productivity) due to CQT: 14 to 20%.
- Improvement in continuous casting capacity because of the improved simultaneous hitting rate: 17%.
- Labor saving due to pushbutton operation: 2 workmen per shift.

Quality Merits

- Reduction of defects in heavy plate: 1.24%.
- Reduction in off-specification rate of aluminum-killed steel slabs: 0.60%. (Both are due to the reduced oxygen level in the steel caused by the improved rates of successful heats.)

CONCLUSION

As shown in Table 6, all our operational BOF plants have already or are starting to adopt the CQT system. Nearly 20 years have passed since the concept of BOF dynamic control was first presented. Needless to say, the rate of successful heats depends on the accuracy of the existing techniques applied in the dynamic control system. We therefore had to carry out many fundamental tests and experiments before finally achieving the current high rates of attainment of successful heats. The merger with us of the former Yawata and Fuji Steel helped push forward the development of the dynamic control system.

Table 6. Installed and planned sublance equipment in Nippon Steel Corporation (NSC).

Steelmaking Plant		Furnace	Waste Gas Treatment Equipment	Main Specification for Sublance Equipment		Start-up Date
				Probe Exchange (type)	Length (m)	
Muroran	No. 2	110t×2 120×1	Boiler	Manual	16.8	Sep.69 Oct.68
	No. 3	(270×2)	OG	Automatic (swing)	22.4	(Oct.77)
Kamaishi		90×2	Boiler	Manual	14.7	Jun.69
Kimitsu	No. 1	(220×3)	OG	Automatic (fixed)	20.0	(Oct.77)
	No. 2	300×2	OG	Automatic (fixed)	22.4	Jul.71
Nagoya	No. 1	170×2 (170×1)	OG	Automatic (swing)	17.9	Dec.75 (Sep.76)
	No. 2	250×2	OG	Automatic (swing)	20.6	Dec.72
Saka		170×3	OG	Automatic (fixed)	16.0	Apr.73 Jul.76
Hirohata	No. 2	120×1 (100×2)	OG	Automatic (swing)	15.2	Apr.75 (Aug.77)
Yawata	No. 1	(150×1)	OG	Automatic (swing)	19.8	(Nov.77)
	No. 2	170×2 (*170×1)	OG	Manual, Automatic (swing)	13.6-15.7	May, Oct.72
Oita		300×2 (330×1)	OG	Automatic (fixed, swing)	23.4	Apr.72 (Oct.76)

Total: 19 sets (in operation) 10 sets (under construction or planning)

(Note) (*): installed in Apr.1968 but not operating now
( ): under construction or planning

Our attainment of successful heats is now only a little over 90%. All our engineers concerned with steelmaking will continue exerting their utmost efforts for making the rate of achieving successful heats as near 100% as possible.

Discussion

The participants appreciated the good results achieved by Nippon Steel Corporation (NSC); they were very impressed by the high accuracy of the system.

A group of questions were raised concerning the organization of the general control systems. It was pointed out that for the successful operation of a control system, a system of factors were needed, as mentioned in the previous report. A dynamic system based on waste gas control is presently not being used by NSC. About two or three years ago, NSC was unsuccessful in its attempts to obtain information on basic dynamic systems, and thus decided to concentrate their efforts on sublance construction which now operates with a computer-based static model. In NSC, 50 to 60 percent of heats were produced manually from a given value, 70 to 80 percent by implementation of a static model and, even for the production of high carbon steel, 90 to 95 percent by joint implementation of the sublance and the static systems.

Replying to questions on process characteristics, one participant characterized certain features of the BOF technology implemented in NSC. The blowing time is less than 20 min, the iron content in the slag is about 17 to 18 percent, and the ingot casting temperature is 1500 to 1600 ^{o}C; for continuous casting the latter figure is somewhat higher. The hot metal is transported by torpedo gun, usually without the use of a mixer, and only one sample is taken from each torpedo gun. There are no problems with phosphorus and sulfur because there is desulfurization clearance. After blowing is completed, a sample is taken immediately for low carbon, although for high carbon it is necessary to wait about five min.

The design of the sublance for each plant depends on the design of the plant. A number of questions were asked about the accuracy of the system. In order to have an end-point temperature error of only 6 ^{o}C, it is necessary to have a temperature measurement in the blowing converter with a high accuracy. Some participants expressed doubt about the possibility of accurately measuring the temperature because thermocouple errors alone are more than 8 ^{o}C. The same negative comments were given regarding measurement of the solidification temperature for carbon content determination. The unlikelihood of achieving accuracy in temperature measurement of 1 ^{o}C was stressed by several participants.

The need for systematic calibration of measurement systems was underscored. It was noted that no special calibration had been implemented except normal carbon analysis from the same sample that was used for measuring solidification temperature.

As regards the cost of a sublance system, the author said that the cost for three vessels was about 3 million dollars.

Dynamic Operation of the LD Process: A Model for End-Point Control

W. Lanzer and E. Weiler

The subject of this workshop at first sight seems very general. The reason is that computer application is not a field within itself. Because of the development of computer technology, leading to computers of increasing capacity and lower price, their application has become widespread.

Apart from technical solution of the substantive problem, other factors are of importance, such as organization in the EDP area and problems of maintenance, as well as the personnel structure. The ways in which problems are solved are thus specific to each firm and can be applied in others only under certain conditions.

Computer use for the Basic Oxygen Furnaces (BOFs) of Mannesmann AG Hüttenwerke ranges from data collection, static and dynamic processing, a model for calculating optimum alloying additions, and control of bin feeding to quality control. Much of this is similarly dealt with in other steel works. With this general background, we discuss in this paper a field of application in which some problems are still unsolved and a good deal of "metallurgical precision work" is still needed.

Attempts to operate the LD process fully automatically by means of a dynamic model have often been made. The starting points for problem solution are manifold, ranging from simple secondary control of process variables to highly complex mathematical process descriptions. Apart from secondary control, process representation requires continuous process information by means of measurements. It is in the nature of steel production that these measurements must be made under very difficult circumstances. Nevertheless, various attempts have been made, e.g. to determine slag conductivity, the weight of the vessel and its vibrations, radiation temperature at different points, continuous bath temperature, lance expansion, vessel sound and waste gas analysis.

The usefulness of measurements for dynamic processing lies in their reproducibility and their direct relation to the metallurgical process. Waste gas analysis and bath temperature measurement during the blow meet these conditions well.

In oxygen steel plant I of Mannesmann AG Hüttenwerke, instruments for waste gas analysis and measuring vessel sound are installed. Our studies for process automation in this plant have two main features. We examined the contribution of waste gas analysis to the metallurgically based process description and to the resulting process control; and we focused on the end point of blowing in order to reach a better accuracy of hit.

In the first part of our investigation [1], the melt history and especially the slag history as deduced from waste gas measurement was represented. The basis of such a representation is the continuous oxygen balance; the result is the oxygen flow entering or leaving the slag. These results, derived purely from measurements, can be refined by metallurgical assumptions in such a way that all the relevant variables of the slag history can be represented. Figure 1 shows the course of the slag in the quasiternary system.

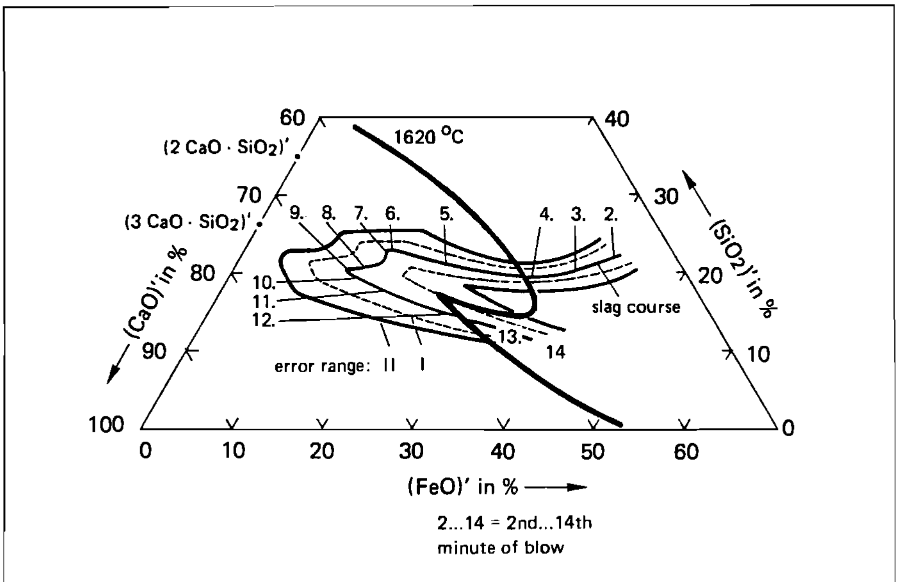


Figure 1. Error in the description of the slag course.

The accuracy of this representation is important if it is to be used as the starting point for process control. Figure 1 therefore also shows the inaccuracy of the slag diagram as established by error calculation. It comprises:

Error range II: Due to metrology and the metallurgical model (BOF shop 1);

Error range I: Assuming the best conceivable metrology and no model error.

Clearly the inaccuracy of the representation is still considerable in the most favorable hypothetical case (error range I), and is too great to permit process control in terms of confirmed metallurgical target rates. Figure 2, showing the iso-slag lines [2] for phosphorous, illustrates how narrow the range is in slagging control. The inaccuracy of the measurements by far exceeds this range.

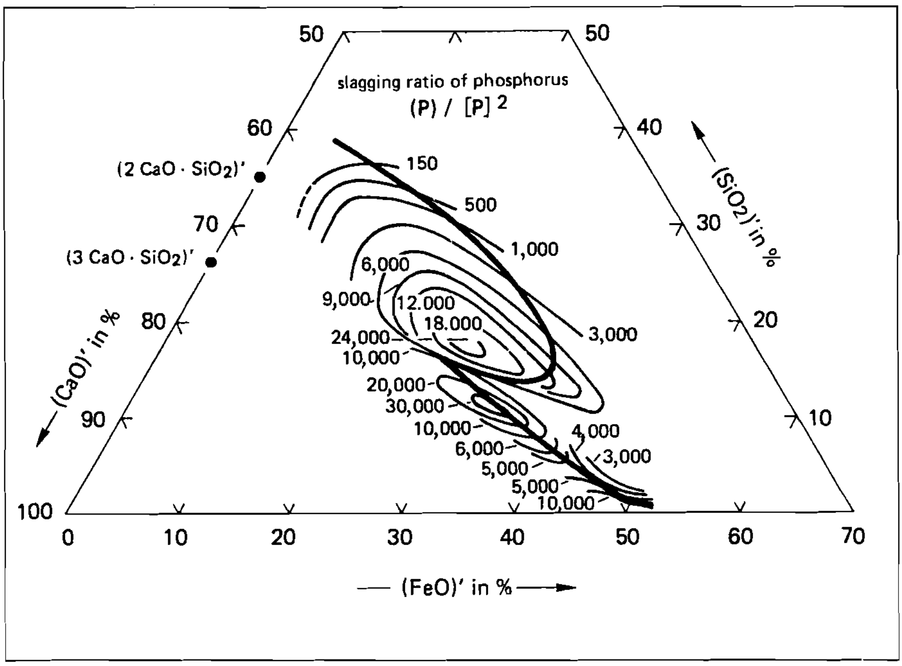


Figure 2. Phosphorus slagging in the (CaO)' · (SiO2)' · (FeO)' System.

Apart from the oxygen balance, waste gas analysis transmits other process information, such as the decarburization rate. Here too, extensive attempts have been made to develop control algorithms or establish process controls. The relationship to the process can, however, be established only empirically by many observations. Such methods have no causal relationship derivable from theory.

In the area of low carbon content, however, such a relationship can quite well be shown. This is because, as the process approaches equilibrium, it takes a path that can be described in terms of reaction kinetics. This is seen in the well-known relation between carbon and decarburization rate which, after experimental validation, is often used for carbon end-point evaluation.

In the second part of our investigations [3] we tried to derive this relation from reaction kinetics so as to become more independent of changing reaction parameters. This approach, in which the process course was described essentially by means of the intermediate formation of FeO in the focus resulted in a very useful mathematical relation between the bath carbon and the decarburization rate. This relation--and the integral derived from it, which shows the carbon oxidation loss curve--led to a new display of the end point. With this method the residual blowing time (t_{blow}) is continuously determined by computer, as shown in Figure 3. The residual blowing time, which results from the measured decarburization rate, the target carbon value, and the lag time of the waste gas measurement, is displayed on a graphic device. This form of display has the following advantage. If the process runs in accordance with the preset reaction parameters, a 45° straight line is displayed, given appropriate paper speed. If, however, the process takes an unintended course, the shape of the graph will show it. In this case a lower accuracy of hit may be expected.

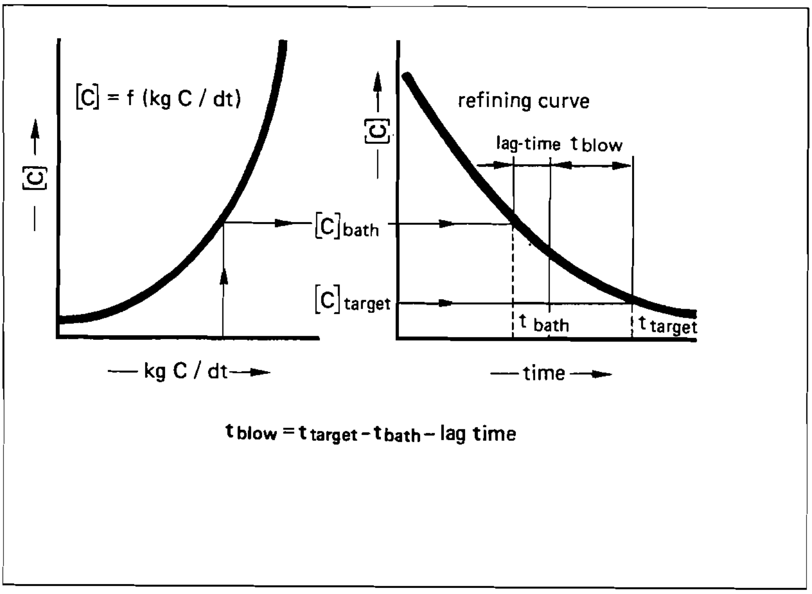


Figure 3. Carbon end-point control ("Countdown").

Before the end-point method was tested, a static model had been in operation in oxygen steel plant I for some time. This model, which is based on chemico-physical equations, has the task of calculating charges, additions and quantity of oxygen to be blown. Introduction of the dynamic end-point method caused an overlap of the two techniques: for the blower goes by either the residual blowing time or the oxygen quantity to be blown.

A possible solution of this problem is to combine the two methods with the underlying idea of improving the results by linking two measurements. The presupposition for improvement, however, is that while the measurements differ in method they are comparable in their accuracy. This is the case with the dynamic and the static methods, which basically are merely ways of measuring carbon and temperature (see Figure 4). If one blow only by the dynamic method, accuracies of hit would be as on the left side of the figure; if by the static method, as on the right.

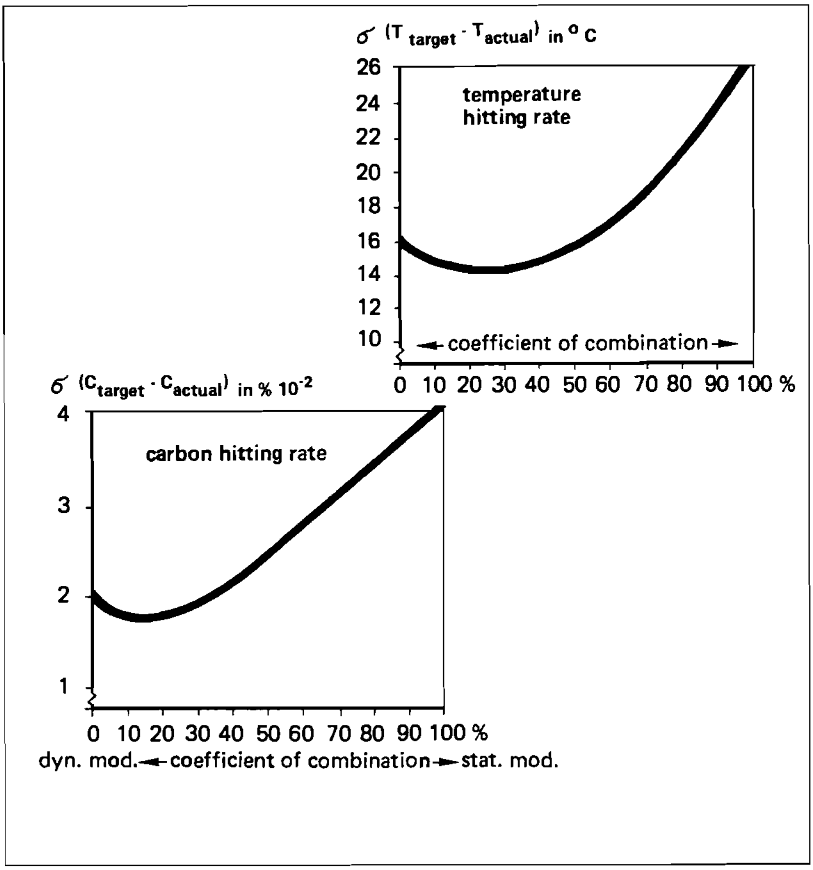


Figure 4. Combination of the dynamic and the static control systems.

As can be seen, the best results are obtained if the two methods are combined according to the simple equation:

$$t_{gas} = t_{dyn} + p \times (t_{stat} - t_{dyn}) \quad ,$$

where

t_{gas} = residual blowing time, combined methods,
t_{dyn} = residual blowing time, dynamic method,
t_{stat} = residual blowing time, static method,
p = combination coefficient.

The combination coefficient allows for the different accuracies of the two techniques in that the more accurate always has a correspondingly larger share in the combination. For equal accuracy of hit of both, the combination coefficient must be 0.5; but as Figure 4 shows, this is not the case here.

With the dynamic method, the charge of the heats is of course determined by the static method, and only the point in time when the process ends is established by the dynamic method. The greater accuracy of hit of the temperature with the dynamic method is interesting. The reason for it is that the process is finished with a certain decarburization rate, i.e. at a certain oxidation stage of the slag, so that overoxidation of the slag is prevented.

The results of the combination is two timings, one for carbon and the other for temperature. Both indicate for how long blowing must take place before the desired values are reached. In the ideal case both tend to zero in parallel, as is shown on the left side of Figure 5. This means that the two end points are reached simultaneously, the process has taken the intended course, and we can expect a good accuracy of hit. If the carbon end point is ahead, the carbon content of the heat must be reduced by further blowing so as to obtain the desired temperature. If the end point of the temperature is ahead (see right side of Figure 5), the computer indicates the cooling correction necessary to prevent the melt from being superheated.

In principle it is now possible to finish blowing fully automatically. We did not so do for the following two reasons.

As soon as the static technique was introduced, it turned out that the blower contributes to improving the results. For example, the accuracy of hit of the static model, in terms of deviation, increased from $\pm 24\ ^{o}C$ to $\pm 17\ ^{o}C$ for temperature and from $\pm 0.04\%$ to $\pm 0.03\%$ for carbon. Introduction of the dynamic method has a similar effect. The reason is that the blower, with his observations and his fund of experience, is himself a kind of measuring method which, in combination with other methods,

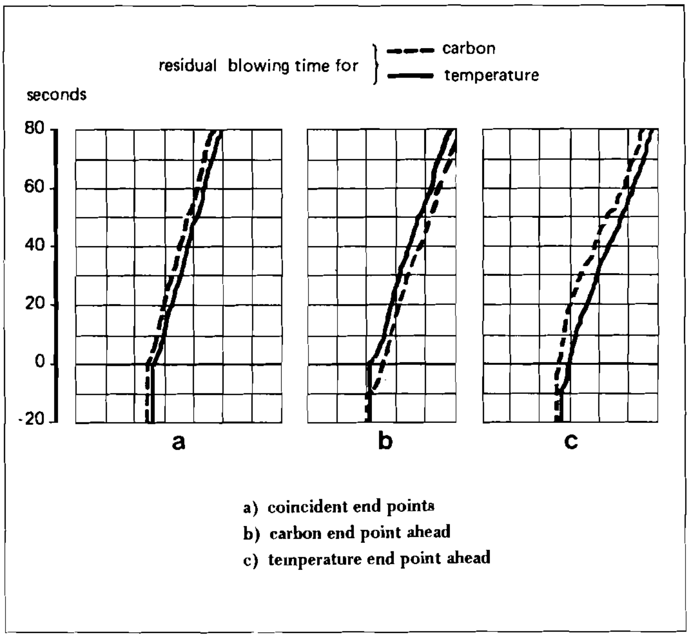


Figure 5. End-point display for temperature and carbon.

improves results. The difficulty here is that this combination cannot be represented in mathematical terms. This can be compensated to some extent by narrowing the latitude of the blower for departing from the instrument indications. The efficiency of this combination must be checked by continuous statistical evaluation.

The second reason is that we want to enable the blower to guide the process better by giving him as much information as possible. The final responsibility, and thus involvement with the process, should be left to him, however, also with a view to continuous improvement of the techniques used.

SUMMARY

Waste gas measurement delivers important process information for the LD method. For metallurgically based process control, however, this information is not sufficiently accurate. This is in contrast to determination of the end point, where the results of the dynamic method developed via waste gas measurement are good. They may be further improved by combining the dynamic and the static methods. The idea underlying this linkage is to combine measurements of unequal precision.

REFERENCES

[1] Dörr, W., and W. Lanzer, *Stahl und Eisen* 93 (1973), 876-884.

[2] Bardenheuer, F., internal paper, Mannesmann-Forschungsinstitut GmbH, Duisburg.

[3] Dörr, W., W. Lanzer, E. Weiler, and H. Trenkler, *Stahl und Eisen* 94 (1974), 381-386.

Discussion

Several points were raised about BOF operations and computer systems, with a view to understanding the functions of the system more fully. It was stated that Mannesmann produced steel with a carbon content of 0.20-0.5 percent. While there are no problems with sulfur, phosphorus presents problems. Thus Mannesmann uses the information on the converter sound, which is a good indicator of the slag consistency available for the operator on display.

Calculations for the dynamic model on the waste gas analysis and for the static charge calculation model begin after a certain amount of oxygen blowing. The decarbonization rate must be below a certain level. In the last two minutes of blowing, the oxygen flow rate and the lance position are at the same levels. The combined results of the calculations for the static and the dynamic models are available to the operator at the end of blowing, thus giving improved accuracy.

One participant pointed out that accuracy of waste gas analysis was not sufficient. Even the use of mass spectrometers does not make it possible to control the decarbonization process. A combination of this information with the static model improves the final results. There is, however, no dynamic information about the temperature.

The man-computer interface was also discussed. It was pointed out that the Mannesmann approach was to not entrust the computer with all control functions, and to keep the operator informed about the process, making it possible for him to make decisions in a particular area. To keep the operator informed about the decarbonization rate, sound and time of blowing are used. The final decision lies with the operator.

Process Control Computer Systems for Basic Oxygen Steelmaking: Experience at the British Steel Corporation Teesside and Scunthorpe Steel Plants

D. Anderson and J.D. Gifford

INTRODUCTION

The Lackenby Basic Oxygen Steelmaking (BOS) Plant was commissioned in 1971 and consisted of two 260 t oxygen converters with a rated output of 2.2 Mt. Later, in 1972, a third converter of the same size and design was added. Operation of three converters in a shop designed originally for two has proceeded until the present, but despite several improvements carried out over this period serious deficiencies remained. A major expansion scheme has been undertaken therefore to raise the production capability of the plant to 4.85 Mt per annum. Completion has been phased to coincide with the commissioning of a 10,000 per day blast furnace at Redcar in 1978.

Significant among the changes will be a reduction in the operating cycle time, tap-to-tap, which, apart from the logistic considerations, necessitates a high level of process control.

Within the British Steel Corporation (BSC), the most modern application of process control computer facilities is that at the Appleby Frodingham and Normanby Park BOS Plants at the Scunthorpe Works. Therefore, in the design of the system for Lackenby attention was given to the experience gained and to the process control developments centered at the Appleby Frodingham and Normanby Park Plants.

In this review, the process control facilities at Scunthorpe are described before dealing with the proposals for the system at Lackenby.

APPLEBY FRODINGHAM

Plant Characteristics

The construction of the BOS and continuous casting facilities was part of a major modernization and expansion of steelmaking in the Appleby Frodingham Works. Total capacity was raised from approximately 2.5 Mt of liquid steel per annum to about 4.25 Mt in the fully commissioned works. Currently 3.6 Mt can be cast into ingots and 0.65 Mt feed the continuous slab casting plant. The plant was commissioned in 1973. Future developments will raise the potential capacity of the Appleby Frodingham plant further to 6 Mt per annum. A plan of the BOS shop is given in Figure 1 and the materials flow in relation to this is given in Figure 2. Key operating data for the plant are given in Table 1.

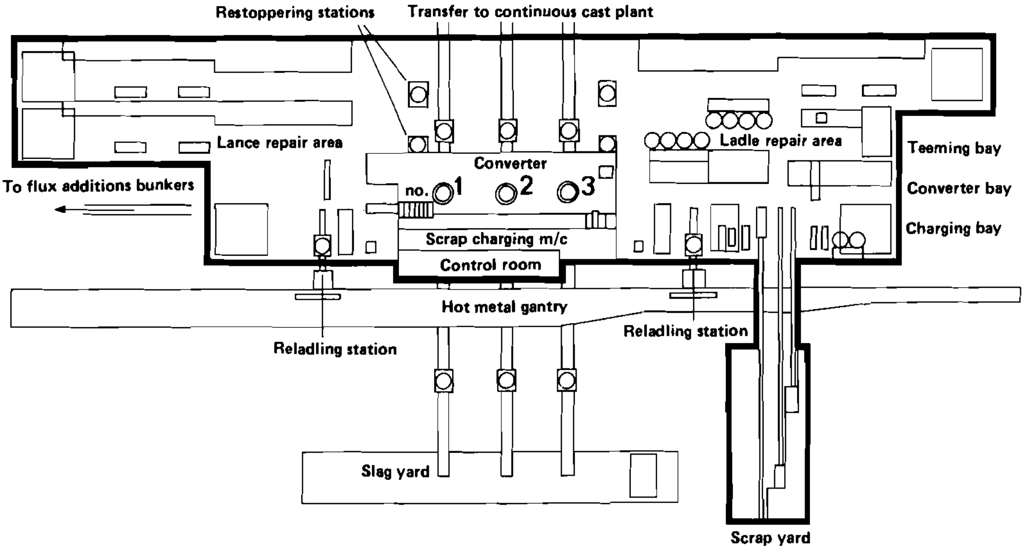


Figure 1. Plan of BOS shop at Appleby-Frodingham.

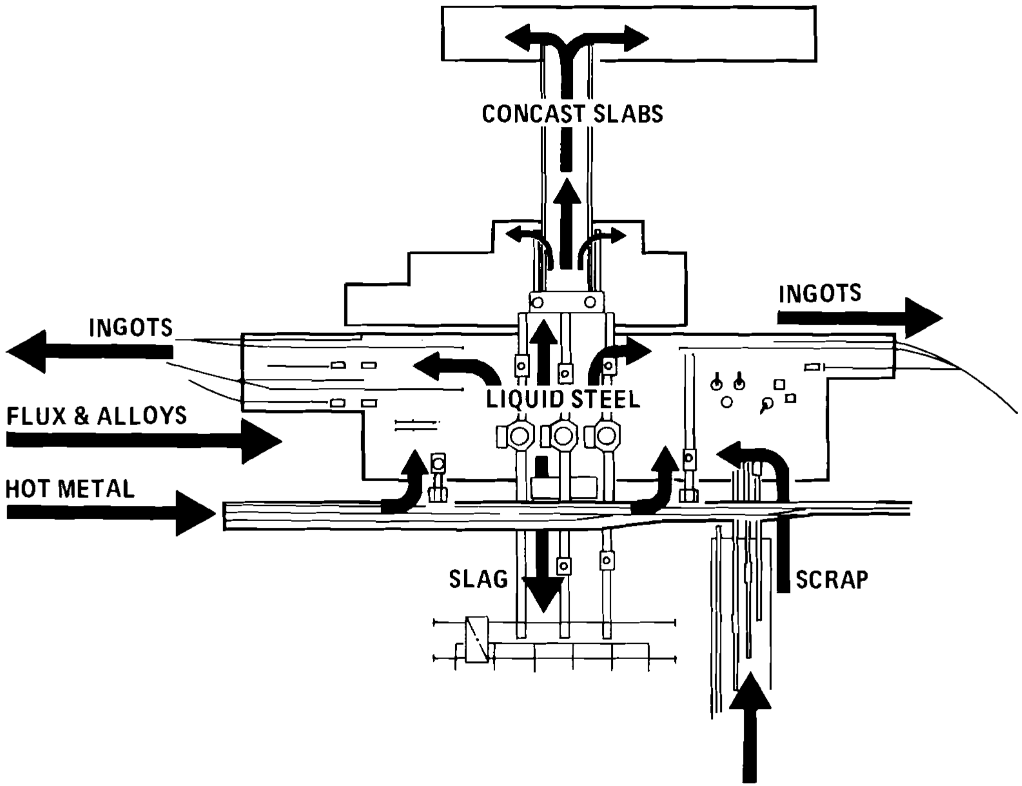


Figure 2. Materials flow through Appleby-Frodingham BOS shop.

Table 1. Key operating data for Appleby Frodingham.

Hot Metal Analysis

Typical average analyses and standard deviation values are given. However, as iron is supplied from up to ten blast furnaces, considerable variations can occur within short time scales.

C(%)	Si(%)	Mn(%)	P(%)	S(%)	
4.15	0.98	0.55	0.28	0.042	Average
0.17	0.21	0.06	0.02	0.012	Standard Deviation

Vessel Data

Number of vessels	3
Specific volume	1.0 m^3/t
Nominal capacity	305 t
Average charge weight, hot metal	260 t
scrap	80 t (23%)
Average tap weight	305 t
Average specific oxygen blowing rate	2.9 $Nm^3/min.t$

Steel Product Summary

Steel Type	*Percentage of Product*
Rimming	25
Balanced	45
Killed	10
Concast	20

The Computer System

General

The plant is equipped with a Ferranti Argus 500 computer which provides an extensive data logging and information service to key operators. The computer facilities available to them are given in Figure 3. The essential feature of the plant operation is the preparation of the charge based on heat and mass balance calculations performed by the computer. The information is output to the key operators but at all times the values predicted can be overridden by the vessel controller.

Description of the computer operation is illustrated best by reference to the progress of a typical heat through its various stages. These are indicated schematically in Figure 4.

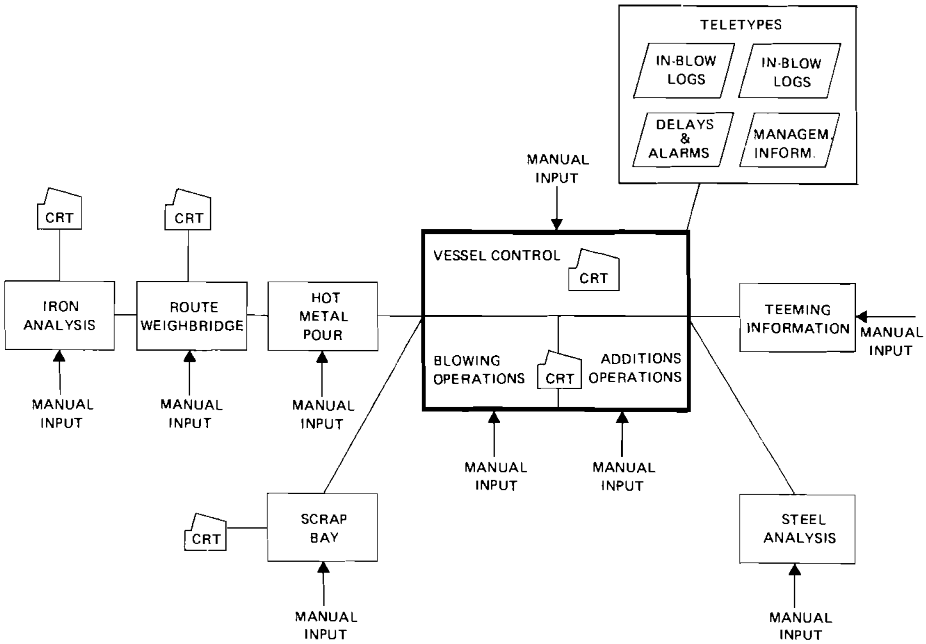


Figure 3. Key manning areas for computer process control.

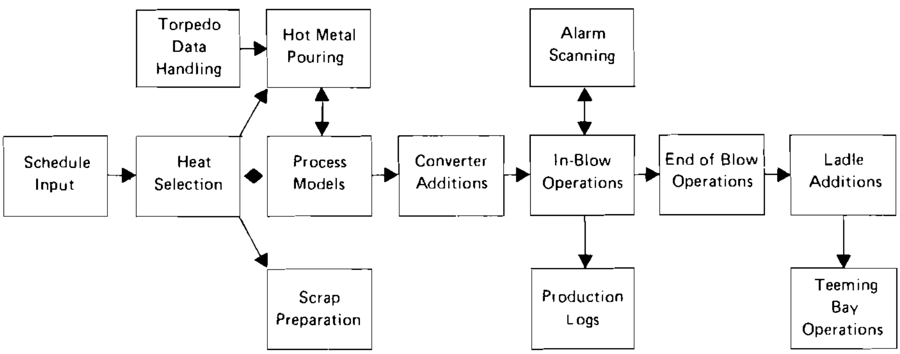


Figure 4. Sequential progress of typical heat.

Vessel Schedule

As conceived, the vessel schedule of steel specification was to be input to the computer once per shift and assessed from either of the two vessel control rooms. Experience has shown, however, that greater flexibility was necessary in the selection of heats. Therefore, the vessel controllers input the heat quality to be made only when availability of the continuous casting plant and the hot metal analysis is known.

In permanent computer store is a central file relating each specification code to the aimed vessel and ladle temperatures and analyses. Entry by the controller of a specification code at the time of heat selection will cause the aimed values to be displayed on a cathode ray tube (CRT) forming part of the manual input panel. Once this has been checked the specification can be attached to one of the vessel schedules. As each specification is attached to a schedule the computer will generate a unique three digit sequence number for reference purposes.

When the controller enters a specification code he may optionally enter a casting code according to whether the ingot or continuous casting route is to be used. At this stage the aimed temperature can be overridden if necessary. The approximate tapping weight determined from vessel lining life and specification requirement is displayed on the controller's CRT.

Having obtained a tapping weight, the computer will then calculate the approximate weights of hot metal and scrap necessary to achieve the weight based on an average hot metal analysis. It will check that the appropriate hot metal station is free and that the hot metal station operator has entered the next three torpedo numbers in the queue. The analyses of the torpedos and weight contents are read if available. If the analyses are not available a shift average will be used and a note made. Using the tapping weight, torpedo analyses, and weights, the computer will then calculate the latest estimates of hot metal and scrap weights required.

Hot Metal Pouring

The hot metal requirement information is transferred to the hot metal transfer car weighing by manual entry at the vessel control room. The hot metal station control operator signals his acceptance and the demand weight appears on the local display panel. Hot metal is poured from two or three torpedo cars to the empty and previously tared ladle. At the end of each pouring operation the operator at the weighing station actuates the computer to read weighbridges. At the end of the pouring sequence the computer calculates the average analysis and temperature and totals the weight poured. On this basis, a revised scrap weight may be predicted, but in any event the first estimation of the converter additions is made.

Following the end of pouring the hot metal transfer ladle is moved to the deslagging machine where the actual temperature is measured and a sample taken for chemical analysis. Another dip temperature may be taken before the metal is charged to the converter. At each stage the temperature value is read by the computer automatically and this causes a revision of the scrap and vessel additions requirements.

The charged weight of metal poured into the converter and the spectrographic analysis of the transfer ladle metal sample information provides further opportunity to revise scrap weight (unless charged previously) and/or vessel additions.

Scrap Preparation

This is carried out in two stages. The outer scrap bay produces preloaded scrap pans perhaps to one or two standard weights. Trimming scrap additions determined by updated information from the hot metal pour station is conducted at the inner scrap trim bay.

The computer logs the usage of the various types of scrap loaded in the outer yard and identifies these weights against a scrap pan number. Variations in the trimming weights are entered by the vessel controller.

The outer scrap bay controller is provided with a CRT display from which he can monitor plant operations and determine scrap requirements. Scrap weight and scrap types are transferred to a display for the magnet crane driver who signals the controller when each stage is complete. The computer is then made to read the weighbridge. The scrap controller by observation of the CRT display can determine whether updated scrap requirements may be met and gives appropriate instructions to the crane driver.

Vessel Additions

The high level hoppers are capable of dispensing remotely the desired weight of materials instructed by the weighing equipment. Most of these hoppers are provided with batching facilities whereby instead of dispensing a single batch of the desired weight, a number of batches can be demanded at set but adjustable intervals.

The vessel additions operator is presented with the following information:

- Desired weight,
- Number of batches required,
- Number of batches dispensed, and
- Storage hopper contents indication.

The materials are fed to a charge holding bunker and when required the operator causes the bunker-gates to open allowing discharge to the vessel. The computer reads the weight of the charge holding bunker at the end of each stage.

In-Blow Operations

The computer calculates the oxygen flow rate from the temperature differential and static pressure values at the orifice plate. Comparison between the integrated value of oxygen and the latest estimate of oxygen requirement based on the heat and mass process model allows the operator to determine the end of the blowing period.

From lining life, hot metal, and scrap charge weights, the computer calculates the bath height of the charge contents. Manual entry by the blowing operator of this value causes the lance height above bath height value to be displayed.

Every minute during the blow the process oxygen consumption and lance height position are logged and presented on a teletype together with the decarburization rate and total weight additions. The decarburization rate is calculated from the waste gas flow and analysis. The values computed are recorded by the computer at 1 min intervals but in addition are fed to the graphical display unit at 15 s intervals and a chart record is obtained via the analog output system.

At the end of the blow, a sample is taken and the temperature measured. Automatic determination of the recorded temperature plateau causes the result to be displayed to the operator on a large wall-mounted display. If it is considered to be a valid determination the operator presses an "accept" button and the computer records the information. The results of the rapid carbon analysis are input to the computer via the laboratory manual input panel and also displayed to the operator on the other large wall-mounted display. As a result of the information on carbon and temperature, a decision is taken on whether to reblow or wait for a full spectrographic analysis.

When acceptable analyses and temperatures are achieved the computer calculates the ladle additions based on the requirements for the final steel analysis.

Ladle additions are obtained manually from six storage hoppers sharing three weigh hoppers. The materials are dispensed to the feed hopper one at a time and are recorded by the computer.

Casting Data

Data from the teeming bay indicating

- teeming bay platform number,

- types of ingots used,
- number of ingots teemed,
- ingot size,
- mold additions,
- teeming times, and
- teeming weights

are all entered manually. The computer subsequently calculates the yield data and other management information.

The only data recorded by the computer of the steel continuously cast is the steel temperature in the teeming ladle.

Development of Process Control Facilities

General

The control performance achieved at Scunthorpe, assessed in terms of the proportion of blows that are correct at first turn down, is between 40 and 60 percent. The level of success achieved is usually determined by a combination of the quality of the information relayed to the operator, and the control action taken by the operator in response to the information provided. Too often, unfortunately, the operator is asked to compensate for undetected variability in the raw materials with relatively little guidance. Attempts have been made therefore at the nearby Normanby Park BOS Plant, which recently has also been fitted with a Ferranti Argus 500 computer to evaluate the benefits to be gained from a decarburization rate display, with a suggested guide path, and an audiometric monitor of the slag development pattern, while conforming strictly to the static charge calculation requirements.

Concurrent development at the Appleby Frodingham plant of the Bethlehem secondary lance system should allow the eventual merging at this plant of a process control system comprising

- a computer based heat and mass balance ("static") model,
- an optimized blowing technique determined from decarburization and slag development guidelines and monitors, and
- an in-blow carbon and temperature check.

Equipment

Waste Gas Analysis: A fast responding but reliable waste gas sampling and analysis system requiring minimum maintenance was set as a first priority in the development of in-process control. The general arrangement and critical transit times at Normanby Park are shown in Figure 5.

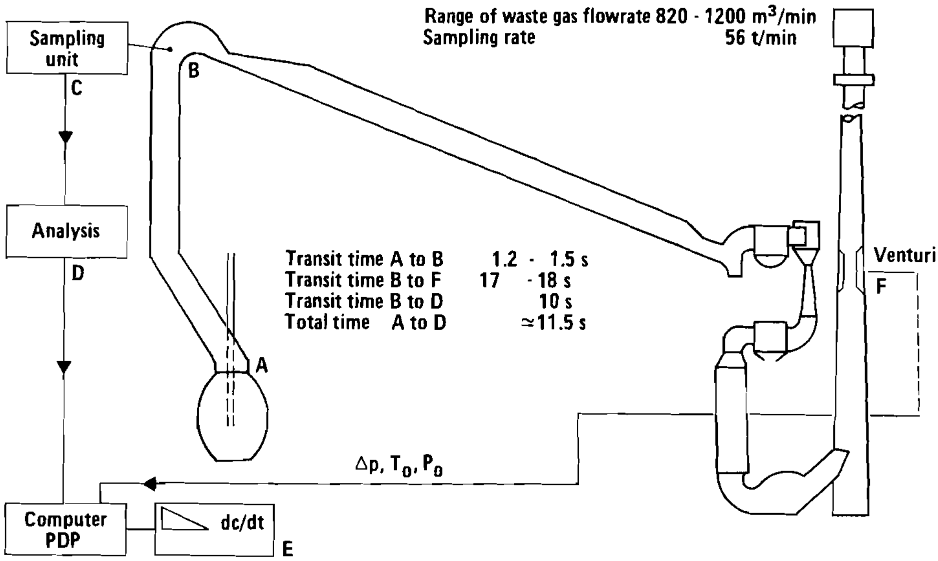


Figure 5. Waste gas analysis measurements and transit times at Normanby Park.

The water-cooled gas sampling probe is set into the upper hood and is designed to withstand temperatures up to 1500 °C. Subsequently the hot gases are filtered in four stages before infrared analysis for CO and CO_2 and a paramagnetic analysis for O_2. In the current trials program, a mass spectrometer operates in parallel with these analyzers for comparative evaluation.

After a period of training for the instrument maintenance personnel, the availability of data from the equipment rapidly climbed to greater than 90 percent, and as experience is gained it is confidently expected that reliable data will be available to the vessel operator at all times.

Audiometer: The optimum siting of the audiometer for slag volume monitoring and the selection of the audio frequency most sensitive to changes in the slag volume has been the subject of extensive research at Normanby Park. Although the work is not entirely complete the best results to date have been obtained with the microphone sited close to the gas sampling probe and filtered to the frequency band 400 $\pm$ 50 Hz.

Data Display: The decarburization rate calculated by a PDP 11/10 computer is output to a CRT in the vessel control room simultaneously with the filtered audiometer signal. To provide some guidance to the operators, control limits have been set for the decarburization rate and ultimately a target level for the audiometer values. Plant operation using such a display has only recently begun, but operator acceptance has been high and no difficulties have been experienced in operating within the required limits. An indication of the steel carbon content calculated from the decarburization rate towards the end of the blow will also be displayed as operator familiarity with the system increases.

Although it is too early to report detailed results from this work, progress has been sufficiently encouraging for provision to be made in the enhancement scheme at Lackenby of similar displays.

Bethlehem Lance: A secondary lance-probe system has been built under license from the Bethlehem Steel Corporation and installed initially on one vessel at Appleby Frodingham.

Following extensive cold engineering and electrical checks, the lance-probe system has been used regularly during recent production campaigns concentrating on end-blow measurements. During subsequent campaigns it is intended to bring this equipment to its full operating potential.

LACKENBY

Plant Characteristics

As currently operated, iron is supplied by the Cleveland Works blast furnaces at a rate of about 30,000 t per week in 250 t capacity torpedos. Selected iron can be directed to a Polysius desulfurization station located adjacent to the BOS plants. After desulfurization, iron for each BOS vessel charge is weighed on a rail weighbridge with a local operator station as it is dispensed into the transfer ladle at one of the two pouring stations.

Scrap is prepared in a bay adjacent to the BOS shop. Four transfer cars, with two scrap pans per car, each stand on individual rail weighbridges during loading so that the crane driver can load the required weight as indicated by large matrix displays. Unlike the Appleby Frodingham shop, no provision is made for the adjustment in scrap weight once the scrap pan has left the preparation bay.

Converter additions are made from a total of 18 weigh hoppers. Two hoppers are dedicated to each of the three vessels but the remainder are capable of feeding two vessels by a reversible conveyor. The weighing and discharge of converter additions are controlled from the two vessel control pulpits.

Key vessel and product mix data are given in Table 2.

Table 2. Key operating data for Lackenby.

Hot Metal Analysis

The average analysis of hot metal delivered to the Lackenby steel plant from Cleveland and Redcar blast furnaces will be:

	C(%)	Si(%)	Mn(%)	P(%)	S(%)	Temp.(°C)
Redcar	4.5	0.6	0.6	0.12	0.045	1350
Cleveland	4.5	1.0	0.8	0.08	0.030	1310

Vessel Data

Number of vessels	3
Specific volume (newly bricked)	187 m^3
Nominal capacity	260 t
Average charge weight, hot metal	219 t (76%)
pig iron	6 t (2%)
scrap	63 t (22%)
Average tap weight	261 t
Average specific oxygen blowing rate	2.8 Nm^3/min.t

Steel Product Summary

Steel Type	*Percentage of Product*
Rimming	7.6
0.08/0.15C	15.4
0.16/0.25C	48.7
+ 1.00 Mn	0.8
High yield	8.6
Killed C/Mn	5.4
Killed high yield	1.5
Pipe steel killed	1.8
Rail steel	9.2
Medium carbon	1.0
Continuously cast	50 (approx)

Proposed Production Facility Changes

In addition to the continuing supply of iron from the Cleveland blast furnaces, iron will also be delivered from the new 10,000 t per day blast furnace in 320 t capacity torpedos. The delivery weights will be determined on three new weighbridges. Waste gas cooling and cleaning will be changed from the Institut de Recherches de la Sidérurgie-Française (IRSID) CAFL system to the oxygen gas (OG) system and at the same time secondary ventilation cleaning equipment will be attached.

Extra scrap handling, vessel and ladle additions, handling, and weighing equipment are to be built together with a new slurry handling system. Changes to the ladle preparation bay and an extra twin-strand slab casting machine are among the more important improvements.

The Case for Improved Process Control Facilities

The factors deciding the need for improved process control facilities throughout the steelmaking plant were primarily concerned with the changed waste gas handling system and the increase in steel production rates. They were:

- The need to handle more iron, scrap, vessel additions, ladle additions, finished steel, and all associated raw materials.
- Increase in torpedo iron capacity from 250 to 320 t to serve the new 10,000 t per day blast furnace.
- Increased workload on the operators caused by the higher rates of working which required a change in the job content of the operators and the control of steelmaking operations.
- A need for faster, more efficient communication between key operators.
- An increased workload in the steelplant analysis laboratory.
- A need to ensure safe operation of the OG system, particularly with respect to waste gas composition in the stacks.
- A need to improve the sampling system of the waste gas analyzers used to assist steelmaking control.
- A need to improve some aspects of the static charge calculations.
- A requirement for improved oxygen lance height control.

With account being taken of the above, an examination of the existing, and obsolete, computer facilities confirmed the need for a new computer system.

The New Process Control System

General Philosophy

The new plant process control system is a complex package including new instrumentation, plant control equipment, new operator practices, and new computer systems in the BOS Plant and laboratory. The main objectives are to meet the requirements outlined above, in particular:

- Improved steelmaking control,
- Improved information presentation and flow to key operators,
- Management information reporting at plant level, and
- Automatic data input to computers wherever possible.

Hot Metal: The three new weighbridges will each be equipped with a PDP 11/03 microcomputer mounted locally in the pouring station control pulpit to perform poured weight calculations, display demanded weight and poured weight in analog and digital form to the pouring station operator on a visual display unit (VDU) and provide a serial interface with the new process control computer.

Temperature measurement of both the hot metal and steel will be by conventional disposable dip thermocouples. However, the plateau detection and display of metal temperature will be performed by self-contained hardware units. These will be mounted in the steelmaking controller's desk with a display of the temperature at the dip station and will be linked with the process control computer.

The existing weighing equipment on the charging and casting bay cranes will be linked by radio and a serializer to the process control computer to allow automatic input of charged and teemed weight.

Additions: The vessel additions system will largely remain unaltered, but additional bunkers will allow the trickle feeding of trimming coolant throughout the blow to each vessel. The provision of the sophisticated batching and charging of additions such as that available at Appleby Frodingham was considered not to be necessary at Lackenby.

The new ferro-alloys ladle additions weighing system, consisting of two groups of six bunkers feeding three weigh hoppers, will be installed. Each group of weigh hoppers will be capable of feeding two vessel ladle stations and each weigh hopper will be a parallel four digit BCD voltage-free contact closure link to the computer. Required alloy weights will be transmitted to the local operators desk by the computer.

In-Blow Measurements: Oxygen measurements are to be made in the waste gas stack and excessive levels will activate an alarm display in the vessel control pulpits.

Carbon monoxide and carbon dioxide measurements will also be measured in the OG system by infrared analyzers. The analysis and sampling units will be of the type developed by BSC Research and proven over a long period at Scunthorpe, but now marketed commercially by Grubb-Parsons.

Audiometers will also be provided, again of the design developed at Scunthorpe, that will give a direct analog input to the process control computer.

New digital lance height control systems will replace existing analog systems. As with the Appleby Frodingham displays the lance height will be set by the operator with respect to the calculated bath height. Although nominally accurate to $\pm$ 30 mm experience in use with the equipment suggests that $\pm$ 5 mm may be obtained. Interlocks to the OG control system are provided.

Laboratory: The detailed engineering of the improvements to the spectrographic laboratory is currently being completed. The functional requirements have been specified in detail. It is expected that new optical spectrographic analysis instruments will be installed, each with its own dedicated control computer, to allow all analysis functions to be carried out. The results from the optical spectrographic analyzers, the x-ray analyzer and new Leco analyzers will be transmitted directly to a laboratory coordination computer, which will collate results and transmit them after checking to the BOS Plant computer. The coordination computer will also provide facilities for producing cast history reports, cast summary reports, shift summary reports and information storage and processing for special project analytical work.

The analyses produced in each steel cast include:

- Hot metal analyses: after desulfurization,
- Hot metal analyses: after pouring into transfer ladle,
- Vessel analyses: at vessel turn down,
- Ladle analyses: before and after stirring, and
- Teeming analyses: up to 6.

Plant Manning

Key plant operators have been identified as an integral part of the process control scheme and attention has been given to their job descriptions. A brief description of each of these key jobs is given below.

Hot Metal Controller: Located at the Polysius desulfurization plant, his job is to control the movement of torpedo cars between rail exchange sidings and hot metal pouring stations to ensure that hot metal of the required specification is available to the steel plant.

Scrap Controller: Located in the scrap bay, his job is to plan and supervise scrap loading into scrap pans by displaying scrap requirements to crane operators so that the steel plant scrap requirements are met.

Plant Controller: Located in the central control pulpit, his job is to monitor and control the plant logistics to ensure that all the raw materials, plant and services are available at all times to keep the steel plant operating at rated outputs and to act as a communications "center".

Steelmaking Controller: Located in the central control pulpit, his job is to monitor and control the steel production to ensure the correct specification is made to schedules required for casting. He has to specify requirements to hot metal, scrap, and plant controllers and coordinate production with the casting controller.

First Vesselman: Located in the vessel control pulpits, the jobs of the first vesselman are to control the making of each heat of steel to produce the required steel specification and to supervise vessel "housekeeping".

Spectrographic Laboratory Supervisor: Located in the steel plant laboratory, his job is to ensure the steel plant gets the analytical service necessary to produce steel of a specified composition and output.

Casting Controller: The casting controller will be located in a pulpit in the casting bay. He will coordinate with the steelmaking controller and will control the logistics of continuous and conventional casting operations.

BOS Plant Process Control Computer System

A detailed functional specification has been prepared for the new system, the more important aspects of which are indicated in the following:

Steelmaking Control Calculations: The heat and mass balance ("static") model will be of the same style as that used at Appleby Frodingham for which a detailed description has been given earlier. Figures 6 to 10 indicate schematically the calculation structure to be employed.

Operator Information Display: Each of the key operators will have a visual display unit with a function keyboard for data input and display selection. He will be able to select displays essential to his job or displays giving an overall view of the plant status and shift performance to date.

The first vesselman will have in addition a semigraphics visual display unit showing decarburization rate and acoustic intensity curves with recommended trajectories and recommended lance and oxygen practices.

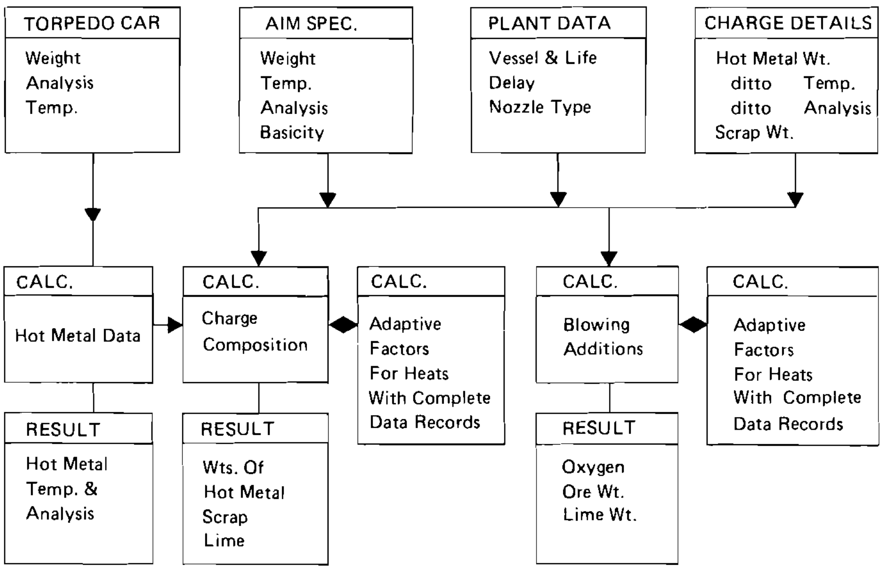


Figure 6. Structure of the static model.

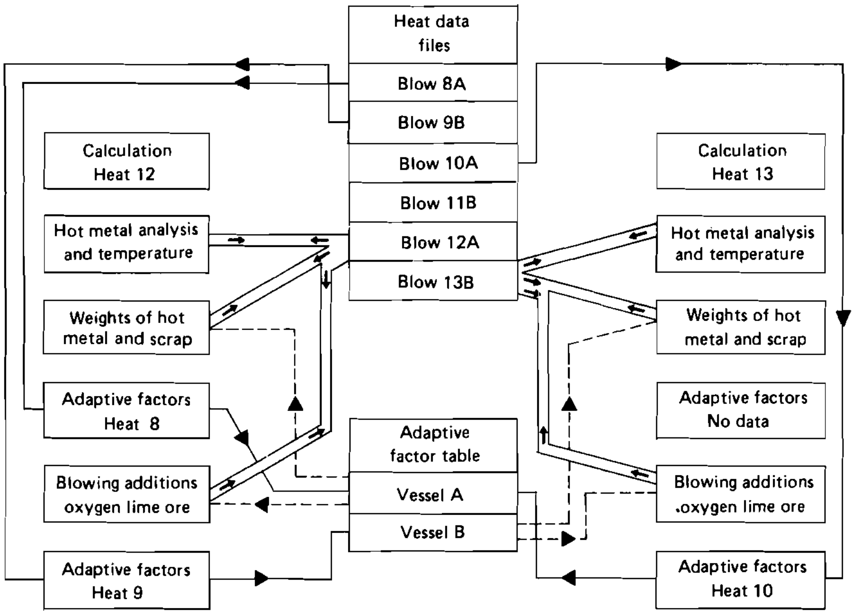


Figure 7. Sequence of model operations illustrating how the model segments are adaptively modified.

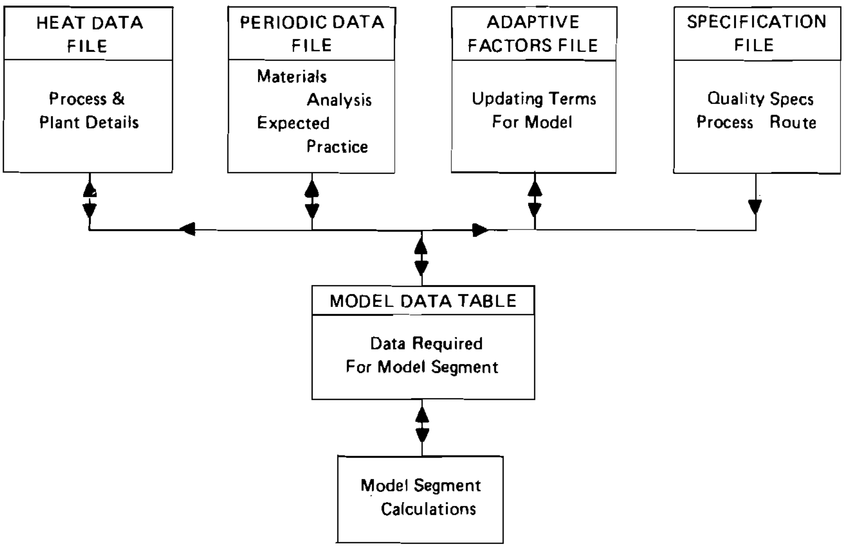


Figure 8. Organization of the data necessary to run the model.

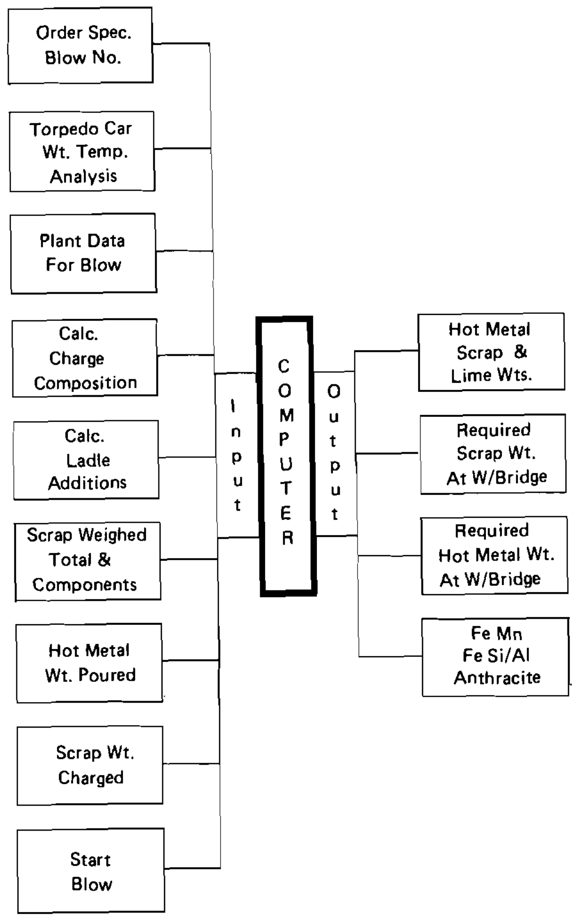


Figure 9. Outputs from the model in relation to plant activities before the heat.

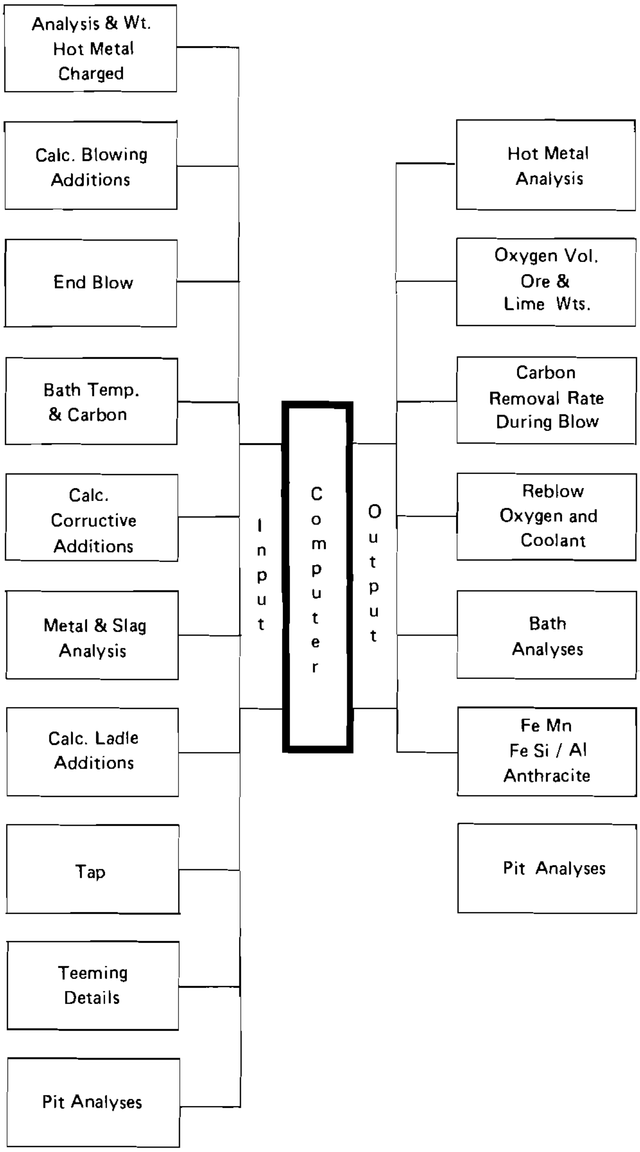


Figure 10. Outputs from the model in relation to plant activities during and after the heat.

Management Information Reports: The system will provide printouts of "heat event" and "alarm logs", a "heat summary", and a "weekly performance summary". In addition, it will provide facilities for the storage of selected data on the last 1000 heats with the ability to perform statistical analysis of this data.

SUMMARY

A brief description of the BSC Scunthorpe and Lackenby steelmaking and process control facilities and planned improvements has been given. The developments at Lackenby have been influenced by experience and research work done both at Scunthorpe and Lackenby BOS Plants. The major objectives of the new process control system at Lackenby are improved control of the steelmaking process while producing steel at increased rates with the use of improved operator information and in-blow guidance systems.

Discussion

A number of questions were raised concerning the policy of employing basic oxygen furnaces (BOFs) within the British Steel Corporation (BSC). It was reported that BSC has made good progress with waste gas analysis especially in evaluating its benefit and has various process monitoring devices in addition to those mentioned. Ideally BSC would like to have them all in one particular vessel so as to make a proper comparison. This is not a simple task since different plants are concerned with different facilities; some have progressed and are successful, others less so. BSC has been concentrating on waste gas analysis because it is possible to maintain it reliably and to give a continuous output to the operator.

Research has been done at Llanwern Works (Wales) with a weighing facility, and papers have been published indicating some of the advantages of that system. There was a possibility that it could predict or improve temperature control. Since then, similar equipment has been installed at the Ravenscray Works, but it is not certain whether the same information as is received from Llanwern can be applied elsewhere. It has to be established whether the equipment will give the same information for each plant: it could be that it is specific to the one plant, i.e., to Llanwern. Nevertheless BSC thinks that it has some potential.

The weight of the hot metal is only one feature of this measurement. Another is that the information corresponding to the decarburization rate is dynamic. It appears possible to use the information for these purposes, and BSC will check different measurement systems with a view to installing relatively cheap and easy ones.

An inquiry was made about dephosphorization; in reply the authors said that, in general, there have been no problems with phosphorus because middle- and low-carbon steels are produced. BSC implemented audiometric control so that slag volume can be monitored: clearly a great amount of yield would be lost by slopping. Specific volume is also very important. BSC has typically 0.7 m^3/t, and control of slag volume is essential. Equally important are the measurement of slag volume, and the decarburization rate, since any indications that there is a change in the decarburization rate coupled with a large slag volume generally gives rise to slopping. At higher cylinder levels the problem is accentuated.

All agreed that the performance level of the operators and management is very important. The Japanese representatives stressed that before the installation of the sublance the difference between the various shifts and the operators varied enormously. Since the use of the sublance, the difference has decreased continuously. Since the morale of the operators has to be considered, different programs have been implemented for them.

The Application of Computer Technique to Process Control of Bottom Blown Oxygen Converters in the German Democratic Republic

H. Burghardt and C. Bollwien

In the German Democratic Republic, 72.6 percent of steel is produced in open hearth furnaces by the pig-and-scrap process, 17.9 percent in the electric arc furnace and plasma arc furnace, together, and 9.5 percent in the bottom blown oxygen converter. These portions of the individual processes will change in the next few years because new electrical steel capacities are being put into operation.

Up to now, the application of computer techniques has been just to process steering and control of open hearth and electric steelworks, and the steering and control of bottom-blown oxygen converter steelworks. The extension of the application of computer techniques to electrical steel production seems to be practicable. The treatment of these problems by IIASA is desirable, and the GDR steel industry is interested in their solution.

Steel production in the bottom-blown oxygen converter by the QEK (Qualitäts-und Edelstahl-Kombinat) process takes place in 20 t converters which use pig iron rich in phosphorus.

The factors for which computers are applied in this process are:

- Calculation of the amounts of raw material necessary, such as pig iron, cooling medium, lime, and alloying materials,
- Determination of the end point of oxygen blowing, and
- Compilation of the charging and casting reports.

The computing system used for the solution of these tasks consists mainly in:

- A process control computer type PR 2100 and its peripheral equipment of both first and second order. It has 4096 memory locations (drum memory) with a word length of 33 bits and possibilities of direct connecting to the process.
- A calculator of the type C 8205, which also has 4096 memory locations.

- Digital and analog indicators.
- A punch tape data transmission unit to the works computer center.
- Various means of communication (teleprinter, correspondence systems, TV system for the transmission of information, etc.).

In Figure 1, the jobs of the process control computer system, divided into the operation process and the substitution system, are presented. For every job, mathematical submodels have been developed with the exception of the compilation of the charging and casting reports. The submodels are in general stochastic. Those shown in Figure 1, in chronological order of a heat run, have the following functions:

- Calculation of the metallic raw material depending on the intended type of steel, the chemical composition and heat of the pig iron, and the necessary tap weight by a statistically secured multiple regression function. The amount of cooling medium necessary is calculated in a similar way.
- Calculation of the additional amount of lime necessary to guarantee the final phosphorus content desired is by the algorithm:

$$m_{Z,\ell} = \frac{m_{RE}}{100} K_{\ddot{u}} \; [4.45 \; Si_{RE} + 3.02(P_{RE} - P_{VP})] - m_{\ell/c}$$

where:

$m_{Z,\ell}$ is the additional lime (kg),

m_{RE}, the pig iron (kg),

Si_{RE}, the silicon content of the pig iron (%),

$K_{\ddot{u}}$, the excess lime multiplication factor,

P_{RE}, the phosphorus content of the pig iron (%),

P_{VP}, the phosphorus content of the preliminary test, and

$m_{\ell/c}$, the amount of lime per charge.

The calculation of the amount of lime in the first few minutes of blowing has precedence over the other arithmetic operations, as slag formation has a big influence on the process. The amount of lime is included in the submodel "end-point determination of the charge".

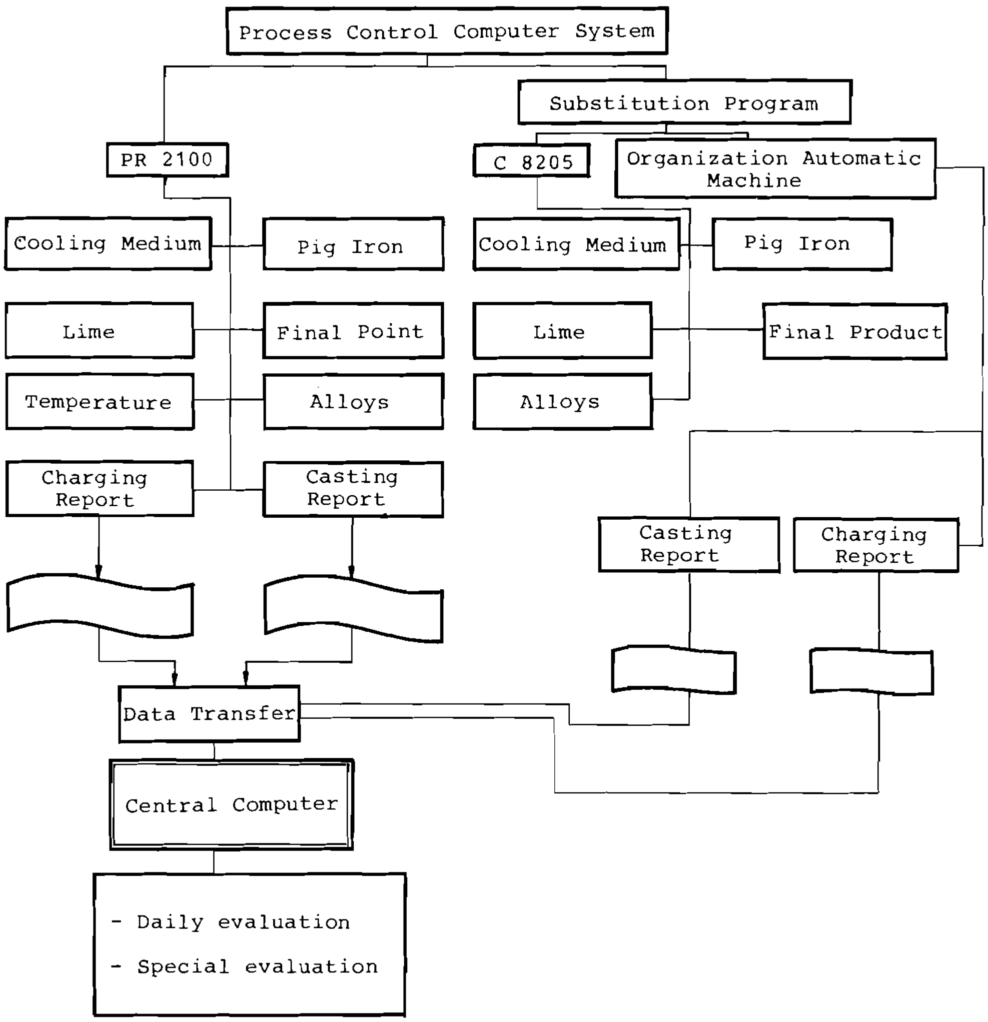


Figure 1. Computer technique and equipment for the process control system of the steel plant.

The end-point determination of the charge, i.e. the end of the oxygen blowing, depends on many factors and is carried out by means of a stochastic function of high precision:

$$m_{O_2} = f(m_{RE}, m_{Km}, C_{RE}, Mn_{RE}, P_{RE}, T_{RE}, m_{lime}, m_{ore},$$

$$O_{2\ddot{U}}, Mn_{VP}, \text{ and } P_{VP})$$

where:

m_{ore}, is the amount of added ore,

m_{Km} , the amount of added cooling medium,

C_{RE}, the carbon content of the pig iron,

Mn_{RE}, the manganese content of the pig iron,

Mn_{VP}, the manganese content of the metal in the pre-test,

T_{RE}, the temperature of the pig iron, and

$O_{2\ddot{U}}$, the amount of oxygen before the conversion.

In this function, the contents of manganese and phosphorus of the preliminary test serve as control media and the oxygen consumed in the conversion serves as an effective process parameter. As some information of the proceeding of the process is used, this algorithm is of dynamic character.

Under the specified operation conditions, the calculated amount of necessary oxygen is available approximately three minutes before the end of the blowing and allows the operator to define the end of the blowing exactly by comparison with the cumulative oxygen consumption indicated.

The calculation of the yield of steel as well as of the alloying materials required for the desired steel type is carried out by multiple regression functions. The compilation of the charging and casting reports is carried out by further processing in the computer center of the data stored for every melt via punch tape.

The control media necessary for directing the melting process are transmitted to the smelters directly, whereas the complete reports are prepared when all the information is available.

The application of the process model led to an improvement of the operation process and the quality of the produced steel; besides which labor needs were reduced. The yield increased by

0.4 percent and the lime saved by the economies was 5 percent. These results mean that the plant redeems the cost of the computerization within 2.3 years.

Discussion

The discussion centered on process technology and organization in the steel industry. It was pointed out that in the German Democratic Republic, basic oxygen furnaces (BOFs) are not used; their use in steel plants may be included in the next Five-Year Plan.

By means of the bottom-blowing process, about 600,000 t of steel are produced annually; phosphorus-rich pig iron is also processed using this technique. Oxygen and diesel fuel used as coolants are injected simultaneously. There are no problems with slag formation and phosphorus removal. In crude steel there is less than .01 percent phosphorus.

Attention then focused on the organization of integrated systems in steel plants in the GDR. It was stated that the sectorial system is partly in operation for the steel industry. Several steel plants have implemented a central computer system for planning, scheduling, stock control, and the like.

Adaptation Methods in Investigations, Monitoring, And Control of the Oxygen Converter Process

Yu.A. Vasilevsky, R.A. Simsariyan, and B.I. Chernov

The oxygen converter is a promising process whose development is limited chiefly by the degree of control possible. The chief reason preventing the development of a perfect control system is the continual change caused both by reactions in the converter and by the frequent developments of the process. Stabilization of the raw material and blowing modes does not eliminate this problem; furthermore, no stable statistical variables seem to exist that could be used to describe the process.

The continual change prevents sufficient a priori data (accurate statistical characteristics of the variables and the noise) from being obtained for a monitoring and control system; but adaptation methods [1,2] seem to be useful in studying, monitoring, and controlling the process.

Problems solved by adaptation methods have been formulated [1,2] as problems in estimating the parameters with a view to minimizing certain loss functions.

In a general case, the loss function can be represented as

$$J(\underset{\sim}{c}) = \int Q\ (x,\underset{\sim}{c})\ p(x)\ dx \quad , \tag{1}$$

where $p(x)$ is the distribution density of the random quantity x and $Q(x,\underset{\sim}{c})$ a certain function of x and the parameter vector $\underset{\sim}{c}$ [1].

One of the a priori data lacking is $p(x)$. The adaptive approach to the minimization of $J(\underset{\sim}{c})$ yields a recurrence algorithm for estimating the parameter vector $\underset{\sim}{c}$:

$$\underset{\sim}{c}[n] = \underset{\sim}{c}[n-1] - \gamma\ [n]\ \nabla_c Q\ [x[n],\ c[n-1]]) \quad . \tag{2}$$

The shortage of a priori data if the form $p(x)$ is offset by the current data contained in $x[n]$. The algorithm (2) ensures asymptotic convergence to the value $\underset{\sim}{c}$ which minimizes the loss functions (1) if the convergence conditions of [1] are met.

The choice of the function $Q\ (\cdot)$ is in most cases dictated by the objective for which the parameters are estimated. The choice has not been formalized but if p(x) is known to belong to a certain class P then the choice of $Q(\cdot)$ can indeed be formalized. Minimizing on the class P the Fisher information I(p) the "worst value" for the given class P distribution $p^*(x|\tilde{c})$ is found, which gives the lower bound for the estimate variance in the Kramer-Rao inequality. One should assume [3] that

$$Q(x,\tilde{c}) = - \ln p^*(x|\tilde{c}) \quad . \tag{3}$$

This approach results in the so-called robust algorithms [4]. Consequently, adaptation methods are a standard way to obtain algorithms for the investigation of real-time (statistical data processing, design and analysis of mathematical models, experiment design, etc.), automatic monitoring (quantization of data reduction), and control.

The multipurpose adaptation algorithms are convenient for the development of program packages and make the software easily restructurable and extensible. Because they are iterative, they can be conveniently used for designing real-time data processing programs and they are fairly insensitive to computation, in particular, rounding errors.

The basic difficulties in applying adaptation or any other mathematical methods are chiefly in the problem statement, the choice of variables and methods to measure them, and in the choice of the loss function and the vector of adjustible parameters. Another difficulty is the need for an easily operable control system.

Table 1 presents adaptation algorithms used in solving specific problems of oxygen converter process control. Two examples will be used for illustration.

Measuring the Level of the Slag Metal in the Furnace

The sound intensity p during the melting is known to depend on the difference H_{f-n} between the slag metal level in the furnace and the cutoff of the tuyere nozzle [5].

This dependence can be modeled as a piecewise linear function:

Table 1.

Name and Notation	Algorithm	Application
1. Moment estimates: n, step number $\gamma[n]$, factor that satisfies convergence condition, $x[n]$, value of a random quantity, m_κ, moment of the κth order	$m_1[n] = m_1[n-1] - \gamma_m[n](m_1[n-1] - x[n])$ $m_\kappa[n] = m_\kappa[n-1] - \gamma_m[n](m_\kappa[n-1] - (x[n]$ $- m_1[n])^\kappa)$	Analysis of sampling procedures, of metal oxidation meter characteristics; determination of the optimal scrap-pig iron ratio; analysis of measurement credibility in monitoring systems; analysis of factors influencing the rolling performance.
2. Estimate of α -quantile: d, confidence probability, q, α-quantile.	$q[n] = q[n-1] - \gamma_q[n]F(\alpha,q[n-1],x[n])$ $F(\cdot) = \begin{cases} 1-\alpha, & \text{if } x[n] < q(n-1] \\ -\alpha, & \text{if } x[n] \geq q(n-1] \end{cases}$	Determination of the boundary to eliminate erroneous data; sampling analysis; measurement credibility.
3. Histogram plotting: Δ_j, the jth decomposition interval, δ, size of decomposition intervals, g_j, histogram parameters.	$g_j[n] = g_j[n-1] - \gamma_g[n](g_j[n-1] - \Psi_j(x[n]))$ $\Psi_j(x) = \begin{cases} 1/\delta, & \text{if } x \in \Delta_j \\ 0, & \text{if } x \overline{\in} \Delta_j \end{cases}$	Development of a sampling procedure; monitoring the level of the slag and metal crucible; analysis of metal oxidation meter characteristics; noise and vibration analysis.
4. Estimating the parameters of a piecewise-linear model: $y[n]$, value at the nth step associated with that of the argument $x[n]$.	$a_i[n] = a_i[n-1] - \gamma_c[n](y[n] - a_i[n-1]$ $- b_i[n-1]x[n])\Theta_i$ $b_i[n] = b_i[n-1] - \gamma_c[n](y[n] - b_i[n-1]x[n]$ $- a_i[n-1])\Theta_i$ $\Theta_i = \begin{cases} 1, & \text{if } x \in (x_{i-1}, x_i) \\ 0, & \text{if } x \overline{\in} (x_{i-1}, x_i) \end{cases}$	Calculating carbon content in metal; change determination; sampling procedure analysis; decarburization rate to forecast; determining the optimal scrap-pig iron ratio.

Table 1. (cont'd)

Name and Notation	Algorithm	Application
5. Forecast: $S_\kappa[n]$, exponential κth average at the nth step, β_i, factors of the forecasting model, m, forecasting interval.	$y[n+m] = \beta_0 (S_1[n],\ldots,S_\kappa[n]) + \beta_1(S_1[n],\ldots, S_\kappa[n])m + \ldots + \beta_{\kappa-1}(S_1[n],\ldots,S_\kappa[n])m^{\kappa-1}$ $S_1[n] = S_1[n-1] - \gamma_s[n](S_1[n-1] - y[n])$ $S_j[n] = S_j[n-1] - \gamma_s[n](S_j[n-1] - S_{j-1}[n])$; $j = 2,\ldots,\kappa$	Forecasting the decarburization rate; investigation of the decarburization rate as a function of temperature in the reaction zone.
6. Obtaining a random value with specified characteristics: $x[n]$, value of a random quantity with arbitrary characteristics, $y[n]$, value of a random quantity with desired characteristics, a_i parameters of the functional converter.	$a[n] = \mu\{a[n-1] - \gamma_a[n](h_y[n] - h_3)\}$ $\mu\{a_i\} = \begin{cases} a_i, & \text{if } a_n - a_i \geq a_i \\ a_{i-1}, & \text{if } a_{i-1} > a_i \\ a_n, & \text{if } a_i \geq a_n \end{cases}$ $Y[n] = \sum_{i=1}^{n}\left(a_{i-1} + (a_i - a_{i-1}) \frac{x[n] - x_{i-1}}{x_i - x_{i-1}}\right)\theta_i$	Metal oxidation meter analysis; investigation of input-output models.
7. Automatic classification: F_1, F_2, loss function, u_1, u_2, class centers.	$u_j[n] = u_j[n-1] - \gamma_j[n]\, F_{ij}(x[n], u_1[n-1], u_2[n-1])$ $F_{ij}(\cdot) = \begin{cases} \nabla_{uj} F_1(\cdot), & \text{if } F_1(\cdot) - F_2(\cdot) \leq 0 \\ \nabla_{aj} F_2(\cdot), & \text{if } F_1(\cdot) - F_2(\cdot) > 0 \end{cases}$ $i,j = 1,2$	Decarburization rate plot shape analysis; analysis of factors influencing the rolling performance.

$$H_{f-n} = \sum_{i=1}^{4} \left\{ a_i + \frac{a_{i+1} - a_i}{p_{i+1} - p_i} [p(t) - p_i] \right\} \Theta_i \qquad (4)$$

where p_i and a_i are the X-line and Y-line, respectively, of the ith approximation unit;

$$\Theta_i = \begin{cases} 1, \text{ with } p_i < p(t) \leq p_{i+1} \\ 0, \text{ with } p_i \geq p(t) \text{ or } P_{i+1} < p(t) \end{cases} . \qquad (5)$$

The parameters a_i of this function vary widely in the course of melting and to obtain accurate values of H_{f-n} they need be updated. For this purpose adaptation algorithms of the form (2) are used [6]:

$$\frac{da_i}{dt} = \left(\frac{\delta p(t)}{p_{i+1} - p_i} \Bigg/ \int_0^t \left(\frac{\delta p(t)}{p_{i+1} - p_i} \right)^2 \Theta_i d\tau \right) \varepsilon(t) \Theta_i \quad , \qquad (6)$$

where $\varepsilon(t)$ is the error in computing the desired function.

The values of a_i are determined and updated while the tuyere moves up and down; $\delta p(t)$ is the variation of the noise intensity with the tuyere position.

The crucible level is the sum of H_{f-n} and the tuyere level. Adaptation algorithms ensure an accuracy sufficient for practical purposes. The operator matches the meter and can update its input-output characteristic by moving the tuyere up and down.

Estimating the Oxygen Content in the Converter Crucible Bath in the Course of Blowing

It has been found [7] that starting at a certain time, the oxygen content in the crucible is described well by the differential equation

$$dC/dt = -\kappa C \qquad (7)$$

The carbon content C can be found from

$$C = C_o e^{-\kappa t} \qquad (8)$$

The unknown parameters C_o and κ of equation (8) are determined through changes in the decarburized rate $\nu_c = -\frac{dC}{dt}$

$$\nu_c = \kappa C_o e^{-\kappa t} \quad . \tag{9}$$

The process of continued change calls for readjustment of the parameters κ and C_o during the course of the melt. The parameters are estimated and restructured by using an algorithm of type (2) from the current values of ν_c in each melt:

$$\alpha[n] = \alpha[n-1] - \gamma_i[n] \; (l_n \; \nu_e[n] - \alpha[n-1] - \beta[n-1] \; n)$$

$$\beta[n] = \beta[n-1] - \gamma_2[n] \; (l_n \; \nu_c[n] - \alpha[n-1] - \beta[n-1] \; n)$$

where $\beta = -\kappa$ and $\alpha = l_n \; (\kappa C_o)$,

n are discrete times of t, and

$\nu_c[n]$ are discrete values of ν_c .

Similar adaptation algorithms determine the time at which Equation (7) starts to hold for each melt from current values of ν_c.

The algorithms were tested in the Chelyabinsk and West-Siberian Works. The transient period of parameter adjustment was found to depend on the choice of initial values and did not exceed seven to ten melts with zero initial values. Continuous parameter updating from the current values of ν_c results in a calculated carbon content which does not differ from the actual value by more than 0.02 percent (the liquidus temperature being the indicator).

The adaptation approach seems promising in processes other than oxygen converters and significantly facilitates the systems approach in investigation, monitoring, and control.

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Discussion

Attention focused on two main problems: adaptation techniques of models, and their implementation for control of basic oxygen furnaces (BOFs).

Because of the changing characteristics of the BOF process e.g., during the heat periods and during the life of the converter, adaptation is essential for BOF control. For example, the use of only one standard curve for a period of 100 heats without adaptation may result in an error in measuring the lance position that could be as great as 4 m. The sound intensity of the frequency of 700 to 900 Hz is used as input information. This standard curve may be used for lance position control. The lance may move during the blowing period, and the special display will then show the operator how much adaptation is needed. The operator is able to change the lance position very quickly in such a way that the position of the bath remains the same. The curve calibration is done on the basis of changes in the sound intensity. The new calibrated curve is used for the lance position control in the next heat. This system has been used on a 130 t converter. The implementation of the system makes it possible to prevent slopping and to increase the metal yield by up to 0.4 percent. This method has also been tested for 50 to 300 t converters.

Another subject discussed was carbon end-point control. In this case, model adaptation begins five minutes before the assumed end-blowing time for a 130 t converter, and three minutes before for a 350 t converter. The implementation of the model has resulted in standard deviation for the end point of 0.02 percent; before model implementation, it was 0.04 percent.

Other problem areas receiving attention were temperature measurement in the reaction zone and vibration measure. As to the former, the measurement, which was organized through the oxygen lance, was 2000 to 2100 ^{o}C. The most difficult problem with respect to vibration measure is to determine the point for the sensor statement.

Economic Aspects of Computer Application In Basic Oxygen Furnaces

L. Surguchova

Computer application in basic oxygen furnaces (BOFs) naturally means additional investment and it is important to calculate the efficiency of this. In this paper we consider a basic methodology for this calculation which can be used for calculating the efficiency of both planned and operational computer systems.

It is generally known that computer application in BOFs makes possible a reduction in the number of carbon and temperature reblows and overblow heats--in other words, it increases the number of heats produced for a given value of the output parameters. This changes the number of techno-economic indexes for the BOF process analyzed by the methodology (decreasing the blow-time, the tap-to-tap cycle, the ferro-alloy consumption, waste materials, etc.) and leads to an increase in metal yield, the life-span of the refractory lining, etc. (see Figure 1). This in turn leads to a change in the costs of maintenance, raw materials, additives, etc.

The other important consequence necessary for consideration when calculating the economics of computer application is the change of capital investment in adjoining economic sectors (Figure 1).

The increase in the metal yield is possibly the main source of efficiency. The metal yield depends on the scrap ratio in the charge, the temperature of the metals, the carbon concentration at the end point, the blowing time, etc. Table 1 shows as an example the dependency of waste on the end-point temperature for pipe steel. There is an optimal end-point temperature for minimal waste.

Table 1.

End-Point Temperature of Steel (^{o}C)	1570	1580	1590	1600	1610	1620	1630	1640	1650
Waste (%)	1.7	1.2	0.7	0.6	0.7	0.2	0.3	1.8	2.6

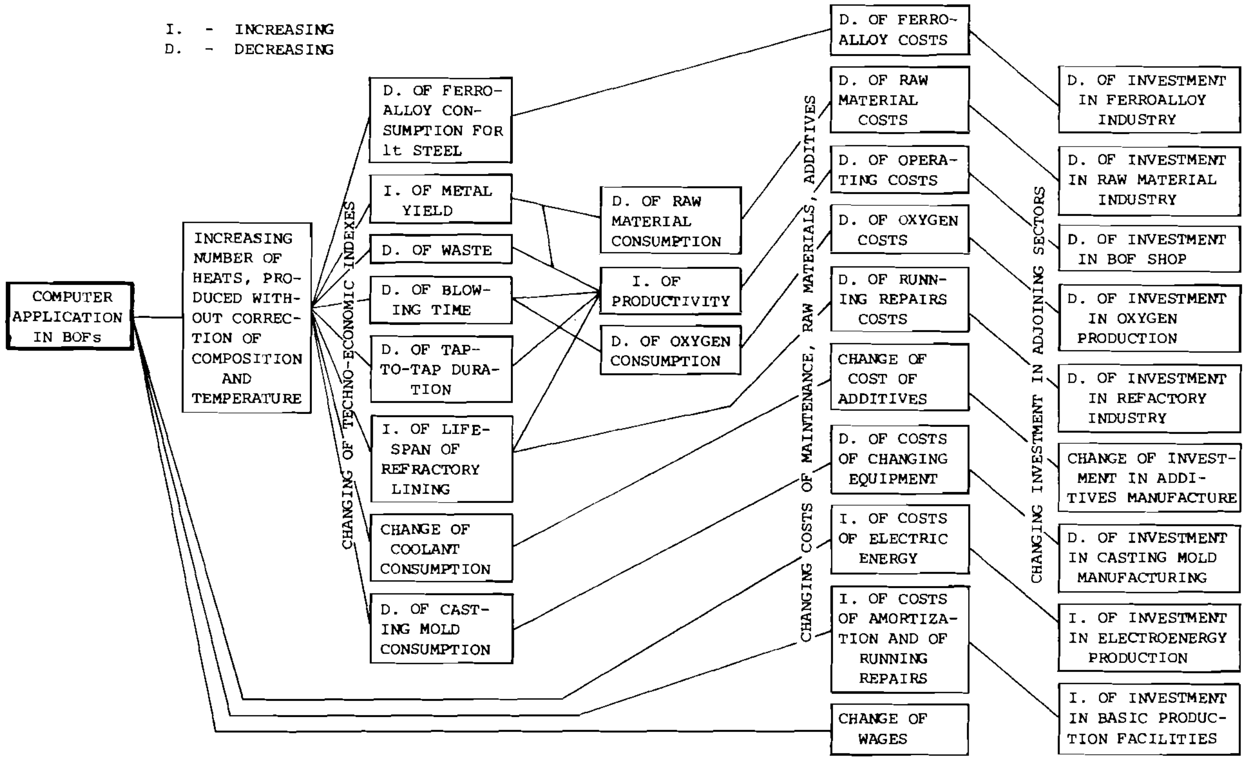


Figure 1. General diagram of calculation of efficiency of computer application in BOFs.

More precise end-point control leads to a reduction in the tap-to-tap and blowing cycles and to a decrease in heat loss. This makes it possible, for example, to increase the fraction of scrap in the charge which is also very important.

Improvement of end-point control by computer application leads, as was shown above, to an increase in metal yield, which means an increase in productivity (Figure 1). It also increases the durability of the refractory lining. It is well known that a number of corrections depend on end-point temperature. It was found, for example, that by reducing the number of end-point carbon corrections by 10 percent, the life span of the refractory lining was increased by 10 percent. The influence of end-point temperature (either higher or lower) on this index is also extremely high. Increasing the life-span of the refractory lining naturally reduces the refractory consumption and the cost of repairs. In addition, it increases BOF productivity. Increased productivity depends very strongly on the accuracy of end-point control. The reduction of blowing time saves some oxygen and leads to a decrease in energy costs for the steel.

The change of investment in other sectors has been considered, making it possible to evaluate the efficiency of computer implementation for the economy as a whole. The efficiency of different computer-based systems for BOFs has been calculated. The various systems installed on a 100 to 130 t capacity BOF are:

- I Specialized analog system for dynamic measurement of decarburization rate;

- II Specialized analog system for end-point control, based on a static, statistical model;

- III, IV, V Systems based on universal minicomputers for static end-point control: the models implemented are combined, e.g. analytical-experimental;

- VI Systems based on a universal minicomputer for static charge calculation and dynamic end-point control;

- VII Systems based on a specialized analog computer--the system carries out the following tasks: charge calculation, decarburization rate, carbon concentration and temperature of metal during blowing, iron concentration in slag, end-point control.

As shown in Table 2, computer application in BOFs improved the control of these processes, increased the percentage of heats produced without corrections, increased the productivity by 1.2 to 4.6 percent, and reduced the cost of steel by 0.12 to 1.0 percent. It is clear from this study of computer application that the sources and value efficiency depend not only on the systems implemented but also on particular features of the controlled object.

Table 2. Some results of computer application in BOFs.

Attributes (%) \ Computer Systems	Dynamic End-Point Control	Static Charge Calculation and End-Point Control				Static and Dynamic	
	I	II	III	IV	V	VI	VII
Increased proportion of heats without correction	9.7	10.2	15.2	15.5	18.0	25.0	35.4
Increased productivity	1.2	1.8	2.8	2.6	2.4	3.3	4.6
Increased metal yield	-	0.05	0.15	0.18	0.14	0.20	0.23
Reduction of waste	-	-	0.10	0.10	-	0.10	0.15
Increased durability of refactory lining	3.7	6.0	9.5	8.0	6.0	13.0	15.0
Reduction of casting mold consumption	-	6.0	7.5	7.5	-	10.0	10.0
Reduction of cost of steel	0.12	0.40	0.70	0.70	0.40	1.10	1.00
Reduced cost of steel in other economic sectors	0.12	0.40	0.70	0.50	0.30	0.80	0.90

It is necessary to emphasize that the results of computer application should be evaluated not only from this purely economic point of view but also from a social point of view--improvement of working conditions, raising the level of the personnel, and so on.

Discussion

The participants underscored the difficulties encountered in eliminating small changes in the parameters because of computer application, as for example, changing the metallic yield 0.05 percent. One participant mentioned a case study in which a special test period was selected, say 200 to 300 heats with a computer, and the same number without a computer. Several different parameters were considered for five different plants. Occasionally, it was found that change occurred because of computer application.

It was stated that improvement of the indexes is more important than cost. Cost-benefit analysis is the optimal method for presenting a good picture of computer application. There are very few published results about the efficiency of systems; results are available for some steel plants in Japan. The development of techniques mentioned in these reports appears feasible.

Attention then focused on the use of computers for improving the results of poor versus good management. Each plant has its own considerations and management system, and the evaluation of improvements must take these factors into consideration. It may be possible that a good manager can control the converter better than a computer.

INTEGRATED SYSTEMS IN LARGE STEEL PLANTS

Integrated Computer Control System for the Steelmaking Plant at the Mizushima Works

Y. Iida and M. Ogawa

INTRODUCTION

Mizushima Works, with an annual raw steel production capacity of 12 million metric tons, is the second integrated steelwork of the Kawasaki Steel Corporation. It produces plates, hot-rolled sheets and strip, cold-rolled sheets and strip, wide-flange beams, steel bars, wire rods, steel castings, and forgings as finished products as well as materials for pipe and tubes to be shipped for a pipe making plant of the company.

Two steelmaking shops are in operation at Mizushima Works. No. 1 steelmaking shop was started in 1967, and No. 2 shop in 1970. Table 1 lists some of the major equipments and facilities at both steelmaking shops.

Table 1. Selected equipment and facilities at Mizushima steelworking shops.

No. 1 Steelmaking Shop:	3 BOFs (each with a nominal capacity of 180 t)
	1 R-H type vacuum degassing equipment (180 t)
	3 teeming yards
	2 stripper yards
	3 continuous casting machines
No. 2 Steelmaking Shop:	3 BOFs (each with a nominal capacity of 250 t)
	1 R-H type vacuum degassing equipment (250 t)
	3 teeming yards
	1 stripper yard
	2 continuous casting machines

A BOF process computer was introduced primarily to control blowing operations. Computerization of steelmaking operations at Kawasaki Steel dates back to 1965 when a computer control system was first put on stream at Chiba Works, the company's first integrated steelworks some 30 miles east of Tokyo. Based on this experience, a H-21 computer system of Honeywell was installed in 1967 at a steelmaking shop in Mizushima Works; since then, there has been research on developing a computer control system for blowing.

Mizushima Works uses an order-to-production system, producing the finished products and materials mentioned above. Since many types of ingot and casting slab and bloom are produced at the steelmaking shops, the processing of information about the shops' operations is a complex process. It is therefore important to automate existing manual operations and to process efficiently information about the workshops within the steelmaking shops. In particular, automation of the technical control is required not only to improve the quality control but also to release managers and engineers from routine work.

Computer application in steelmaking shops may be viewed as having the following goals:

- To achieve stable operations, stable quality, and high productivity by means of advanced blowing control;

- To improve quality and yield by means of immediate and accurate processing of information within and around the steelmaking shops, and optimum operational instructions;

- To process information automatically for technical control.

At Mizushima Works, research for developing an integrated computer control system for total automation of the integrated steelworks has gone on since the company's beginning. Production scheduling, operations control, and process control, have been totally automated through the introduction of a hierarchy computer system. These stages are as follows:

- Stage 1: large-scale computers for order entry, production planning, and scheduling;

- Stage 2: large-scale real-time computers for on-line scheduling and operations control;

- Stage 3: process computers for process control and/or operations control; and

- Stage 4: minicomputers for restricted control tasks or interfaces for automation of process operations.

An on-line integrated computer system for a steelmaking plant was introduced in order to achieve the goals mentioned above;

the system has been effective in processing information about the processes of hot metal handling to ingot making. At the steelmaking plant, this system carries out almost all the functions of the above stages 2 and 3.

This paper discusses the systematization level, effects, and future trends based on operational experience with this computer control system.

INTEGRATED COMPUTER CONTROL OF A STEELMAKING PLANT

Figure 1 shows the computer system for the steelmaking process. An integrated computer system (MELCOM 350/30) is linked to the computer control system (H-21) for the No. 1 Steelmaking Shop, which functions as a kind of satellite system. The system is designed to achieve optimum control of production throughout the entire steelmaking processes from hot metal handling to ingot making. The system is organized so as to improve quality and product yield by total and real-time processing.

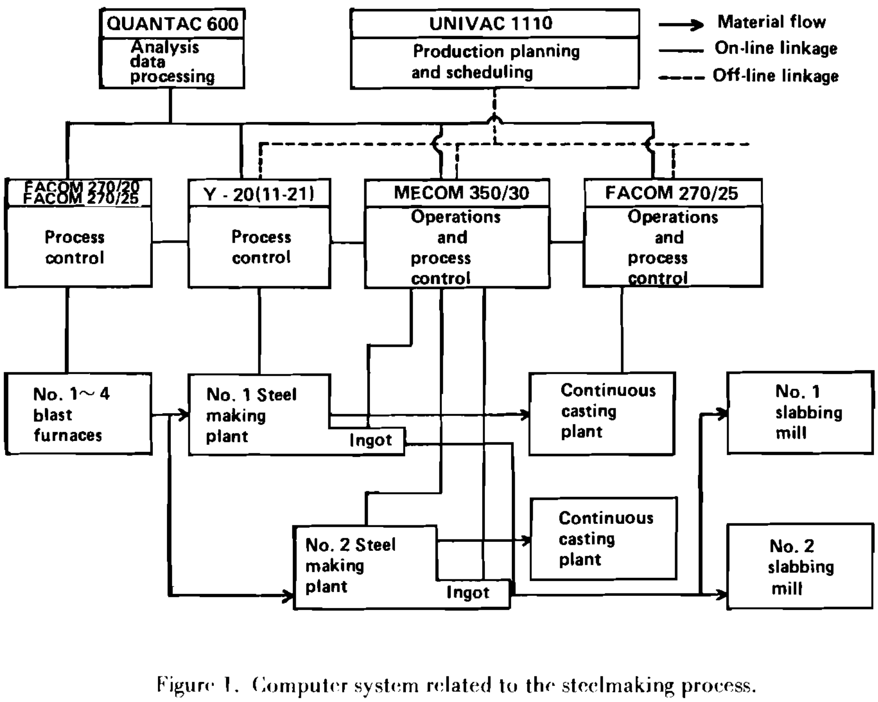


Figure 1. Computer system related to the steelmaking process.

Computer System Functions

Figure 2 shows the functional diagram of the system. The steelmaking orders are scheduled on a daily basis in the central production control computer system (UNIVAC 1110), and delivered in the form of punch card output each day. The orders are manually rearranged for proper blowing schedules in accordance with operational conditions such as mold preparation, teeming yard, degassing equipment, continuous casting machines (CCMs), and rolling orders at slabbing and blooming mills. Before the orders are executed, they are translated into concrete operational instructions, such as preparation instructions for raw materials of hot metal, scrap, etc., or for ingot molds, which are shown on cathode-ray tube (CRT) displays or printed out by typewriters at each pulpit, or directly preset on an instrument to control the operation. Information on molds and stools prepared according to a instruction sheet is fed into the computer. At the same time a teeming instruction sheet for each heat is printed out by a typewriter, covering the target ingot weight controlled by crane scale, which is automatically corrected on the basis of data for molds and stool so as to improve the yield of primary rolling. Likewise to improve the yield of steelmaking, data on these modified weights are reflected in the charge calculation of raw materials.

Computer control and information processing of the BOF process from hot metal handling to tapping are done prior to the ingot-making operation, which is performed in accordance with the detailed teeming instruction sheet mentioned above. Data on the teeming operation (observation data) are fed into the computer through CRT, and transmitted immediately to the subsequent process site of the slabbing and blooming mill. Figure 3 shows the layout of terminal equipment, and Figure 4 shows the schematic data flow of the ingot-making process.

The system has various functions for improving the steelmaking and slabbing yield, etc., by means of overall and real-time control of processes from hot metal handling to ingot making. Selected features of the functions of this system are outlined below.

Charge Calculation

The high level charge calculation for raw materials is made in order to stabilize the blowing operation and to improve the steelmaking yield. The hot metal tapped from the first four blast furnaces is transported by torpedo cars to the steelmaking shop. The targeted amount of steel is composed of both the weight of ingots and the weight estimated on the basis of data on previous prepared molds. The charge weight of raw materials is therefore calculated according to the following equations. Various parameters have been used in these equations to prevent dispersed blowing owing to differences in chemical composition and temperatures between the hot metal of each torpedo car, and to stabilize the blowing operations.

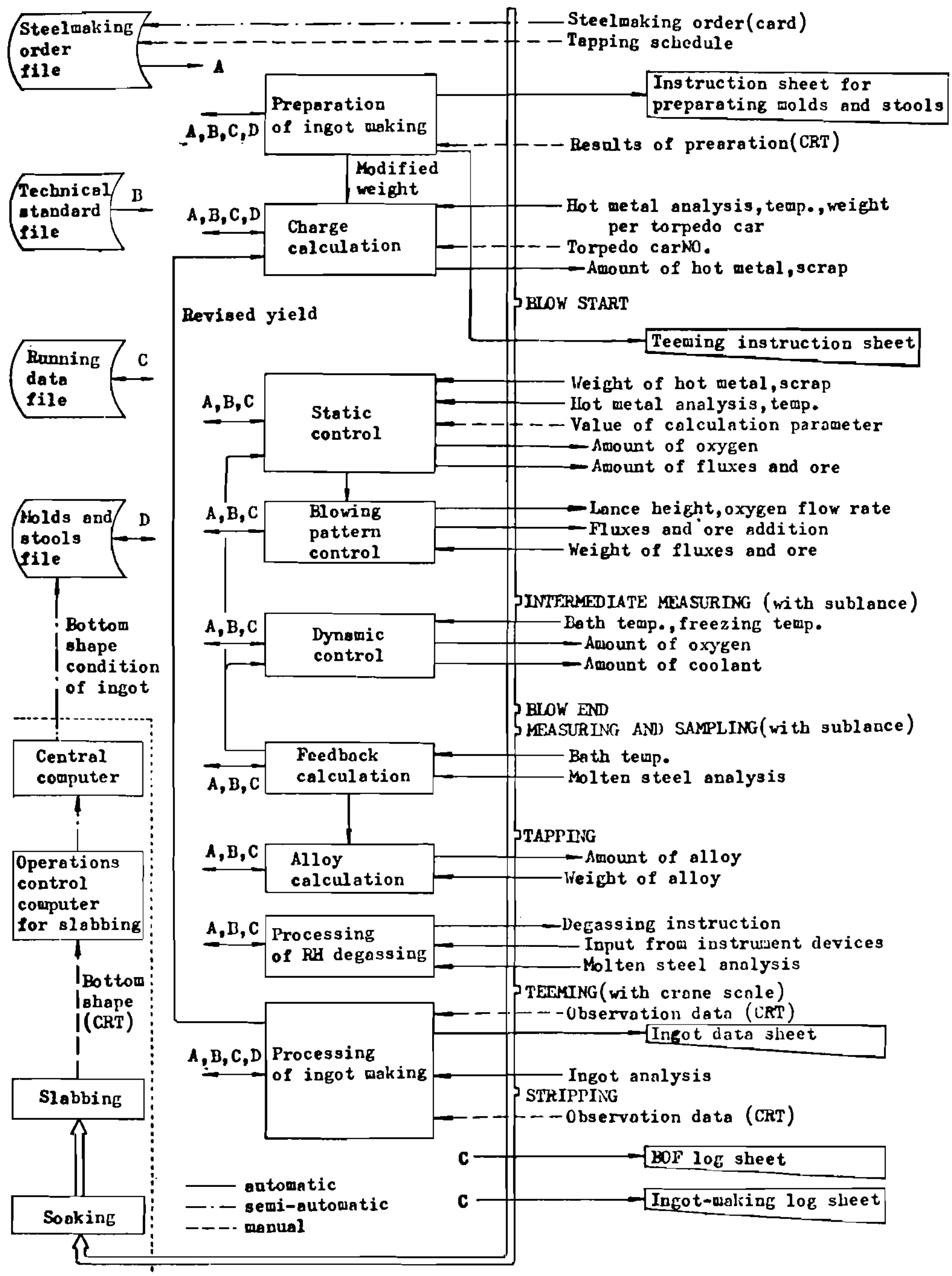


Figure 2. Functional diagram of the computer system.

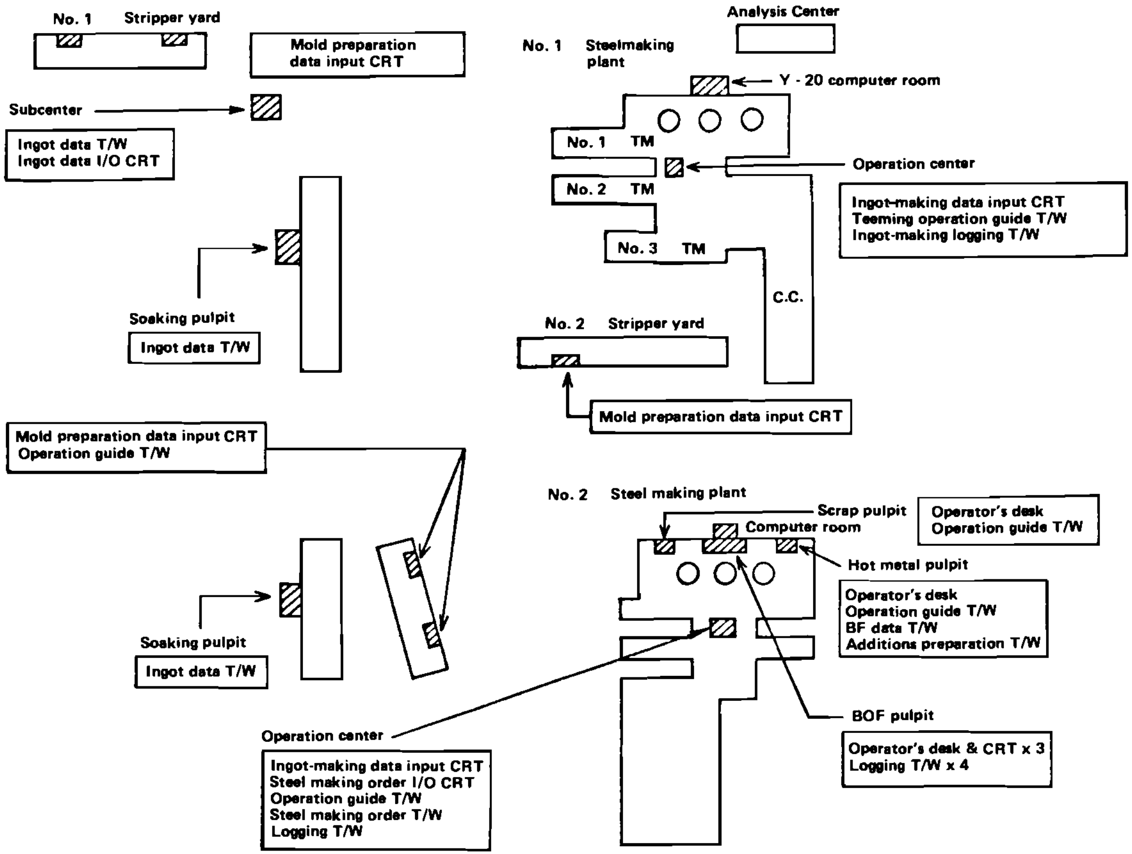


Figure 3. Layout of terminal equipment.

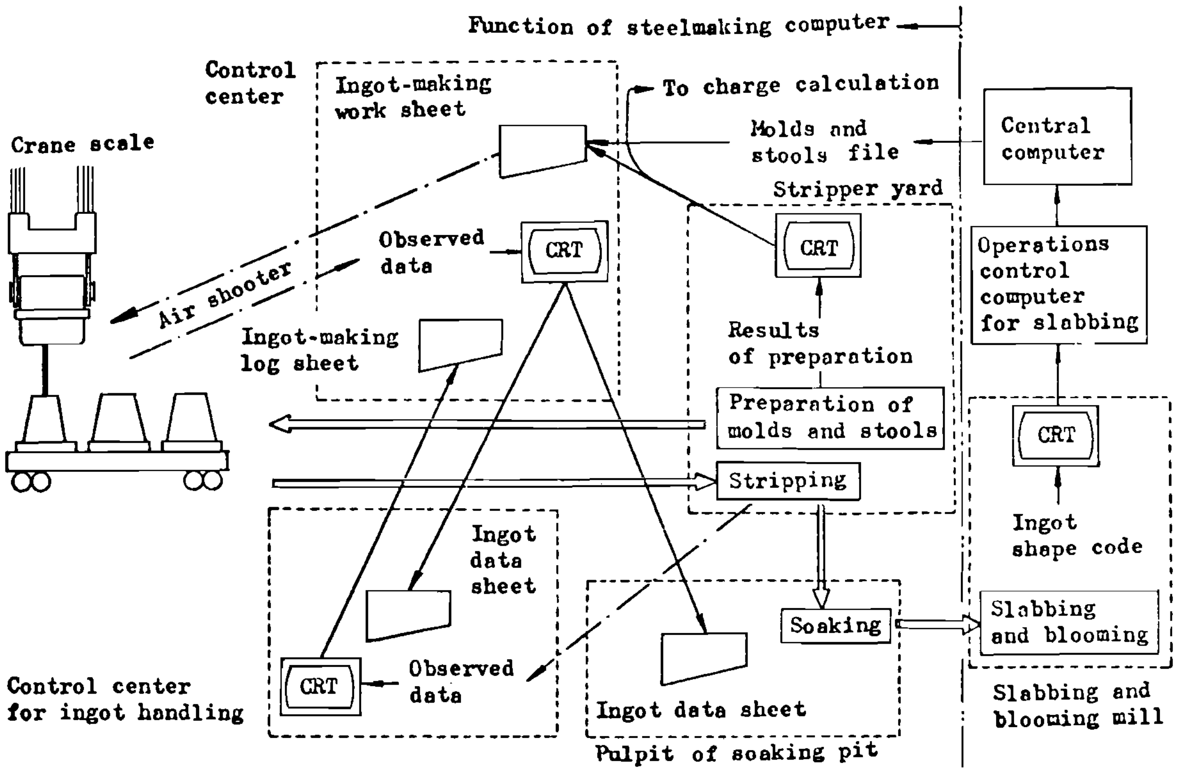


Figure 4. Schematic data flow of ingot-making process.

Hot ratio: $HR = f_1 (\overline{Si}, \overline{T}, G, CR, C_1)$. (1)

Charge weight: $WCH = f_2 (WSTL, HR, CR, CHSTL, \alpha)$ (2)

where:

$\overline{Si}$: estimated Si content of charged hot metal,

$\overline{T}$: estimated temperature of charged hot metal,

G : steel grade,

HR : weight ratio of hot metal to charged raw materials,

CR : weight ratio of cold iron to charged raw materials,

WSTL : target weight of steel,

CHSTL : chemical composition of molten steel at end-point,

C_1 : constant term.

In Equation (2) α is the revised term for the steelmaking yield; this is automatically revised according to the difference between the predicted and the real weight of the steel. If up to three torpedo cars are designated, the calculation is performed so that the weights of hot metal, cold metal, and scrap to be prepared are shown on the CRT display.

Automatic Control of the Blowing Operation

Signals from the weighers, thermometers, flow meters, and other instruments are automatically fed into the computer and used for calculations, data logging, etc. The computer output is given to the analog or digital controller unit--that is, the equipment related to the blowing operation is automatically controlled through the combination of the computer and the instruments. For instance, the adding pattern and the weight of the submaterials of fluxes and iron ore are given by the controllers, and fluxes and iron ore are automatically added by the local sequence control units.

Data Links with the Other Process Computers

This computer control system exchanges information with the other process computers through the direct data link. For example, data on the transportation of topedo cars may be obtained from the blast furnace computer and used in calculating the charge weight of raw materials. The analysis computer gives data on hot metal and molten steel at the BOF and the ingot-making stages, respectively.

Strict Control of Ingot Weight

Strict control of ingot weight has greatly improved the slabbing and steelmaking yield. At Mizushima Works, each teeming crane is equipped with a crane scale that controls the ingot weight. Since a top pouring mold suffers from great dissolution at the mold bottom, the ingot weight is therefore corrected according to ingot shape so as to improve the yield. That is, bottom shape conditions are grouped into 11 classes and coded; the coded bottom shape given for every mold is fed back to this system as the ingot shape is observed at the primary rolling stage. Upon preparation of the mold, the additional weight is calculated for each mold according to its bottom shape code; this weight is added to the targeted ingot weight that has been printed out on the instruction sheet for ingot making. Furthermore, data on these modified weights are reflected in the calculations for charge weight of raw materials. This is one of the most effective functions of the total and real-time computer control system.

Inventory Control of Molds and Stools

The on-line inventory control of molds and stools has greatly contributed to the improved quality of ingots to the reduced mold consumption cost, while also improving the yield. The mold and stool master file contains data on all molds and stools (about 3000 to 4000 molds and about 2000 to 3000 stools) in use at the steelmaking shops in Mizushima Works, and the file is updated on a real-time basis. As shown in Table 2, the number of data items per mold is 13 and that of stool is 9.

Table 2. Date items per mold and stool (mold: 1-13, stool: 1-9).

1	Location	8	Latest pouring time
2	Index of the kind	9	Shop No. in use
3	Index no.	10	Next available time
4	Frequency of usage	11	Ingot shape code
5	Frequency of repairment	12	Parameter 1
6	Total ingot weight	13	Parameter 2 (for ingot weight calculation)
7	Average cycle time		

Organization of Hardware and Backup Problem

Since system failure is to be avoided, a large investment will be necessary to meet this requirement at the present technical level. The problem most feared in a single system is a prolonged system failure, which can happen. Should this be the case, the system should be designed so that the main functions can be performed at the time of a breakdown of hardware, even though these functions will be partially degraded. The features of the hardware organization are summarized below.

The system is composed of a medium-process computer, MELCOM 350-30 made by Mitsubishi Electric, with the load shared by two central processing units (CPUs); it is a duplex system of a load-share type as shown in Figure 5. A standby system is applied to a part of the controller.

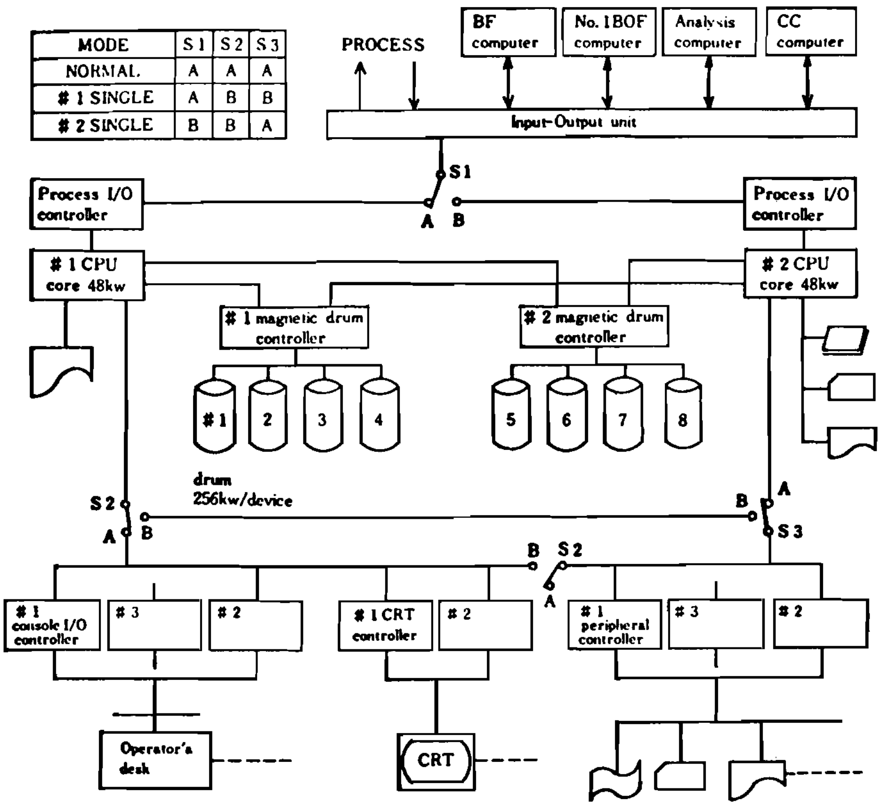


Figure 5. Organization of the No. 2 BOF computer system.

The dual access function of the magnetic drums allows important data (e.g., data on molds and stools which in the case of trouble are not restored) to be stored doubly for data backup.

Video signals from the computer system through the CRT controller are linked with an industrial television (ITV) network so that necessary information common to each workshop is transmitted through this linkage.

Recently, the operation rate for this system has been high (99.9%). In terms of investment, the load-sharing mutual backup system is considered effective for a system of this scale.

Benefits of the System

Since the startup of the system in the winter of 1971, it has been indispensable to the steelmaking operation. Among the major benefits are the following.

The system has been *labor-saving* in two ways. First, its introduction resulted in a savings of about 20 people formerly engaged in data gathering and processing for maintenance and quality control of the products. Second, highly skilled workers were no longer required for the BOF blowing operation, as the computer control or blowing enabled inexperienced operators to do this. At this time the Mizushima Works was under construction, and this feature was particularly helpful.

The system has also resulted in *improvements in yield.* Ingot weight control contributed to improvements in slabbing and blooming yield. Moreover, because of the high-level calculation, the occurrence rate of scrap ingot was reduced by 0.7 kg/t of good quality ingot.

Future Trends

The total automation of an ingot-making process is very difficult to achieve in a steelmaking plant, and there are still some manual operations. Automation of the data gathering process is also difficult, and manual input through CRT plays an important role in this system. Automation of both processes is a problem awaiting solution.

In order to make the most of the existing facilities and produce the various products most efficiently, an optimum tapping schedule must be determined. To do this, an optimum blowing schedule should be determined on a real-time basis, taking into account such restrictions as the amount of available hot metal, operating conditions for facilities and equipment as well as for subsequent processes. For this system, a blowing schedule of a maximum of 10 heats was set up, and on-line tests of this function were conducted. However, the expected results were not obtained because of difficulties in varying operations and accidents at the facilities. In our opinion, completing the scheduling function by improving the existing system is inadvisable. Therefore, a large-scale, real-time system for overall control of steelmaking, slabbing, and blooming is being studied to allow the scheduling function to be completed in the new system.

COMPUTER CONTROL OF BOF

Static End-Point Control

Static end-point control completes the feed-forward control, and involves the use of static mathematical models and calculation models of the amount of fluxes. The static mathematical model is composed of theoretical equations for oxygen balance and heat balance; the regression equation has two unknown variables: the amount of oxygen consumption, and the amount of iron ore. Table 3 shows the factors in these equations. A heat balance equation is used on the assumption that a reaction $C + 1/2\ O_2 \longrightarrow CO$ occurs only for decarburization. That is,

$$\Delta Q = a\ W_{OR} + \sum Qout - \sum\ Qin\ (kcal) \tag{1}$$

where W_{OR} equals the weight of iron ore.

An oxygen balance equation is also used on the basis of the same assumption as that of the heat balance equation. That is,

$$\Delta V = 0_{2F} + bW_{OR} + cW_{MS} - \sum\ Vout\ (Nm^3) \tag{2}$$

where 0_{2F} is the consumption of blown oxygen and W_{MS} is the weight of mill scale, ΔQ and ΔV are, respectively, the amount of heat and the amount of blown oxygen relative to the oxidation of Fe and CO. Since these are theoretically unobtainable factors, we must use the following multiregression equations with parameters of operating conditions.

$$\Delta V = f_v\ (C_{HM},\ B,\ HR,\ CR,\ T_{HM},\ Si_{HM},\ T_F,\ Mn_{HM},\ WCH) \tag{3}$$

$$\Delta Q = f_q\ (\Delta V,\ B,\ HR,\ CR,\ T_{HM},\ Si_{HM},\ C_F,\ T_F,\ TINT) \tag{4}$$

where B is the slag basicity and TINT is the time interval from tapping to charging.

Table 3. The static model.

Raw materials:	Analysis of hotmetal C_{HM}, Si_{HM}, Mn_{HM}, P_{HM}, S_{HM}
	Temperature of hot metal T_{HM}
	Weight of charged hot metal, scrap, and cold iron
Fluxes:	Weight of burnt lime, fluorspar, limestone, etc.
End-point:	Analysis C_F, Mn_F, P_F, S_F
molten steel	Temperature T_F

From Equations (1) through (4) we obtain the amount of oxygen consumption, O_{2F}, and the amount of iron ore, W_{OR}.

The accuracy of static control depends on the accuracy of these factors. Static control has essential deviations owing to furnace and operating conditions, to variations in scrap sizes and flux quality, and so on. In practice, constant terms are introduced into Equations (3) and (4): $\Delta Q = f_q + K$, $\Delta V = f_v + L$, where the values of K and L are estimated from the results of past blowing operations, which depend considerably on an operator. Continued efforts to improve control accuracy are made by studying coefficients such as the chemical composition and the physical constant of Equations (1) and (2) and, the regressive analysis of Equations (3) and (4); however, accuracy of end-point control by static mathematical models has limitation.

Dynamic End-Point Control

Bomb thermocouples were introduced in 1970. By using a dynamic end-point temperature control, the rate of successful temperature control was raised by about 10 percent, which for our purposes was not satisfactory. Accordingly, in order to measure the carbon content and the temperature of molten steel simultaneously, and to have dynamic end-point control, the development of a sublance system was started in 1970. The first experimental system was installed late in 1972, and, after many improvements including the addition of a sensor, was successfully completed. Sublances have been installed on all BOFs in the No. 1 steelmaking shop, and are under construction in the No. 2 steelmaking shop.

Figure 6 shows a schematic view of a sublance system. The sublance system has the following features:

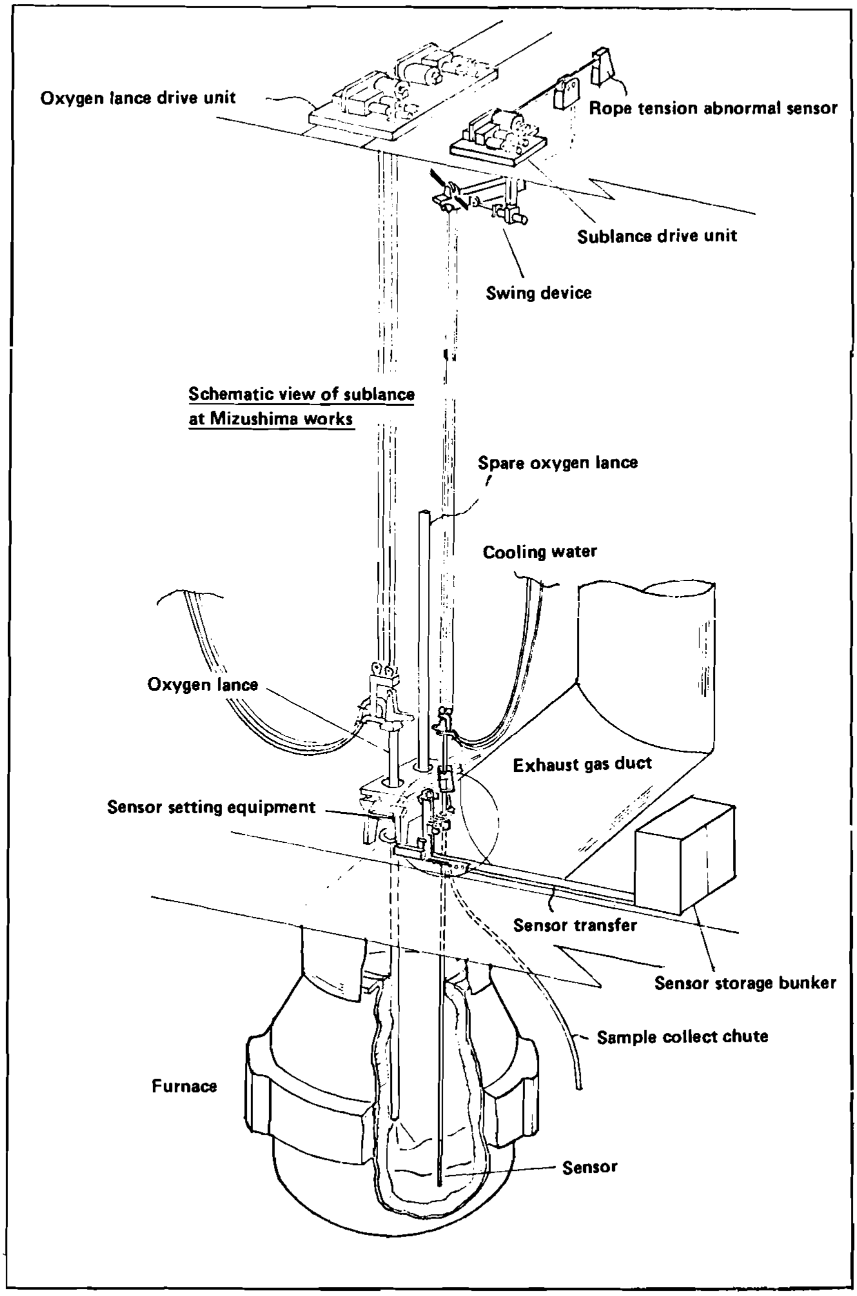


Figure 6. Schematic view of a sublance system.

- Sensor setting equipment and sensor storage bunkers are set up separately, which requires only a small space over a furnace. This facilitates installation of a sub-lance system over an existing BOF. Also, the storage bunker of the sensors can have large capacity.

- Setting a sensor to a stationary lance is performed by a cramp device. This method has high reliability in sensor setting.

- A storage bunker can store up to four kinds of sensors, and free selection of sensor is guaranteed.

- The sublance system can either discard a used sensor into the furnace or collect it for an analysis of the sample.

- The cycle time for measurement is short (82 sec).

- The operation cycle of a sublance system from sensor setting to temperature measurement is fully automatic. In spite of unfavorable environments, the performance rate for the equipment is at least 99 percent.

Sensors, which were developed and remarkably impoved in Mizushima, have contributed substantially to the high success rate and the accuracy of measurement. The relationship between the freezing temperature and the carbon content as determined by chemical analysis is shown in Figure 7.

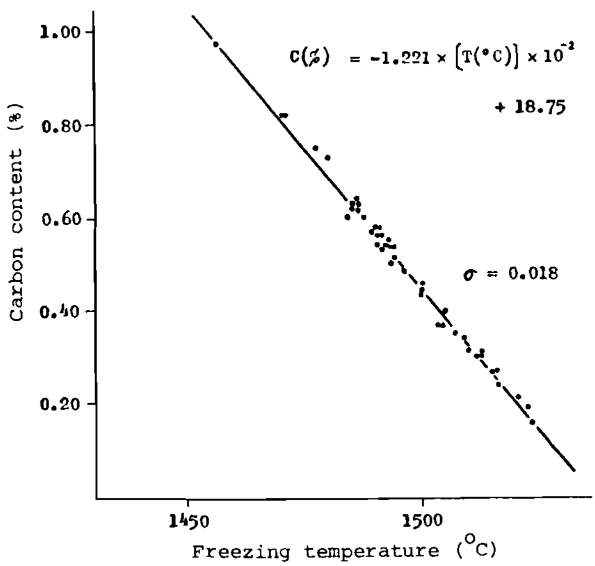


Figure 7. Relation between freezing temperature and carbon content.

As can be seen from Figure 4, the carbon content is concentrated on and around the linear equation of the freezing temperature with a standard deviation of 0.018 percent.

Figure 8 is a flow diagram of dynamic control from start to finish of the blowing process.

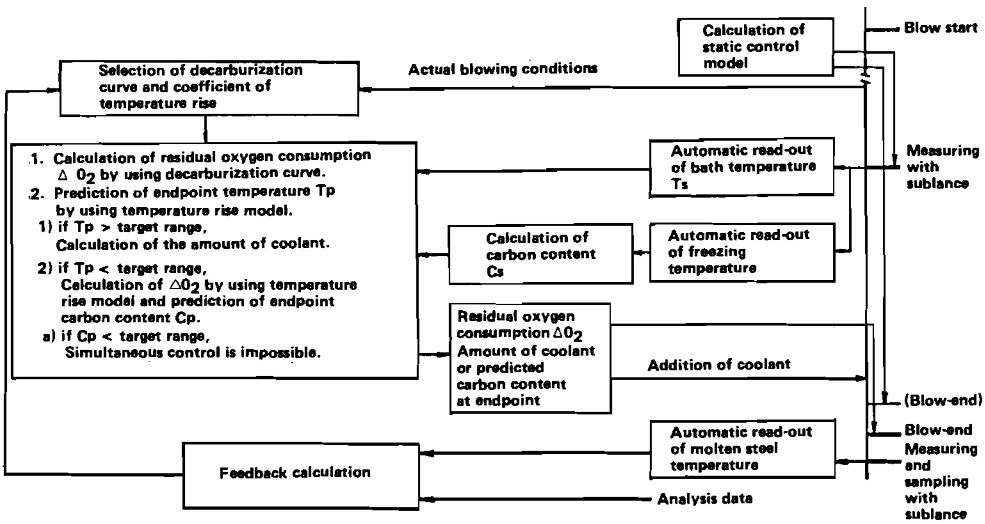


Figure 8. Flow diagram of dynamic control of blowing process.

The timing for measuring the molten steel temperature and the freezing temperature is determined by calculations from the static mathematical models; it occurs about two minutes before the blown oxygen reaches the predicted consumed amount. Measured temperatures are automatically fed into the computer, which then calculates the dynamic end point and corrects the blowing operations.

Decarburization Model

Figure 9 shows the decarburization curves which were determined by studying past blowing operations. In practice, a curve is selected on the basis of the steel grade, the slag volume, the blowing conditions, and the results of the previous heat. Then the residual consumption of oxygen, ΔO_2, is calculated in accordance with this curve to correct the total oxygen consumption.

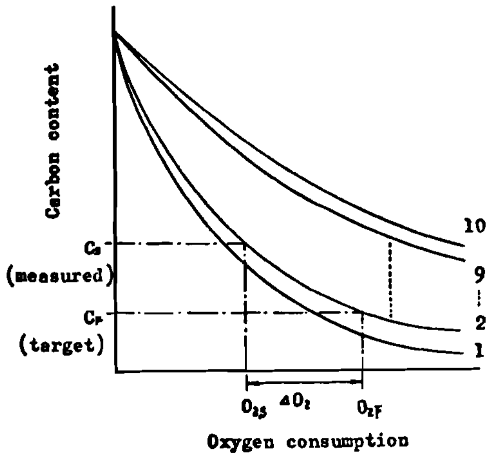


Figure 9. Decarbonization curve.

Temperature Rise Model

In the temperature rise Equation (5), the value of coefficient a is determined in the same way as that for selecting the decarburization curve. The temperature at the blow-end is predicted by means of the residual consumption of oxygen, ΔO_2, calculated as follows:

$$\Delta T = a\Delta O_2 + b\ (1/C_F - 1/C_S) + c \qquad (5)$$

where a: the coefficient of temperature rise,

b,c: the constants,

C_F: the target carbon content,

C_S: the measured carbon content.

If the predicted temperature at the blow-end is higher than the target temperature range at the blow-end, the amount of coolant is calculated.

Effects and Future Trends

In No. 1 BOF shop, production ratios of low-carbon, middle-carbon, and high-carbon steel are 40, 47, and 13 percent, respectively. The introduction of a dynamic computer system using the sublance has improved the success rate of carbon and temperature and allowed simultaneous control.

The introduction of the sublance system has also facilitated temperature measurement and sampling at the blow-end without tilting a BOF. That is, the temperature and carbon content at the blow-end are measured by a sublance, and before tapping starts a sample is analyzed for manganese, phosphorus, and sulfur contents by the spectroanalyzer. This operation shortens the interval between the blow-end and tapping, and relieves operators from doing this work.

In the future, it is planned to develop a model that estimates accurately the manganese, phosphorus, and sulfur content at the blow-end based on data from an interim sampling measurement so that a tapping method can be set up immediately.

It is also necessary to develop a technique for monitoring the refining process between blow-start and blow-end, and to develop complete dynamic control of the overall blowing process.

TECHNICAL INFORMATION SYSTEM (TIS)

In order to control and to upgrade the quality of products, management information systems are needed. At the Mizushima Works in 1976 about 30 percent of the problems of quality control of ingots, slabs, and blooms, were solved using information processing only, and about 45 percent of the problems were solved as a result of information processing and other means such as research and improvements in facilities.

A TIS supported by the central computer is in operation at Mizushima. Figure 10 shows a partial flow diagram for the quality control of ingots, slabs, and blooms. The features of this system are as follows:

- A user extracts the required data and analyzes these to obtain the results in a desired format through CRT.
- Both source data and analyzed results are registered in the data base file.
- Once the source data have been registered, regular analysis operations are automatically performed, on a real-time analysis basis.
- A user is able to control creation, modification, and discontinuance of the periodical reports.

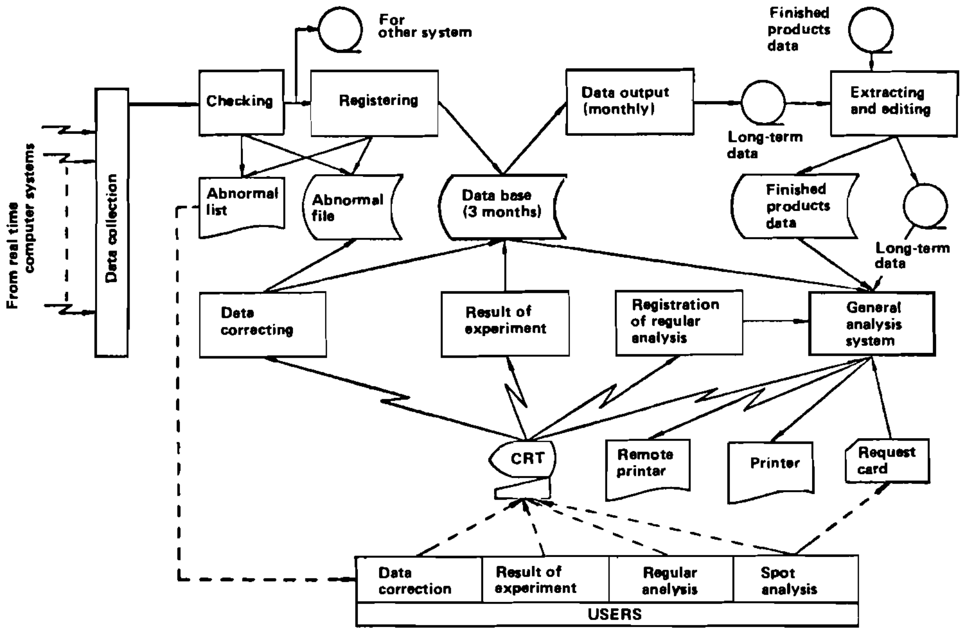


Figure 10. Technical information system at Mizushima works.

CONCLUSION

An on-line integrated computer control system for steelmaking and a TIS have both been installed at Mizushima Works. The former has substantially improved yield and quality as a result of total information processing covering hot metal handling to ingot making and of real-time control of inventory of molds and stools. A dynamic control system has been completed through the combination of a sublance system and a computer system.

At present, Mizushima Works is studying a large-scale real-time system for an overall control of steelmaking, slabbing, and blooming. The new system will be designed to increase productivity and to reduce operating costs by developing those functions that are not possible in the existing systems. A solution is needed for the problem of complete automation of ingot-making process.

Discussion

Discussion focused on the general problem of computer application at the Kawasaki Steel Corporation (KSC). At KSC, priority has been given first to developing process control systems and secondly to developing an integrated system.

Referring to the model development approach, several participants opined that known thermodynamic equations should be used as much as possible; an unknown relationship may be described by regression equations. It was observed that multiregression equations are used mainly because of uncertainty regarding the number of factors. The discussants pointed out that ferrous oxygen exerted a great influence on the heats.

Attention then turned to the subject of the application of the control system at KSC and the accuracy of the results achieved from the first measurement. It was stated that 86 percent of all heats have a carbon deviation of 0.03 percent, and that 94 percent of the heats have a temperature deviation of 12 ^{o}C. Since the implementation of the system, the metal yield has improved by 0.7 kg/t.

Several inquiries were made about the factors causing errors in metal yield calculations. All agreed that it was difficult to determine small differences in metal yield. There may be errors in the weighing system, for example, owing to some slag being weighed as metal. A standard allowance is usually made for this.

Other discussion points included problems of integration and computer communication. For computer communication, inputs fed into the computer are derived from data sent via the air shooter. The I/O interface is used as a communication system. Four cathode-ray tubes (CRTs) are used in the process of ingot making. KSC and the computer suppliers developed jointly the corporation's software problems. About ten people have been working on systems development over a three-year period. Now that KSC has a decentralized architecture for the computer system, the need has been recognized for an additional, even larger computer.

The Computer Control System at the Wakayama Steel Works

H. Tokuyama, T. Takawa,
N. Aoki, and K. Katoogi

INTRODUCTION

Sumitomo Metal Industries has installed computer systems in all of its steel plants as shown in Table 1.

At three steel plants in the Wakayama Steel Works, the integrated computer system, which consists of an on-line business computer NEAC 575 and process computer HIDIC 350, has been introduced for both process and production control. The functions of process control are as follows: control of amount of raw materials and that of oxygen, fluxes, and coolants, end-point control, and steel composition control.

As regards end-point control, a double blowing control model has been developed for the converter of No. 1 steel plant which melts low-phosphorus killed steel, while a dynamic end-point control model that uses both sublance equipment and an exhaust gas analyzer has been developed for one of three converters of No. 3 steel plant which melts low-carbon rimmed and semi-killed steel.

INTEGRATED ON-LINE PRODUCTION CONTROL SYSTEM IN THE WAKAYAMA STEEL WORKS

The Wakayama Steel Works is the largest of all the steel works of Sumitomo Metal Industries, Ltd. and has five blast furnaces, three steel plants, two slabbing mills, one plate mill, one hot strip mill, one cold strip mill, and five pipe mills.

Figure 1 shows the integrated on-line production control system. The feature of this system is that the following three computers are linked to one another through the integrated data file so that information can be centralized:

- On-line steelmaking and slabbing computer,
- On-line rolling computer, and
- Planning and management computer.

New orders are transmitted from the order entry system of the Head Office through the communication network and stored in

Table 1. The steel plants in Sumitomo Metal Industries.

Steel Works		WAKAYAMA			KASHIMA		KOKURA	
Steel Plants		No. 1	No. 2	No. 3	No. 1	No. 2	No. 1	No. 2
Product Mix		Killed	Killed	Semi-killed Rimmed	Killed Semi-killed	Rimmed	Killed Semi-killed Rimmed	
Blowing		Double Blowing	Double Blowing	Single Blowing	Double Blowing	Single Blowing	Double Blowing	Single Blowing
Computer		NEAC 575			IBMI 800	HIDIC 700	IBM 1800	IBM 1800
		HIDIC 350	HIDIC 350	HIDIC 350				
Converter	t/heat	70	150	160	250	250	70	70
	Number	1	3	3	3	2	2	3
Sublance		-	Under Planning	1/3	3/3	Under Planning	2/2	3/3

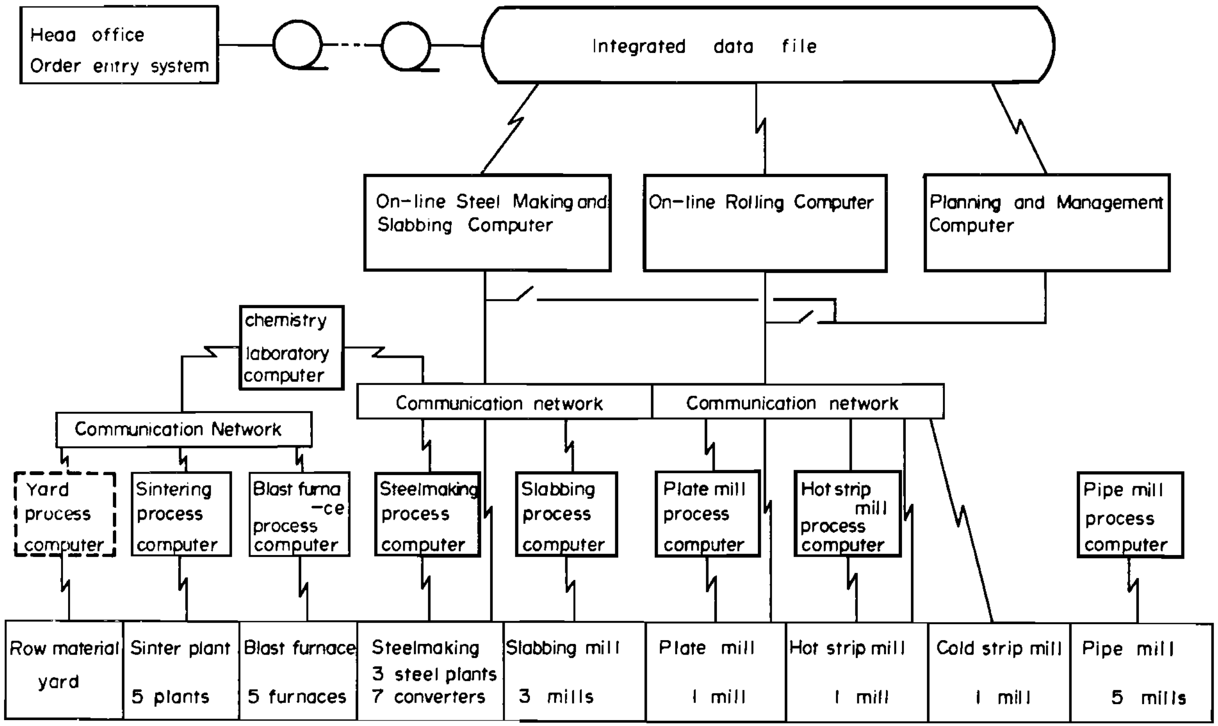


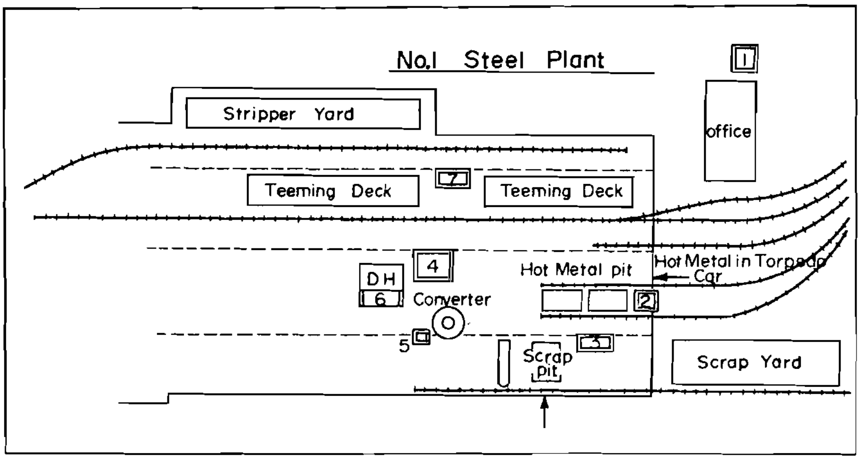
Figure1. Integrated on-line production control systems of Wakayama Steel Works.

the integrated data file. The planning and management computer classifies these orders into production lots every day and determines the grade of heats, from which the melting shop program is made in the production control center. The on-line steelmaking and slabbing computer controls material flow through the steel plants and slabbing mills according to the melting shop program.

CONTROL MODELS AT NO. 1 STEEL PLANT

Operation

In the 70 t converter of the No. 1 Steel Plant, low phosphorus high- and medium-carbon (0.20 to 0.60 percent) killed steel is being melted with a double blowing operation. Figure 2 shows the layout of the No. 1 Steel Plant and the outline of operation is shown in Figure 3. After the first blowing 20 to 30 min, the operator measures the temperature of the molten steel and the carbon content, and by observing the appearance of slag in the converter and a sample of molten steel, judges the degree of the dephosphorizing reaction. The second blowing is put into operation for 2 to 3 min with the intension of meeting the aimed end-point temperature and carbon content. If the dephosphorizing reaction is insufficient, burnt lime is charged.



1. Computer Room
2. Hot Metal Pulpit
3. Scrap Pulpit
4. Main Pulpit
5. Tap Side Pulpit
6. DH Pulpit
7. Teeming Pulpit and Stripper Yard Pulpit

Figure 2. Layout of No. 1 Steel Plant in the Wakayama Steel Works.

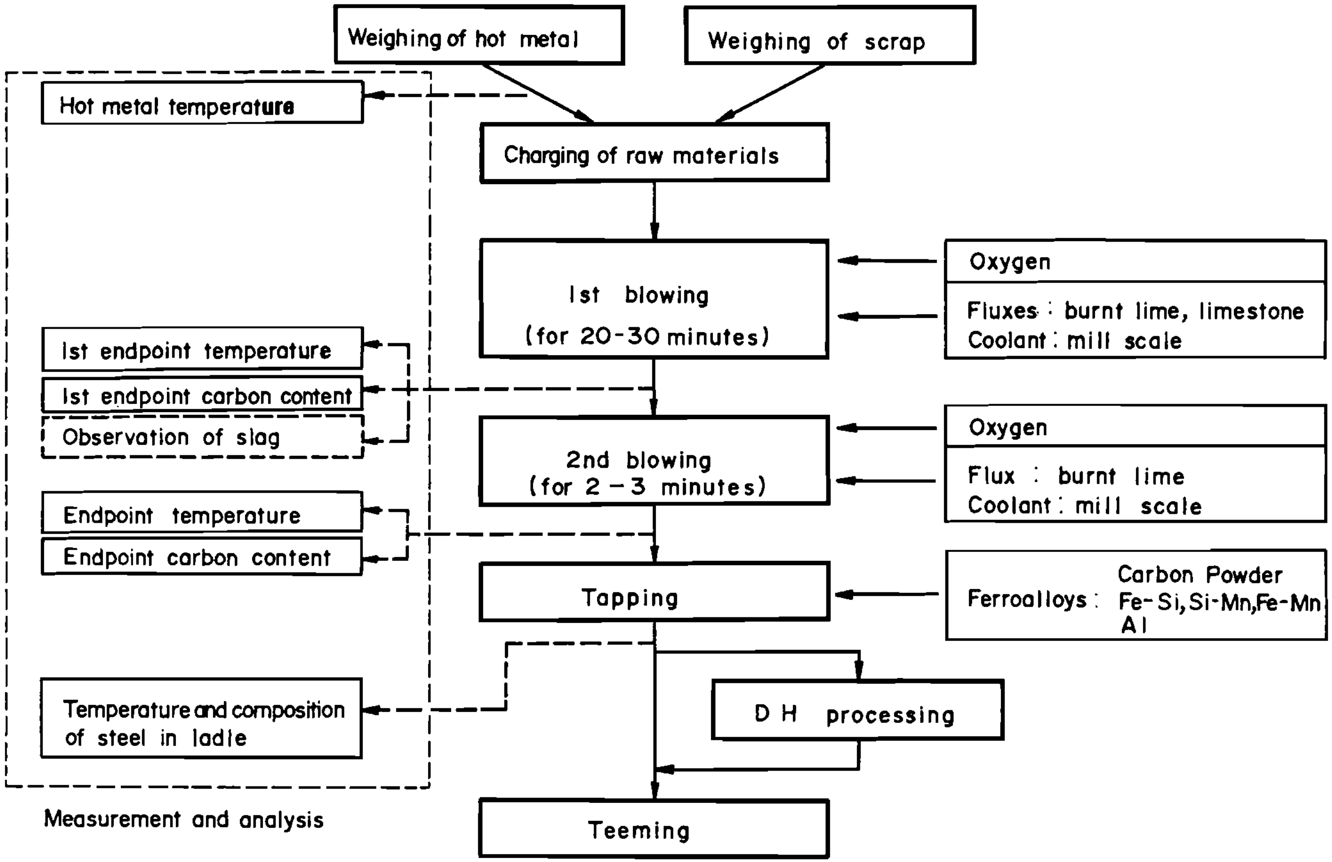


Figure 3. The operation of No. 1 Steel Plant in the Wakayama Steel Works.

Computer System

As shown in Figure 4, cathode-ray tubes (CRTs) and operation panels, which are terminals of the on-line steelmaking and slabbing computer, are installed in all pulpits from the hot-metal pulpit to the stripper yard pulpit.

Analyzed values of samples are transmitted from the computer in the chemistry laboratory through the data transmission network and displayed on the CRTs and the Nixie tube in the pulpits. The process computer gathers process data--molten steel temperature measured by thermocouple, flow rate of oxygen, amount of charged fluxes and coolants, and so on.

Hot Metal Pulpit and Scrap Pulpit

The computer displays on the CRT the melting shop program and the information on hot metal in each torpedo car and calculates the amount of hot metal and scrap to be charged at each heat from the amount of raw materials control model.

Main Pulpit

The computer displays on the CRT the melting shop program and detailed information on the heat to be blown. The amount of oxygen fluxes and coolants to be charged in the first and second blowing are calculated with the charge control model and the second blowing control model. When the phosphorus content, carbon content, and temperature fail to meet the aimed end-point values, and it is difficult to obtain the aimed for steel grade, the computer displays the steel grades of other heats in the melting shop program on the CRT. The operator can choose a proper one from them.

Tap Side Pulpit

The amount of carbon powder and ferroalloys to be charged at tapping is calculated by the steel composition control model and displayed on the CRT.

Control Models

The four kinds of control models shown in Figure 5 have been developed.

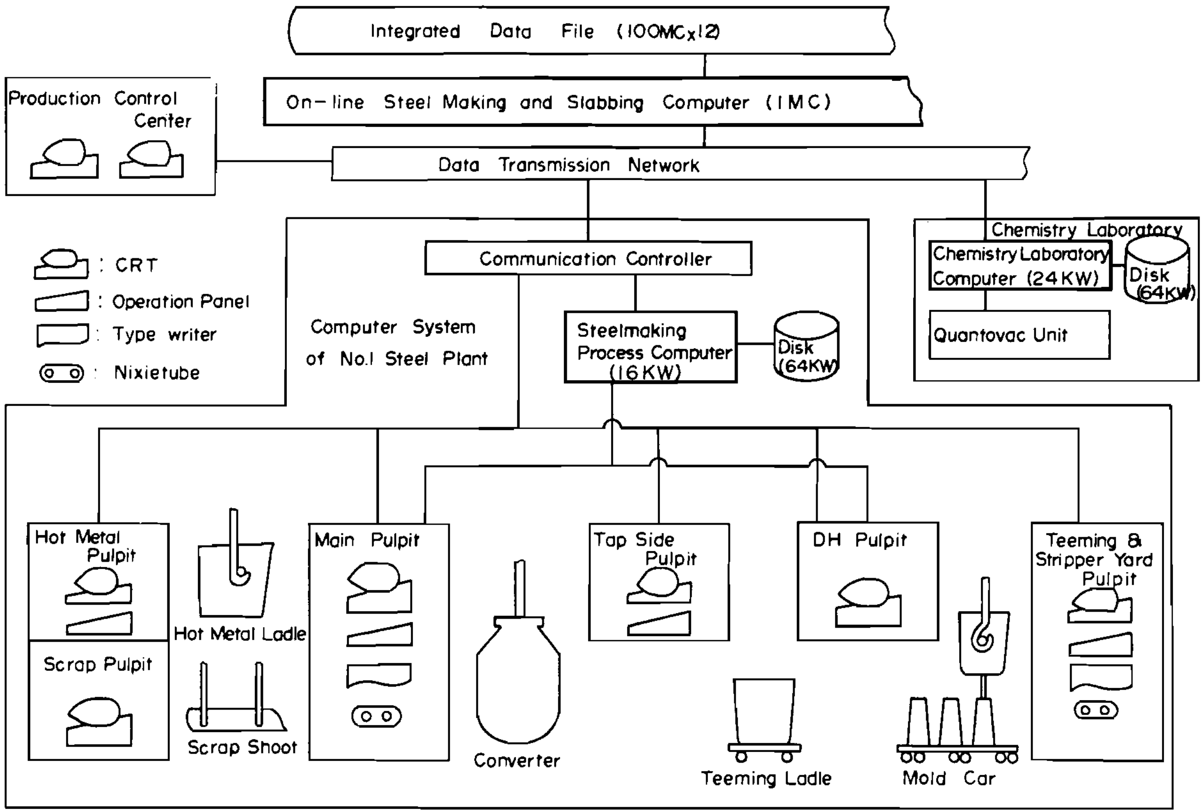


Figure 4. Computer system at No. 1 Steel Plant in the Wakayama Steel Works.

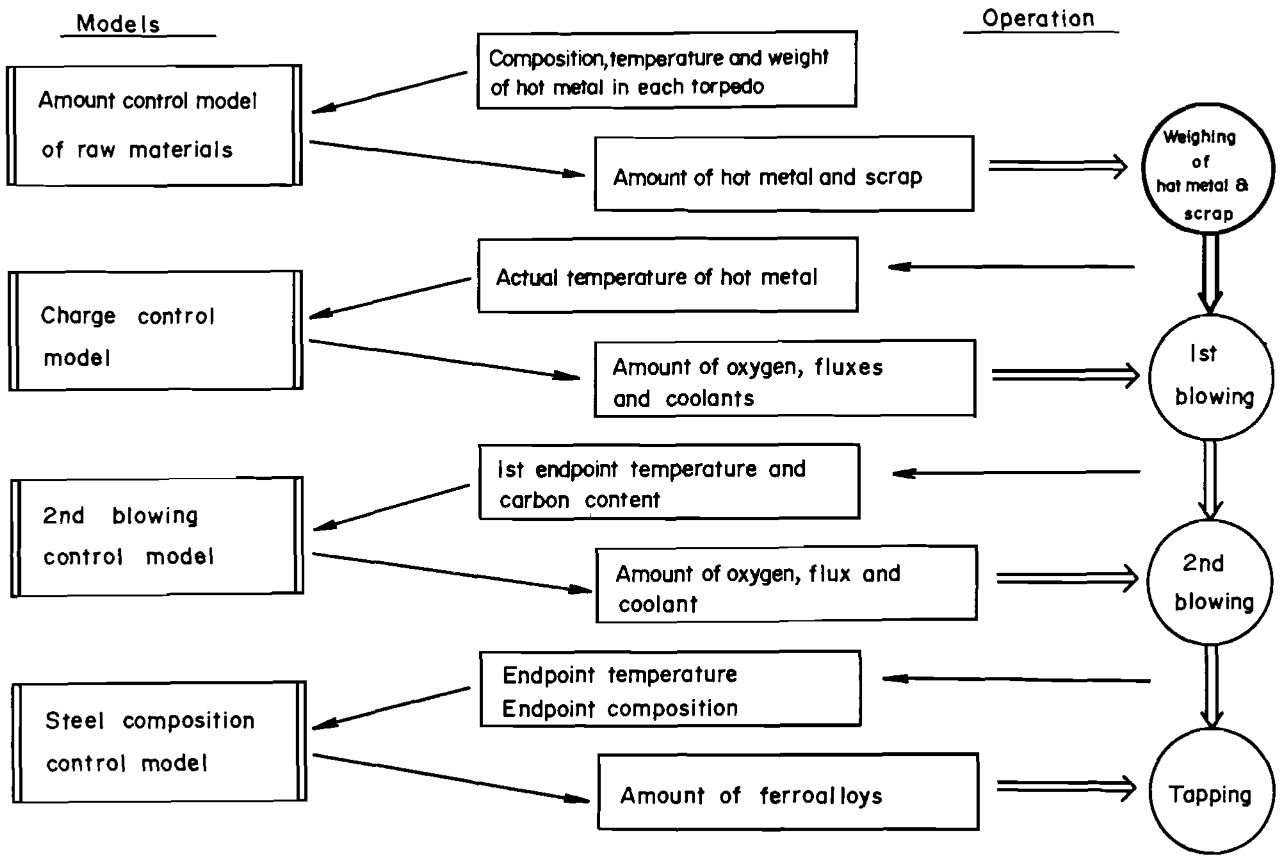


Figure 5. Outline of control model at No. 1 Steel Plant.

Amount of Raw Materials Control Model

The first step of end-point control is the calculation of hot metal percentage in order to take a good balance of heat quantity. As shown in Figure 6, deviation from average heat volume due to the variation of silicon content and the temperature of the hot metal influences the end-point temperature which was modified assuming that data other than silicon content and temperature of hot metal were of average value. The computer calculates the amount of hot metal and scrap which satisfies both the heat balance equation for end-point control and the material balance equation for control of steel amount.

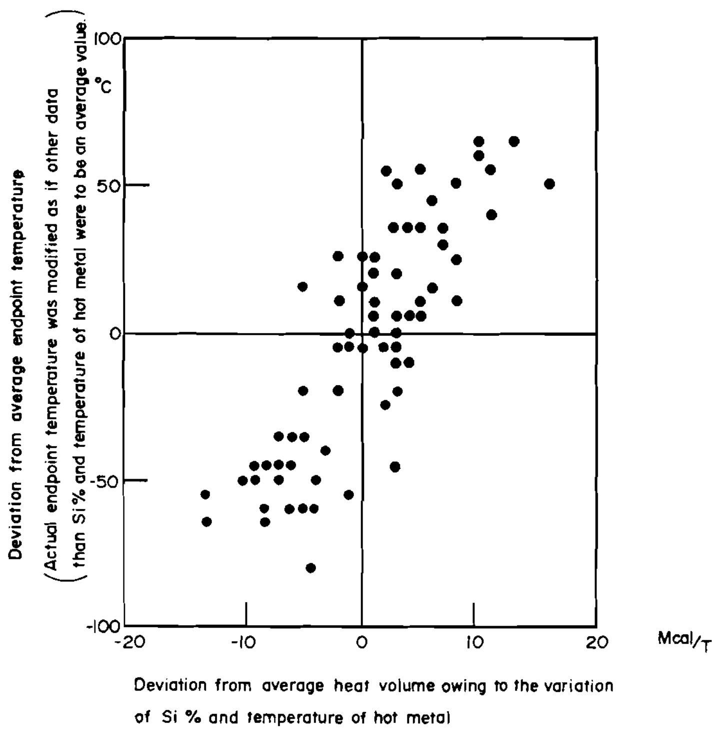


Figure 6. The influence of heat volume of hot metal on endpoint temperature.

Charge Control Model

From the viewpoint of heat balance and oxygen balance in the first blowing (shown in Figure 7) the following equations

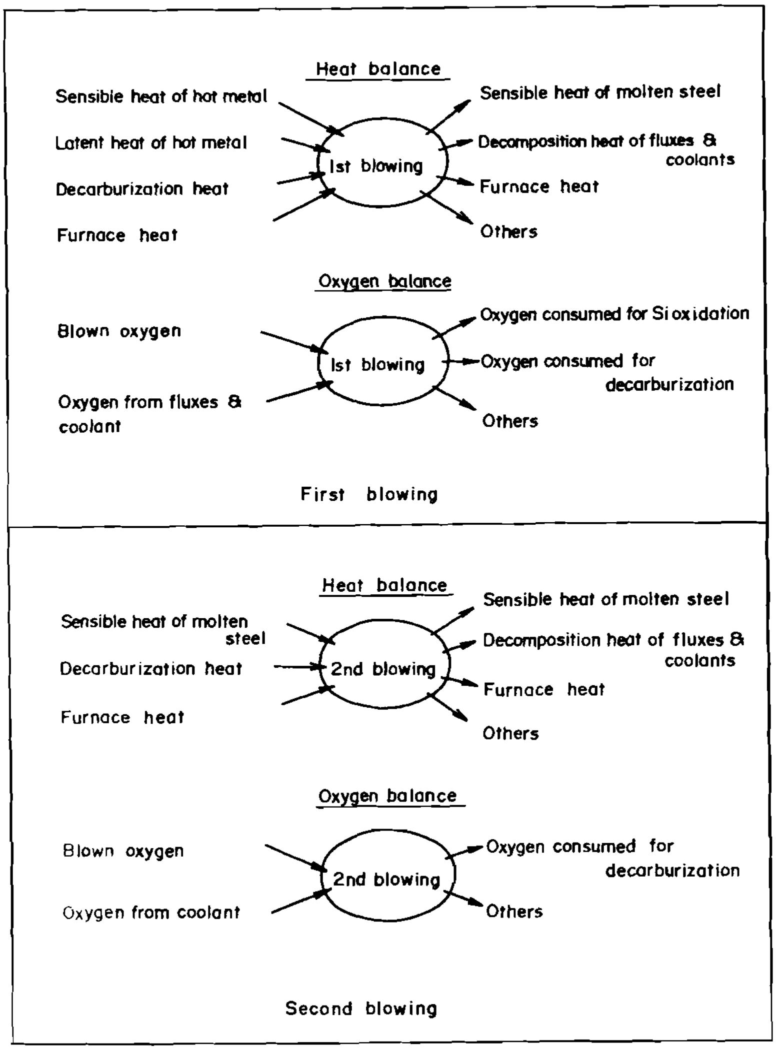


Figure 7. The heat and oxygen balance at the 1st and 2nd blowing.

for estimation of end-point temperature and the amount of required oxygen are used:

$$T_1^{EST}(C_1) = T_1^{STD} + \Delta T_1(C_1) \quad (1)$$

$$O_1^{EST}(C_1) = O_1^{STD} + \Delta O_1(C_1) \quad (2)$$

$\Delta T_1(C_1)$	$= F_1(\Delta T_{HM}, \Delta Si_{HM}, \Delta C_{HM})$	heat volume of hot metal
	$+ k_1 \Delta(W_{HM}/W)$	hot metal ratio
	$- F_2[\Delta(W_{FC}/W)]$	decomposition heat of fluxes and coolants
	$+ k_2 f_T(C_1)$	decarburization heat
$\Delta O_1(C_1)$	$= F_3(\Delta Si_{HM}, \Delta C_{HM})$	oxygen for oxidation of hot metal composition
	$- F_4[\Delta(W_{FC}/W_{pig})]$	oxygen from fluxes and coolants
	$+ k_3 F_O(C_1)$	oxygen for decarburization

where

F_i is linear combination; k_i, constants;

$T_1^{EST}(C_1)$, the estimated value of 1st end-point temperature (°C);

T_1^{STD}, the standard value of 1st end-point temperature (°C);

ΔT_{HM}, the deviation from standard temperature of hot metal (°C);

ΔSi_{HM}, the deviation from standard silicon content of hot metal (%);

ΔC_{HM}, the deviation from standard carbon content of hot metal (%);

$\Delta(W_{HM}/W)$, the deviation from standard hot metal ratio (%);

$\Delta(W_{FC}/W)$, the deviation from standard fluxes and coolants ratio (FC is burnt lime, limestone, and mill scale) (%);

$O_1^{EST}(C_1)$, the estimated value of required oxygen amount in 1st blowing (Nm^3/t of pig);

O_1^{STD} , the standard value of required oxygen amount in 1st blowing (Nm^3/t of pig);

W , the total amount of raw materials (t); and

W_{pig} , the amount of hot metal (t) .

$f_T(C_1)$ and $f_O(C_1)$ are given by the curves in Figure 8 and Figure 9 respectively, which are constructed by data analysis of actual heats.

As shown in Figure 10, the computer calculates the amount of oxygen O_1 and the amount of fluxes and coolants W_{FC} which satisfy the following four conditions:

- Heat balance: $T_1^{AIM} = T_1^{EST}(C_1^{AIM}) + \varepsilon_{T1}$,

- Oxygen balance: $O_1 = Y_1^{EST}(C_1^{AIM}) + \varepsilon_{O1}$,

- Basicity balance, and the

- Restriction condition on fluxes and coolants.

T_1^{AIM} and C_1^{AIM} are the aimed first end-point temperature and carbon content respectively. ε_{T1} and ε_{O1} are feedback terms which are calculated as follows from the actual data of preceding heats and classified into several groups:

$$\varepsilon_{T1} = E\ (\Delta T_1) \quad ,$$

$$\varepsilon_{O1} = E\ (\Delta O_1) \quad ,$$

where ΔT_1 and ΔO_1 are the estimation errors of Equations (1) and (2) respectively.

Figure 11 shows the results of application of this model to actual operation. It is known from the figure that amount of scatter of the first end-point carbon content and of the first end-point temperature has decreased.

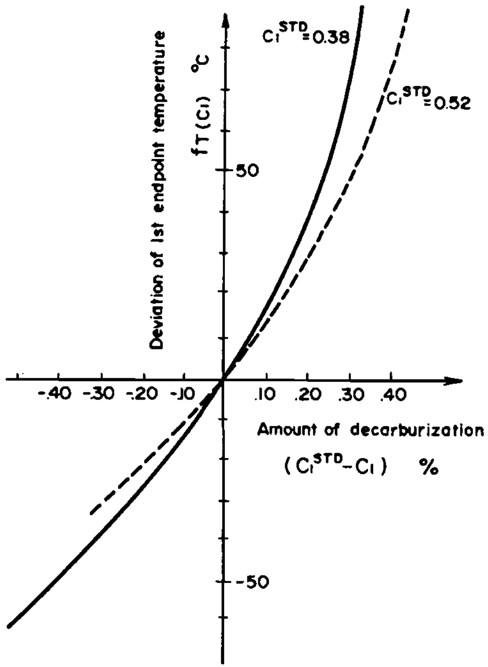


Figure 8. The relation between the change of 1st endpoint temperature and the 1st endpoint carbon content.

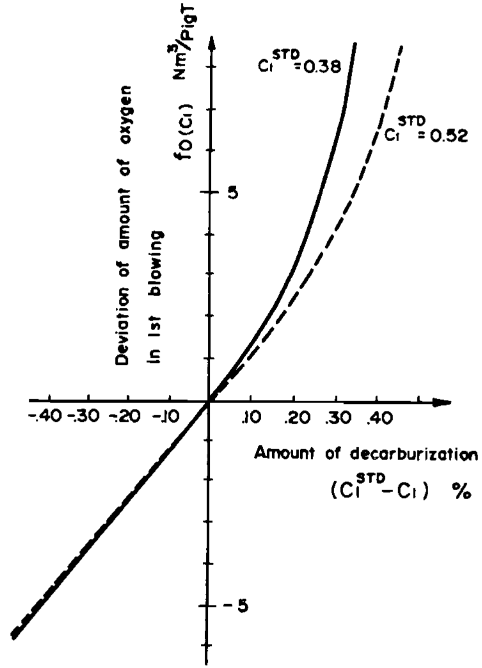


Figure 9. The relation between the change of amount of oxygen and the 1st endpoint carbon content.

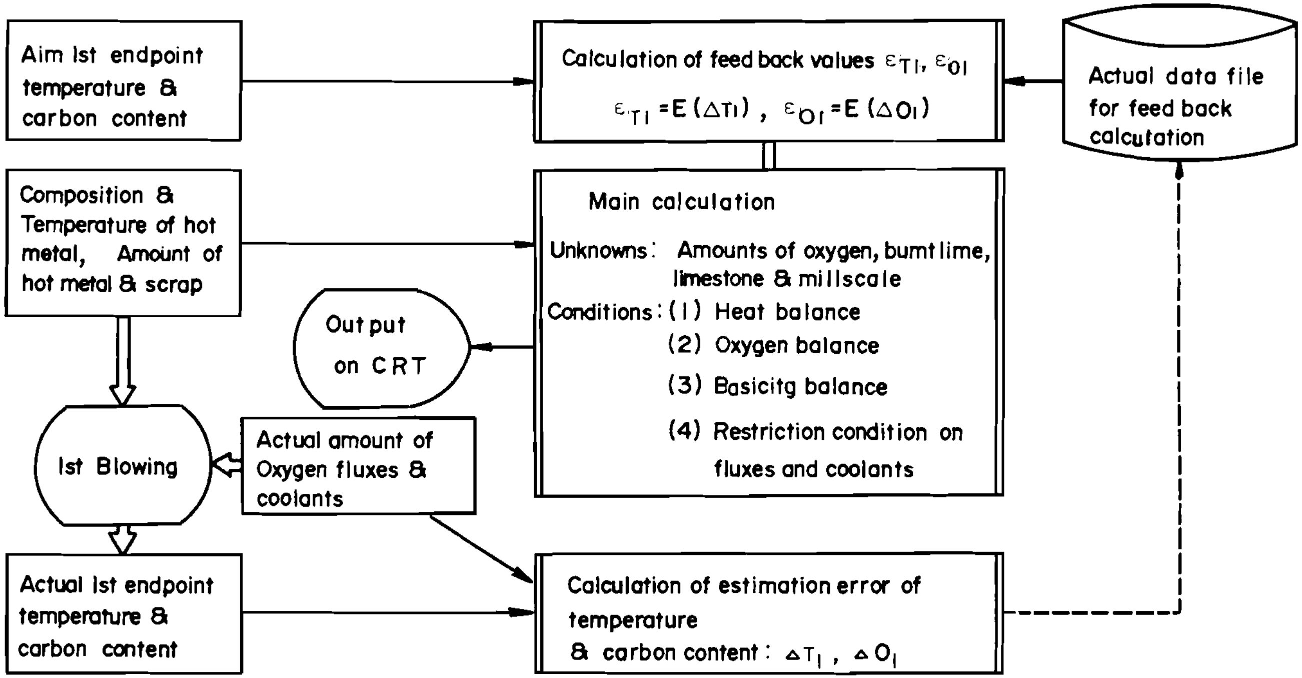


Figure 10. The charge control model.

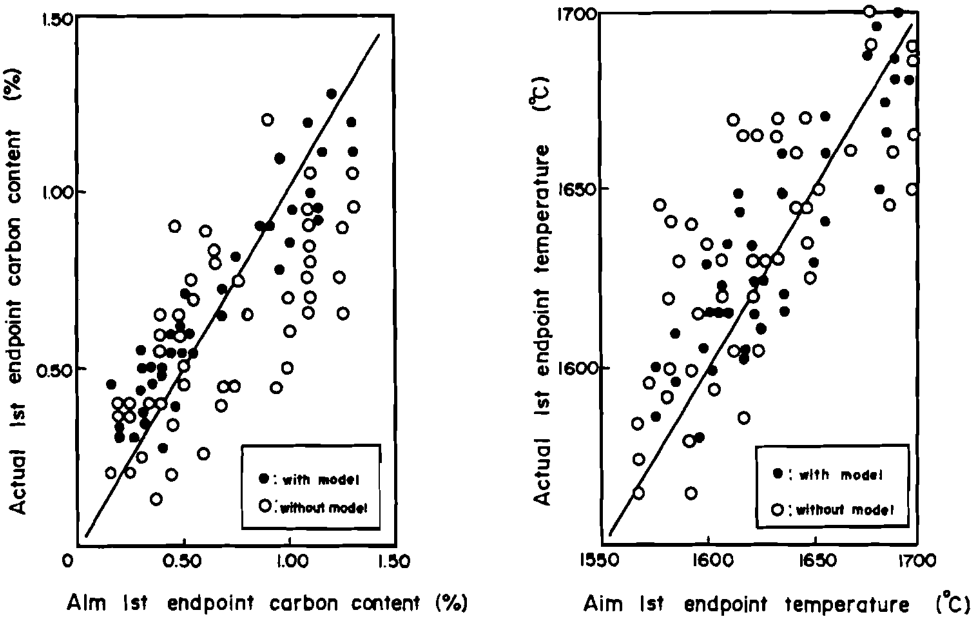


Figure 11. The result of practical application of the charge control model.

Second Blowing Control Model

From the viewpoint of heat balance and oxygen balance in the second blowing (shown in Figure 7) the following equations for estimation of the end-point temperature and the amount of required oxygen in second blowing are used.

$T_2^{EST}(C_1) = T_1$		
$+ \ell_1 g_T(C_2, C_1)$	decarburization heat	
$-G_1(W_{FC}2/W_{ST})$	decomposition heat of fluxes and coolants	
$-\ell_2(T_1 - T_1^{STD}) - \ell_3$	heat loss	(3)

$O_2^{EST}(C_2) = \ell_4 g_O(C_2, C_1)$	oxygen for decarburization	
$-G_2(W_{FC}2/W_{ST})$	oxygen from fluxes & coolants	(4)

where

G_i is linear combination; ℓ_i; constants;

$T_2^{EST}(C_2)$, the estimated value of end-point temperature (°C);

T_1, the 1st end-point temperature (°C);

T_1^{STD}, the standard value of 1st end-point temperature (°C);

W_{FC_2}, the amount of fluxes and coolants in the 2nd blowing (FC is burnt lime and mill scale) (t);

W_{ST}, the amount of molten steel calculated from amounts of raw materials;

$O_2^{EST}(C_2)$, the estimated value (at 0°C) of required oxygen in the 2nd blowing (Nm^3/t) ; and

$g_T(C_2,C_1)$ and $g_O(C_2,C_1)$ are given by the curves in Figure 12 and Figure 13, constructed by data analysis of actual heats.

As shown in Figure 14, the computer calculates the amount of oxygen O_2 and of fluxes and coolants $W_{FC}2$ that satisfies the following three conditions for the aimed end-point temperature T_2^{AIM} and carbon content C_2^{AIM}:

- Heat balance: $T_2^{AIM} = T_2^{EST}(C_2^{AIM}) + \varepsilon_{T2}$,

- Oxygen balance: $O_2 = O_2^{EST}(C_2^{AIM}) + \varepsilon_{O2}$, and

- Ratio of fluxes to coolants: $W_{\text{burnt lime } 2}/W_{\text{scale}} = k$.

Figure 15 shows the results of application of this model to actual operation. It is found that the scatter of both end-point temperature and carbon content has decreased.

Steel Composition Control Model

The model shown in Figure 16 has been developed. Estimation of steel composition in the ladle is difficult because of the variation of oxygen density in molten steel. However, a simple but accurate equation for the estimation of content of the four

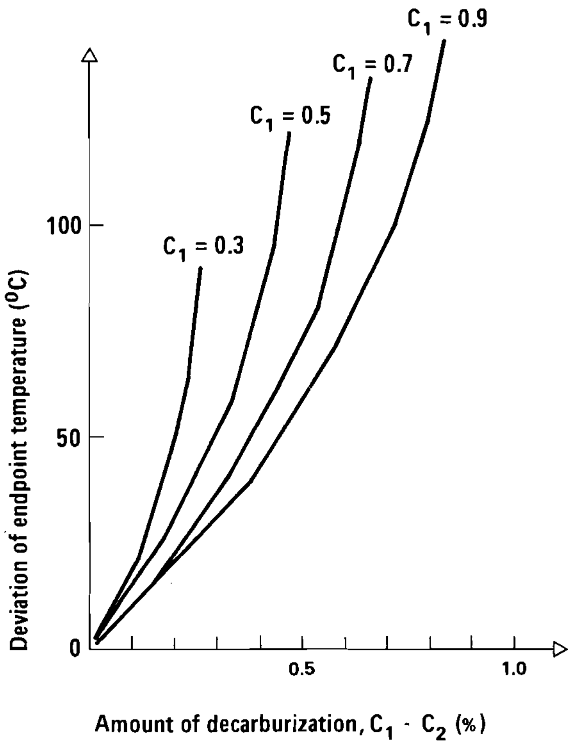


Figure 12. The relation between the change of endpoint temperature and the endpoint carbon content in the 2nd blowing.

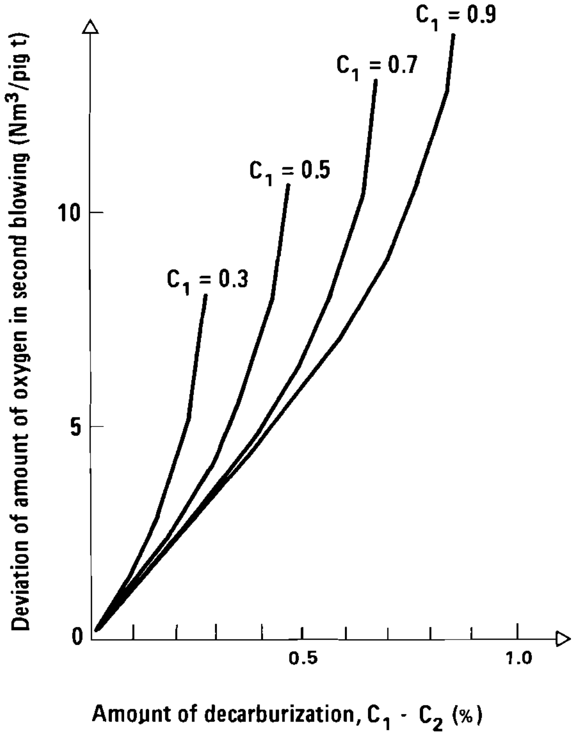


Figure 13. The relation between the change of amount of oxygen and the endpoint carbon content in the 2nd blowing.

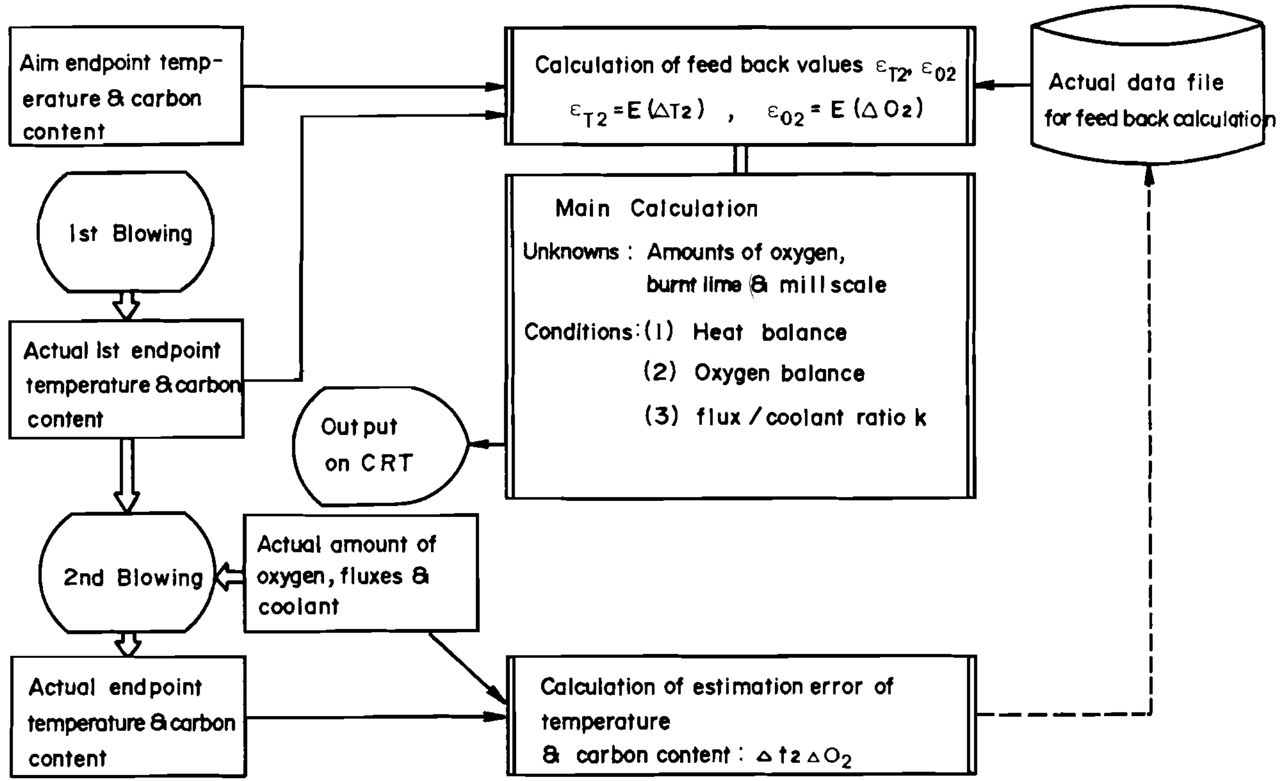


Figure 14. The second blowing control model.

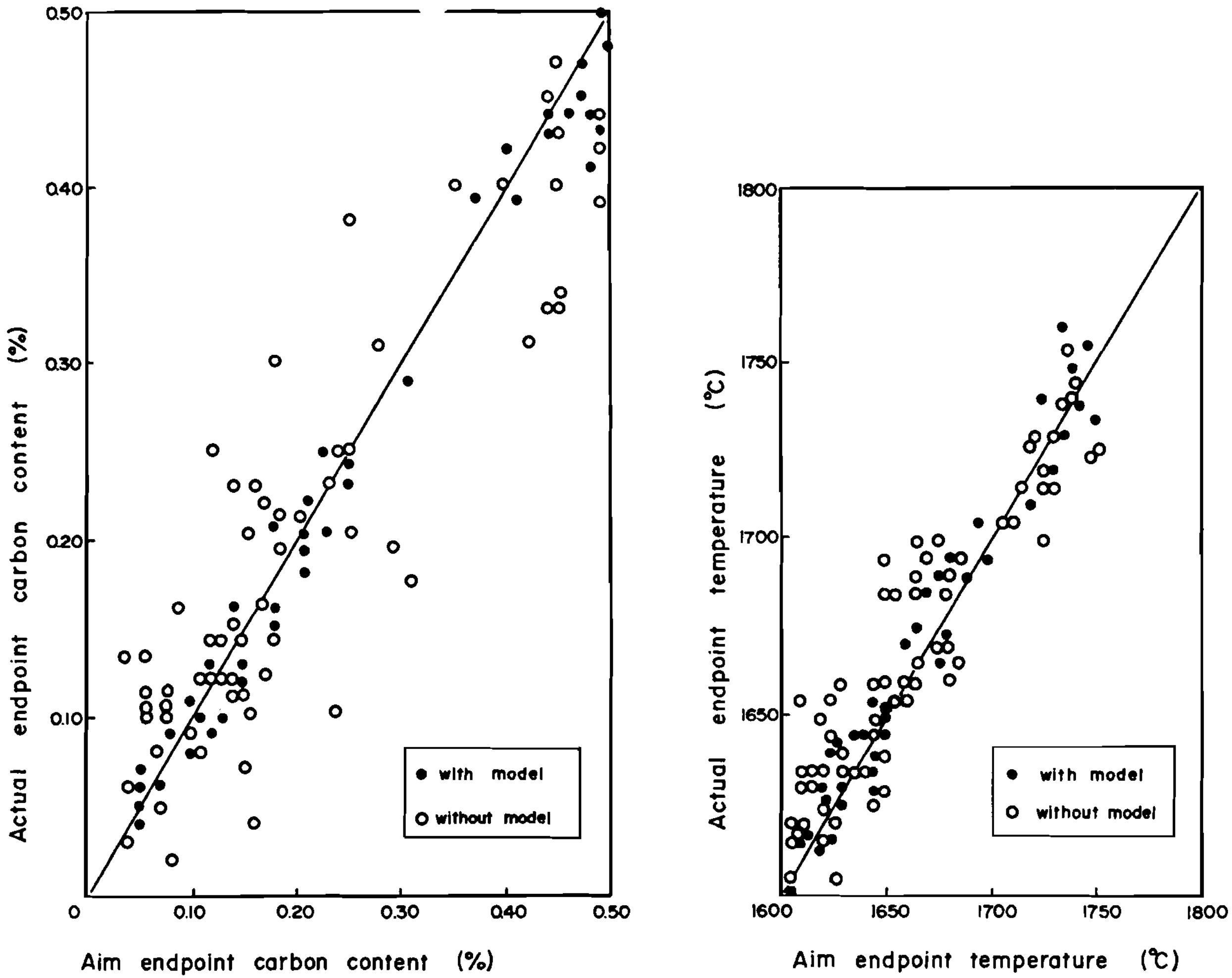


Figure 15. The result of practical application of the 2nd blowing control model.

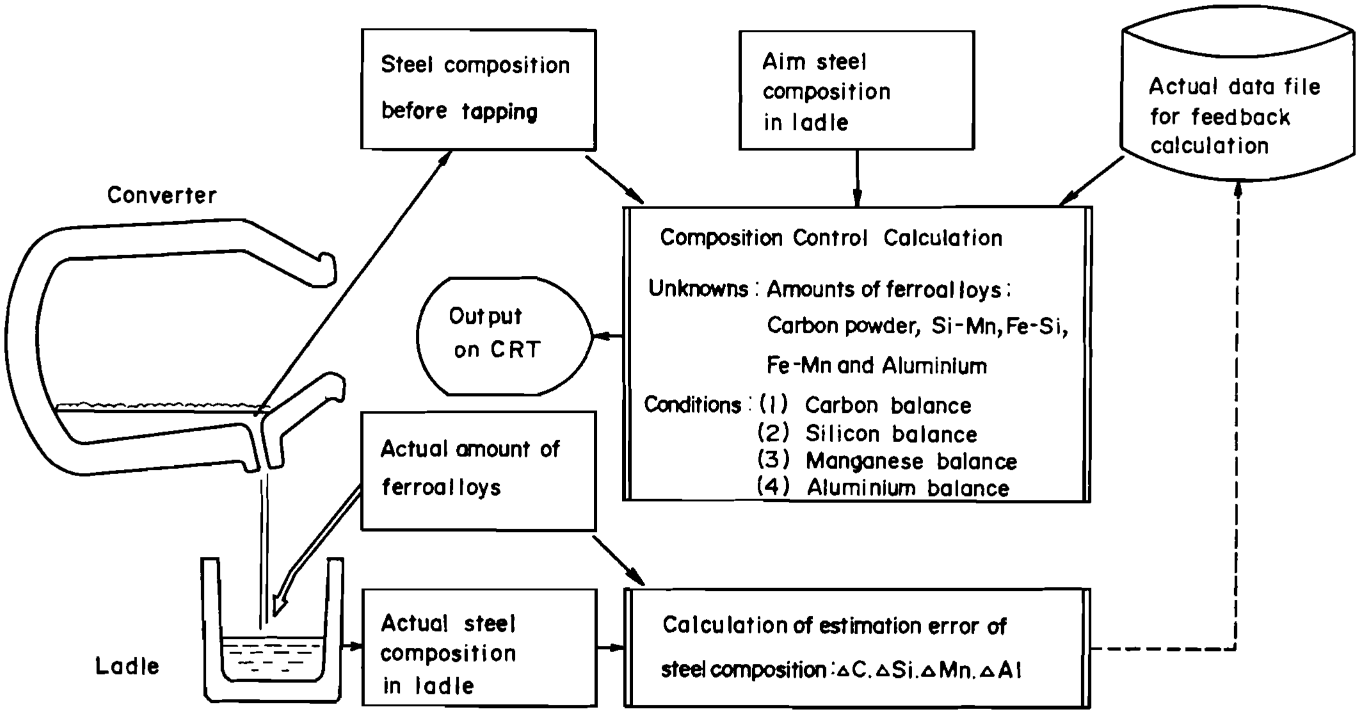


Figure 16. The steel composition control model.

alloying elements, carbon, silicon, manganese, and aluminum, have been obtained by analyzing many actual data.

The computer calculates the amount of carbon powder and ferroalloys to be charged according to the following rules for good hitting rate and minimum ferroalloys cost:

- When carbon content has to be increased greatly, the high-carbon ferromanganese is used preferentially because its yield is stable and the amount of carbon powder is restrained.

- Otherwise, a solution is found to minimize the cost of ferroalloys.

As shown in Table 2, the hitting rate of all four alloying elements is increased.

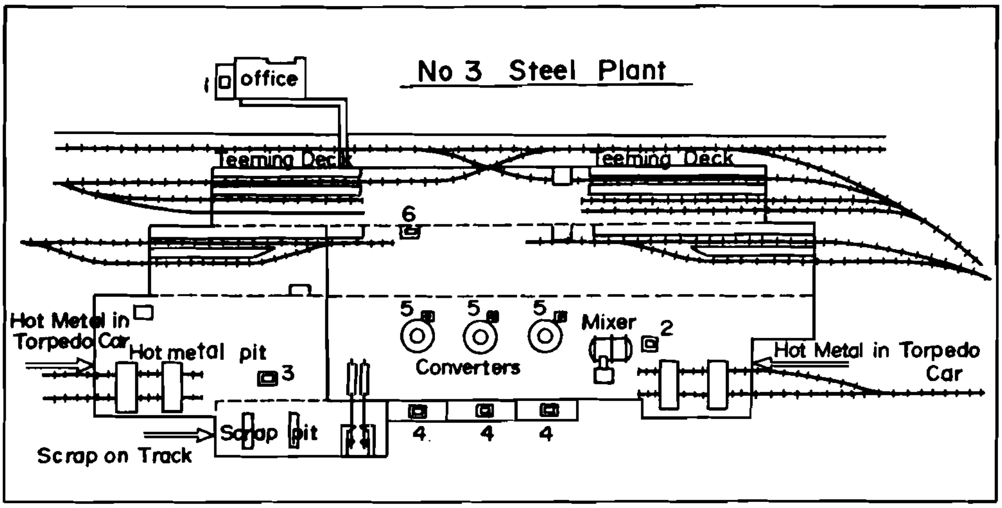
Table 2. Hitting rate of steel composition.

		Carbon	Silicon	Manganese	Aluminum
Permitted range of steel composition		$\pm$0.02% (when aimed carbon $\leqq$0.50) $\pm$0.03% (when aimed carbon $\geqq$0.51%)	$\pm$0.04%	$\pm$0.10% (when aimed manganese $\leqq$130%) $\pm$0.15% (when aimed manganese $\geqq$1.31%)	$\pm$0.015%
Hitting Rate	With model	91%	100%	98%	100%
	Without model	86%	93%	91%	90%

DYNAMIC END-POINT CONTROL MODEL AT THE NO. 3 STEEL PLANT

Computer System

Three 160 t converters are installed at No. 3 Steel Plant where low-carbon rimmed steel and semi-killed steel are melted. The layout is shown in Figure 17. Like the No. 1 Steel Plant, on-line terminals of the computer systems have been provided at every pulpit.



1. Computer Room
2. Hot Metal Pulpit
3. Scrap Pulpit
4. Main Pulpit
5. Tap Side Pulpit
6. Teeming Pulpit

Figure 17. Layout of No. 3 Steel Plant in the Wakayama Steel Works.

At first, the dynamic end-point control model based on the J and L model was developed, which consists of estimating the carbon content of molten metal and calculating the required amount of oxygen and coolant from both the decarburization rate obtained by an exhaust gas analyzing device and the temperature measured by bomb thermocouple. But it was found that, as the decarburization rate is influenced by the blowing condition, this end-point control model cannot bring about a sufficiently good hitting rate.

Then sublance equipment was installed at one of three converters in No. 3 Steel Plant and a new dynamic end-point control model taking advantage of both an exhaust gas analyzing device and sublance equipment was developed. The system is shown schematically in Figure 18.

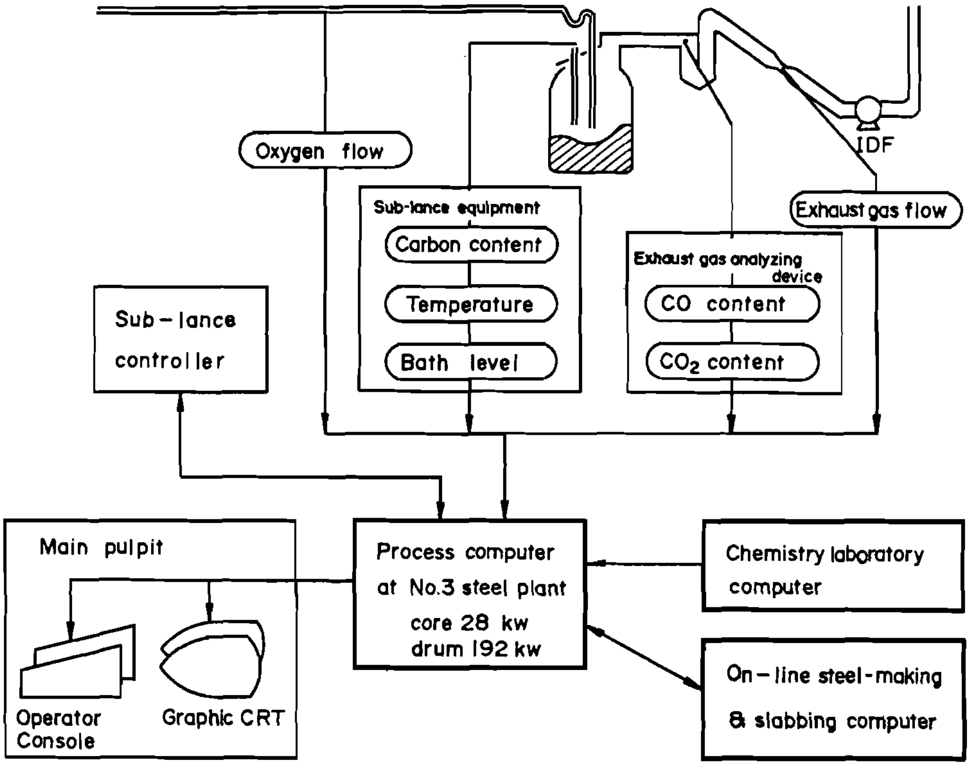


Figure 18. Diagram of the endpoint control system at No. 3 Steel Plant.

Sublance Equipment

As shown in Figure 19, the sublance equipment consists of the sublance, the automatic probe feeding, setting, and withdrawing apparatus, and the sample cutting and transporting mechanism. The measurement of molten steel temperature, quick analysis of carbon content, and transport of the sample to the chemistry laboratory are carried out automatically.

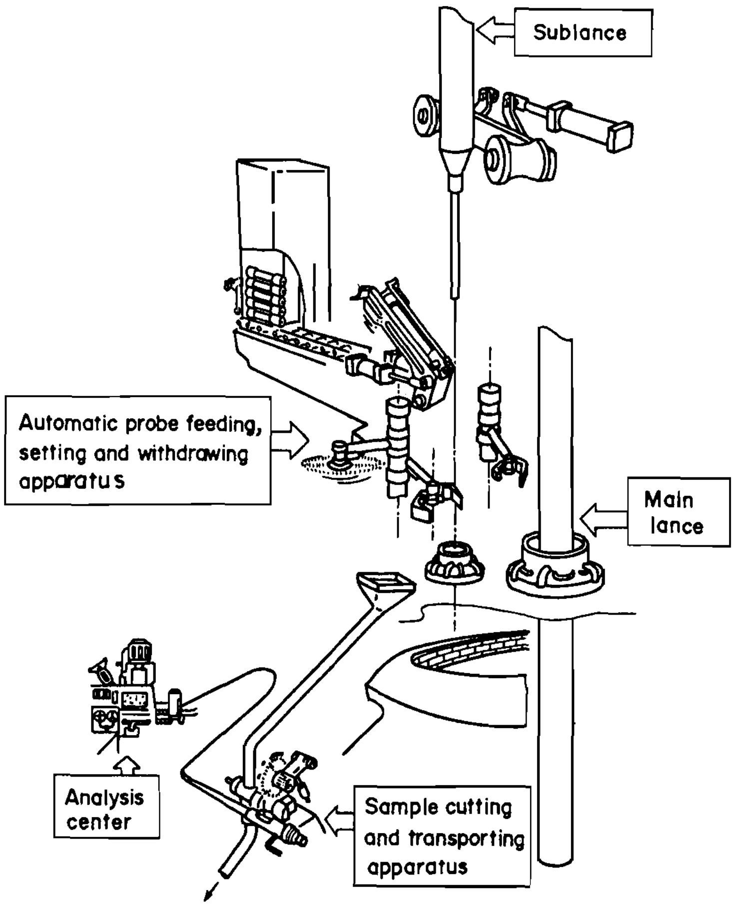


Figure 19. Outline of the sublance equipment.

Automatic Probe Feeding, Setting, and Withdrawing Apparatus

This is the mechanism that attaches the probe to the sublance to measure the carbon content and temperature. It has five portions. The outline is illustrated in Figure 19 and the sequence of operation of the automatic probe feeding, setting, and withdrawing apparatus is shown in Table 3. The automatic opening-and-closing cover of the sublance hole is to protect the automatic probe feeding, setting, and withdrawing apparatus from the heat radiated out of the furnace, except for the period when the sublance is in the furnace. The apparatus requires about 75 s from feeding to withdrawing as shown in Table 4.

Table 3. Sequence of movement of automatic probe feeding, setting, and withdrawing mechanism.

Movement order		Outline of devices
Selecting of probe		Select the desired probe (from three types) in the pulpit room.
Storage banker		Three types of probes (each type accomodates as many as 25) are put in the banker. The selected probe is dropped on the probe-transfering mechanism.
Probe transfering mechanism		Transfer probe to setting-and-grasping mechanism by the kicker.
	Canceling of probe	Cancel probe on the setting-and-grasping mechanism when another probe is needed.
Probe-setting and-grasping mechanism	Erect device	Erect device in order to set probe to holder of sublance.
	Sublance goes down	Sublance proper goes down to set probe.
	Set probe	Push up only grasping mechanism to set probe perfectly.
	Set device horizontally	Set device horizontally to set next measuring probe.
	Withdrawal of probe	Withdraw probe by withdrawing mechanism when setting condition of probe is not good.
Sublance goes up and down		Sublance proper goes down→Measure→Sublance proper goes up.
Probe-withdraw-ing device	Turn with-drawing arm	Turn withdrawing arm to grasp measured probe.
	Sublance goes up	Sublance goes up to initial position and probe is free from sublance by withdrawing arm, then probe drops into furnace.
Probe cutting device	Turn grasping arm	When sample is required, turn grasping arm of this mechanism.
	Cut probe	Cut probe by saw to withdraw sample.
	Withdraw sample	Turn the grasping arm to initial position (above sample shoot) and set sample free.
Sample transporting		

Table 4. Time required for sublance measurement.

Preparation	Time R'qd (s)	Measurement	Time R'qd (s)	Withdrawing and Cutting	Time R'qd (s)
From storage banker to probe erecting and grasping device	10	Descending of sublance	8	Turning of withdrawing arm	2
Erecting of mechanism	5	Stopping of sub-lance (for measurement)	6	Ascending of sublance (from withdrawing position to initial position	5
Descending of sub-lance (to probe attaching position)	5	Ascending of sublance	8	Turning of grasp-ing probe for cutting	2
Setting mechanism to horizontal position	5			Cutting of sample	15
				Returning of withdrawing arm	2
				Returning of grasping arm	2
Total	25		22		28

Swing-Stopping Mechanism

The sublance is raised up at a velocity of 150 m/min after measurement, and stopped by the probe withdrawing mechanism. But if the sublance swings severely at this time, the probe withdrawing mechanism fails in grasping the probe. Consequently, the swing-stopping mechanism has been set up in order to stop its swing and take away the steel attached to the sublance. This mechanism presses the sublance from both sides with rollers sufficiently to attain this purpose.

Automatic Sample Cutting and Transferring Mechanism

The sample dropped into the recovery box through the recovery shoot is still in the probe; the automatic sample cutting and transferring mechanism takes the sample out of that probe and puts it into the air shooter. Results of analysis of the sample are obtained automatically. The sequence of operation of the automatic sample cutting and transferring mechanism is shown in Table 5.

Table 5. Sequence of movement of sample transporting.

Item	Content
From automatic probe feeding setting and withdrawing device ↓	
Sample-pushing part ↓	Push probe from sample shoot to cutting part.
Sample-cutting part ↓	Cut probe for taking out sample of probe.
Sample-leaning part ↓	Lean probe for dropping sample only from probe.
Sample-inserting part ↓	Insert sample to air shooter for transporting it to analysis center.
To analysis center	

Measurement

Carbon content, temperature, and active oxygen content can be measured by one probe. The surface level of the molten metal is measured by this sublance for the purpose of arranging the blowing conditions and of monitoring erosion of the lining. In addition, we are going to experiment on measuring slag formation during blowing.

Dynamic End-Point Control Model

An outline of the model is shown in Figure 20. The computer calculates the decarburization rate $\phi = dC/dO$ every 5 s with exhaust gas analysis and from its trend determines the maximum decarburization rate α. The trend is also displayed on a CRT. The timing of sublance measurement is determined from the mean value of the amount of oxygen consumed in preceding heats having similar maximum decarburization rate and/or by the required amount of oxygen calculated with the charge control model.

From the temperature T_s and the carbon content C_s measured by the sublance and the decarburization rate up to this moment,

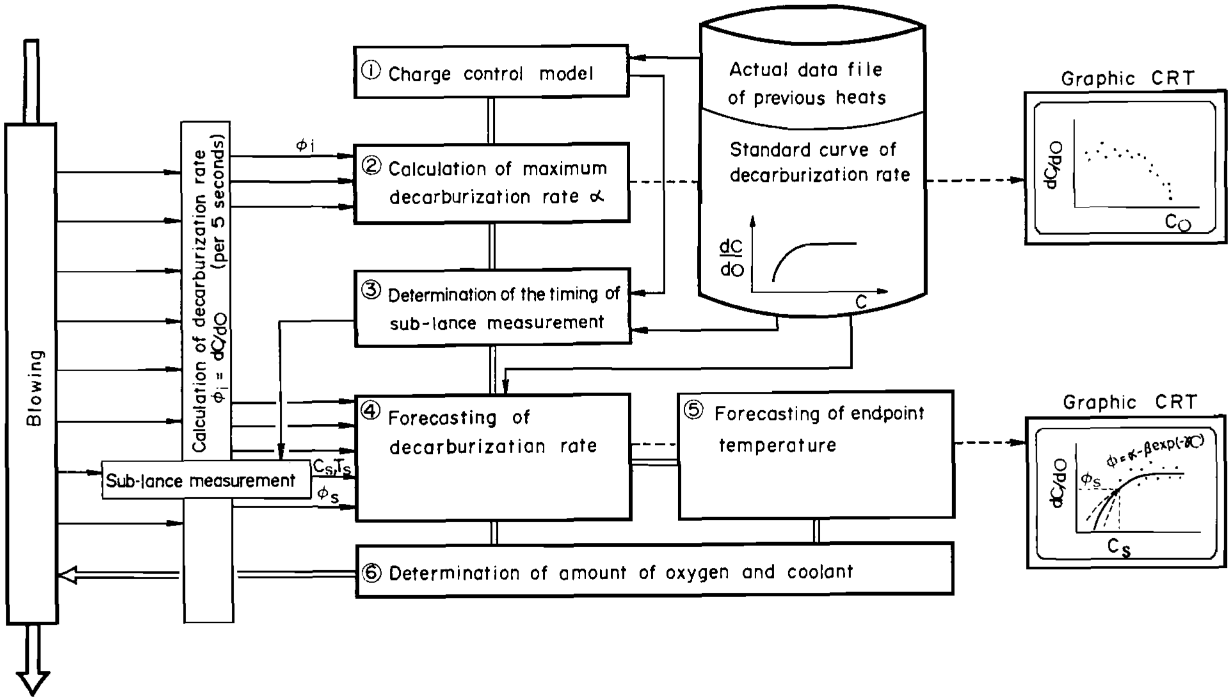


Figure 20. Outline of the dynamic model for endpoint control at No. 3 Steel Plant.

the parameters α, β, and γ of the following equation for forecasting the decarburization rate are determined:

$$\phi = \alpha - \beta \exp(-\gamma C) \quad ,$$

where C is the carbon content of molten steel. The necessary amount of oxygen O_C to meet the aimed carbon content is also found from this equation.

From the following equation for estimation of temperature rise rate, $\lambda = dT/dO$, the amount of oxygen O_T to meet the aimed temperature is calculated:

$$\lambda = a_1 T_2 + a_2 \quad ,$$

where a_1 and a_2 are constants.

Finally the amount of oxygen O_s and the amount of coolant W_{cool} to be charged for end-point control are calculated under the following rules and displayed on the graphic CRT.

If $O_C \geq O_T$, then $O_s = O_C$, $W_{cool} = k(\Delta O_C - \Delta OT)\lambda$.

If $O_C < O_T$, then $O_s = O_T$, $W_{cool} = 0$.

Result of Dynamic End-Point Control Using the Sublance

Success Rate of Carbon Sensor

Since the sublance equipment was installed in April 1975, there have been troubles with the carbon sensor. Consequently many kinds of carbon sensors were tested and improvements were made to it, for instance to its shape, inlet hole, and so on. As a result, a success rate of measurement during blow of more than 95 percent has been achieved (in case of measurement after blow, the rate is 100 percent). The success rate of temperature measurement has been almost 100 percent.

Result of End-Point Control

Several months were taken to improve the carbon sensor, and then full on-line control with the use of the sublance began in December 1975. The result of using the sublance is shown in Figure 21. The hitting rate has increased in proportion to the sublance operation.

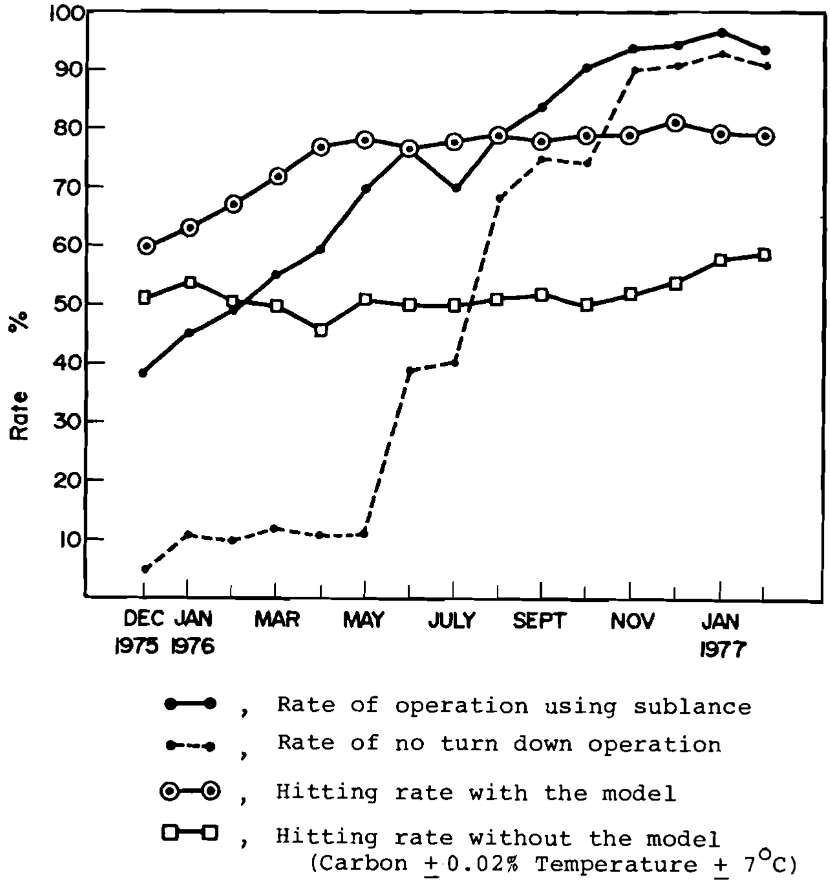


Figure 21. Result of dynamic endpoint control model at No. 3 Steel Plant.

No Turn Down Operation

For more than 90 percent of heats, the sublance equipment is applied to both measuring temperature and sampling molten metal after the blowing with no turn down operation. This no turn down operation has the great advantage of extending the lifetime of the furnace, saving labor, and increasing production. Because of these excellent results, we are planning to install sublance equipment at other converters.

We are going to try to measure slag formation during blowing with this sublance, to try to achieve stable blowing.

CONCLUSION

The control models of the No. 1 Steel Plant have been introduced. These have been applied in the other two steel plants too, and have increased the successful hitting rate of end-point temperature, carbon content, and steel composition in the ladle. The dynamic end-point control model, with the use of both sublance equipment and an exhaust gas analyzing device, has been applied to one of the three converters at the No. 3 Steel Plant and the hitting rate has increased remarkably. Thus application of the computer to end-point control is effective.

However, as the following problems are still left unresolved, we believe that control during the course of blowing is necessary:

- It is often necessary for a second blowing disregarding the aimed end-point carbon content because of insufficient dephosphorization at the first blowing.
- Slopping often causes loss of a large amount of molten steel.
- Excessive slag formation at tapping often makes the steel composition control difficult.

We are considering applying the computer to the control of lance height and automatic charging of fluxes and coolants so that operating conditions can be modified to minimize these difficulties. In addition, a sensor for direct measurement of the slag formation during blowing should be developed. Then computer application to basic oxygen furnace (BOF) control will become even more effective.

Discussion

A number of questions were raised concerning the measurement of temperature, carbon content, and "active oxygen". One participant stated that Sumitomo Metal Industries has developed techniques for measuring all three parameters from one sample. In each vessel there is only one sublance which measures temperature and carbon content. The measurement of active oxygen is not operating 100 percent. The sublance method is used together with a static model.

Regarding the general system architecture, it was stated that a two-level concept has been implemented at the plant level, and a three-level one for the corporation as a whole.

The psychological aspects of computer application were also discussed. The participants stressed the difficulties encountered by personnel in suddenly converting from manual to computerized systems. About three to four months are needed by operators to adjust to the new techniques.

A Standard Communication Subsystem For Steelwork Application

R. Oberparleiter

INTRODUCTION

The process computer system in VÖEST-Alpine is heterogeneous. The method of direct coupling of computers results with growing automation in a total system that is difficult to change. Nearly every computer connection is special either in the hardware or the software. So, in 1974 we started an investigation into the introduction of a standard data communication system.

In our company there is very little interaction between the different plants. Material buffers are used between the plants, so that short-term troubles in one plant have no impact on other plants. The consequent high reliability of the production system cannot be allowed to be destroyed by a poor data communication system. So we have decided to take a system with distributed control and distributed intelligence--distributed control for high reliability of the total system, distributed intelligence for easy connection of process computers to the network. We have discarded the use of mass-storage in the data network for increased reliability. The best solution seemed to be a packet switching system with adaptive routing. Only the price of such a system was in doubt. An investigation has shown that the capital cost will be relatively high, but the connection of the process computers to the network will be cheap, because each computer needs only one datalink. So the costs for the network solution grow linearly with the number of computer connections after the capital investment. The cost for direct coupling of computers grows by nearly the square of the number of computers. The break-even point is between 10 and 15 process computers.

Looking for such a system, we found that DECNET, announced by the Digital Equipment Corporation, should fulfill all our requirements and we started a pilot project with it.

DECNET

We should distinguish between the process computer system and the data-transfer system. Process computers are--as mentioned above--different systems on different types of computers. The data-transfer system is homogeneous (PDP11-RSX11-DECNET, Figure 1). In DECNET three protocols are of interest. The protocol DDCMP permits error control on physical links. The protocol NSP

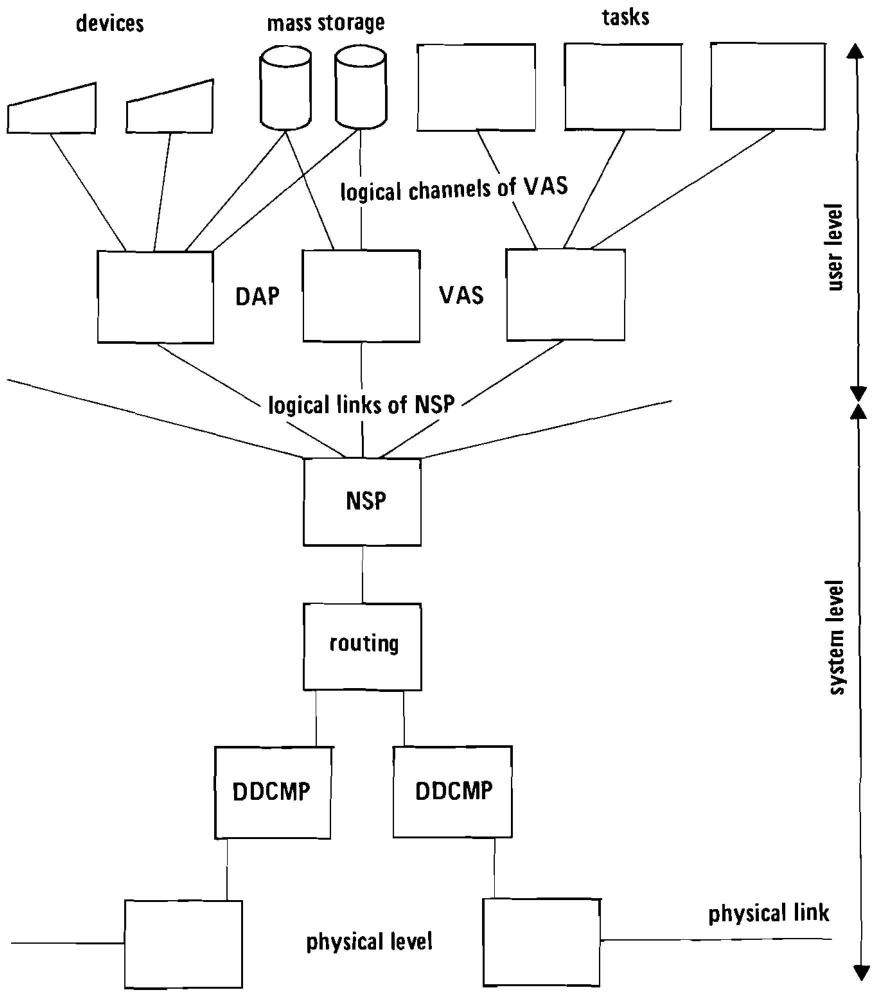


Figure 1. DECNET - hierarchical structure of protocols.

permits end-end control between two tasks on different computers. The third protocol DAP, is for remote file control. The first two protocols are absolutely necessary. With DDCMP the process-computers can be connected error-free to the net. NSP grants flow control and end-end control between two tasks on different process-computers over the network. To use DAP one computer needs knowledge about the other system and that produces a very strong coupling of the systems.

VAS

Instead of DAP, we have defined a new protocol, VAS (VÖEST-Alpine Standardprotocol, Table 1). It contains all the elements necessary for end-end control with NSP as the lower level protocol. The devices and data files are given logical names. The association to physical names is made by the addressed system. So each system has exclusive control of its resources. The elements of VAS correspond to elements of NSP. This gives an additional level of end-end control and flow-control for mass storage and devices (Figure 2). Because the implementation of NSP and DDCMP in an operating system is problematic, we have expanded VAS so that we can use it as a front end protocol to DECNET in a non-DECNET system (Figure 3). The usage of NSP-elements in VAS is very simply defined. Our goal was a simple protocol, easy to implement in a different system.

Table 1. VAS-protocol elements.

ZUGRIFF	Corresponding to NSP-connect Parameters: transmit message receive message transmit directory VAS send and receive channel
DATENMESSAGE	Corresponding to NSP-transmit Parameters: end of data indicator VAS send and receive channel data (1 line)
STATUS	Corresponding to NSP-answer for connect and to NSP status (receive) Parameters: ZUGRIFF-positive or negative parity error transfer positive or negative VAS send and receive channel
FEHLER	Corresponding to NSP error-message Parameters: error code VAS send and receive channel

VAS only works with the standard message format. The messages are segmented into lines and transferred line by line. The last line is terminated by "¢".

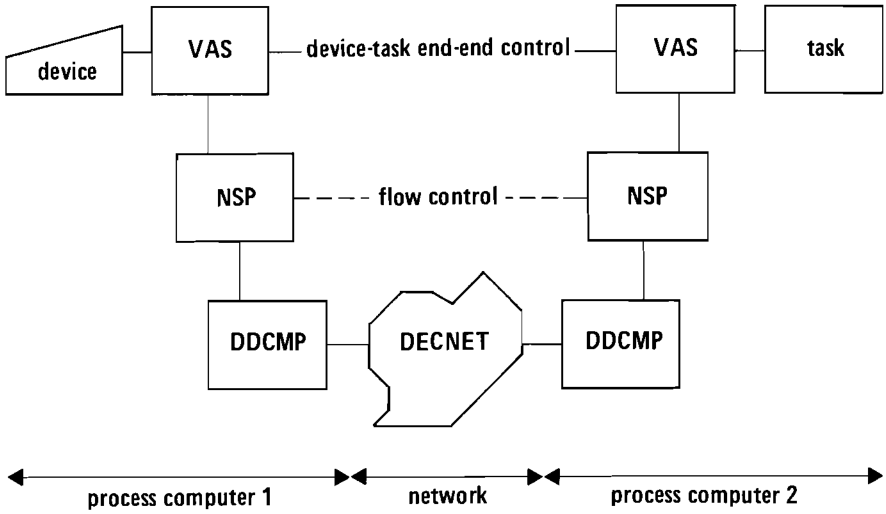


Figure 2. VAS in a homogeneous DECNET system.

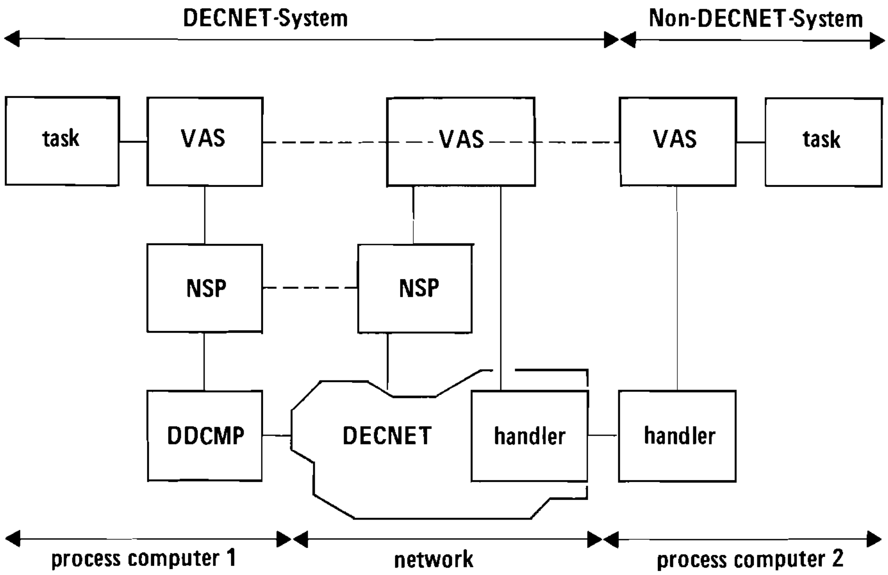


Figure 3. VAS front-end protocol in a non-DECNET system.

Data Format

We have defined a standard format for Data (Figure 4). All data transferred via the net have to use this format. The goal was to have the same very loose connection at the process level as with the help of VAS at the data transfer level. Only alphanumeric ASCII characters are allowed, with a fixed line length (72 characters) and a variable number of lines. All lines have the same division into fields of fixed length. The fields can be combined in defined ways. In the first line is the key-information of the message--defined for all messages in the plant. Each value in the data fields is accompanied by its name. So the whole information about the message is in the message and not, as is more usual, partly in the receiver program. In the latter case, it is necessary with growing automation or when changing a computer installation to adapt the receiver programs in the different systems for integration of the new data. Our new format allows their receiving and storage without previous knowledge of their content.

```
FELD:  A   B        C       D       E         F         G        H       I         K
      |12|34567890|1234567|890123|4567890|12|34567890|1234567|8|90123456|7890123|4567890|12|

      AA LIH2HA 19765  VE   16 RELPO2                        770104  074430  R1XXFK
                               FE      98.88   C      = 0.090   SI     = 0.000
                               MN      0.328   P      = 0.0161  S      = .032
                               AL      0.223   V      = .00004  NB     = .00002
                               MO      0.019  $                                  $

      AS LIS3T8 543654 VF      SLTBO2                        770104  075621  RIZZPL
                               FE      96.562  FE2O3  = 34.76   FE3O4  = 62.11
                               CACO2   17.44   AL     = 0.2231 $                 $

      AZ LIS3SR 770104 0620    RELPO1                        770104  082001  R1ZSNE
                               FE      93.63   C      = 4.601   SI     = 0.40
                               MN      0.90    P      = 0.0921  S      = 0.0789
                               AL      0.0011  CR     = 0.04    NI     = 0.01
                               CU      0.0178  V      = 0.01    TI     = .00001 $
```

Figure 4. Analysis in standard data format.

State of Project

We have installed a data network node as a pilot project in our steelwork LD3 (Figure 5). Its exclusive job is data transfer and interfacing to process computers. For development of programs

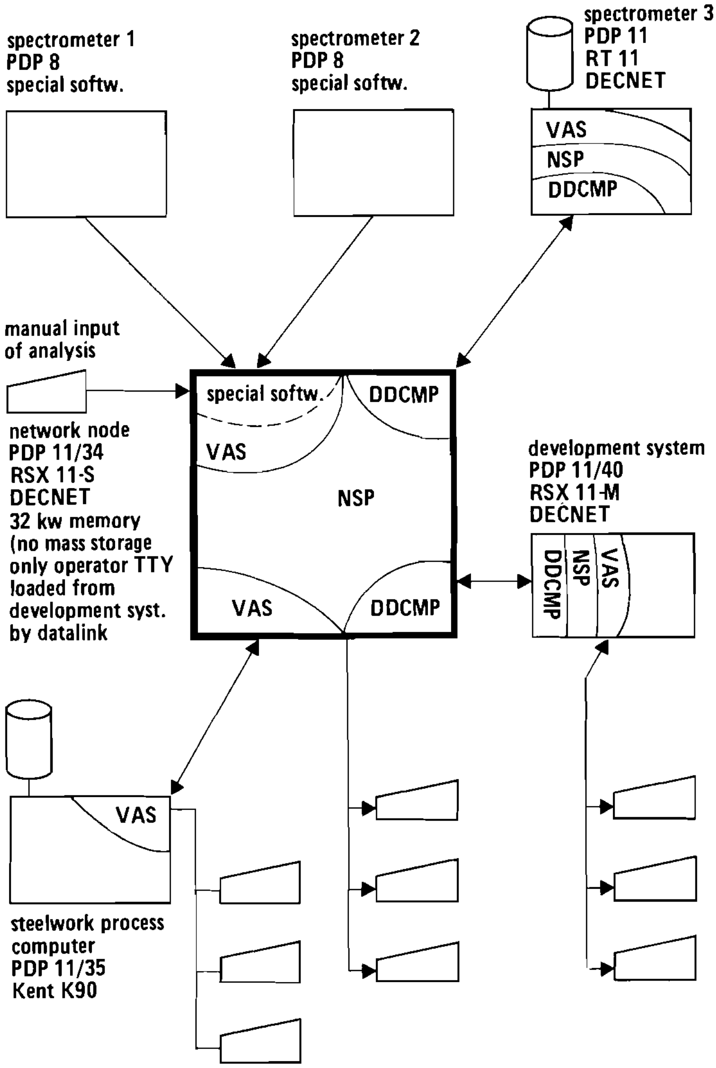


Figure 5. Pilot project data network for steelworks.

and downline load of the network node we use a larger system running under RSX11M. On both systems VAS is implemented. The steelwork computer is a different system (Kent K90). It was not possible to integrate NSP into K90 so we integrated the VAS-front-end protocol in the K90. Two spectrometer computers are connected to the data network with interface software in the node (it was not possible to change the software in the spectrometer computers). An additional spectrometer computer will be delivered this year, also with DECNET + VAS. At the moment it is possible to transfer the analysis to all mass-storage devices and to devices of all integrated computers.

Future Outlook

It is planned to expand the network considerably in the future and to include the production scheduling computers and commercial data processing machines in it.

Discussion

Several participants pointed out that steel firms buy the products of worldwide software suppliers, which have been designed in general to fulfill general user requirements and to provide communication between computers. Often these products are not adequate for the steel firms' purposes. The firm must then modify the software to fit its needs. This does not seem to be the right approach, and it would seem more responsible if the software packages were initially designed to comply with user requirements. To do this requires a dialogue between supplier and user.

Production Planning and Control at Domnarvets Jernverk

K. Holmberg

INTRODUCTION

Domnarvets Jernverk belongs to the Stora Kopparbergs Bergslags AB and is the largest steelwork in Scandinavia employing some 5600 people. In 1975, the crude steel production at Domnarvet amounted to 1.2 million t. Domnarvet produces heavy plate, medium gauge plate, cold rolled medium gauge plate, cold rolled sheet, galvanized sheet, bars, rails, rods, strip, section, and plastic coated sheet. The production flow at the Domnarvet plant is shown in Figure 1.

Domnarvet produces steel in three Kaldo furnaces and seven electric arc furnaces. Two of the Kaldos and two of the arc furnaces have capacities of 80 to 105 t, the remaining furnaces have capacities of 25 to 30 t. The melt times for the Kaldo furnaces are between 1 and 1.5 h, and the times for the arc furnaces are between 4 and 8 h. Each charge produces 3 to 16 ingots depending upon furnace capacity and ingot size. Each melt consists of only one single quality. After teeming, the ingots are poured, and cooled for 1 to 6 h before stripping, then stripped and transported to the soaking pits where they are stripped in the pouring bay. Normally, the ingots are fed hot to the soaking pits, and require an hour or more in the pits to normalize before rolling.

There are two types of ingots produced, square ingots and plate ingots. The weight of the square ingots varies between 3 and 8 t, and that of plate ingots between 6 and 18 t. Square ingots are rolled to blooms in a blooming mill, while plate ingots are rolled to slabs in a universal mill. Slabs are left to cool after rolling and are conditioned before being rolled into heavy plates or wide coils. Blooms continue in one of three directions: to the bloom shears, then to the bloom yards for conditioning and inspection, and on to the medium section mill; to the bloom shears, then to the billet mill for further reduction, then to the billet yard for conditioning and inspection, and finally to the fine section mill; or to the bloom shears, then to a reheating furnace, and directly onto the heavy section mill. Two continuous casting strands produce slabs directly for rolling in the heavy plate mill and in the hot strip mill. The increased continuous casting capacity represents a valuable strengthening of production resources. It is one of the aims to send as much material as possible through the continuous casting plant. The output of finished rolled material made from continuously cast steel is about 10

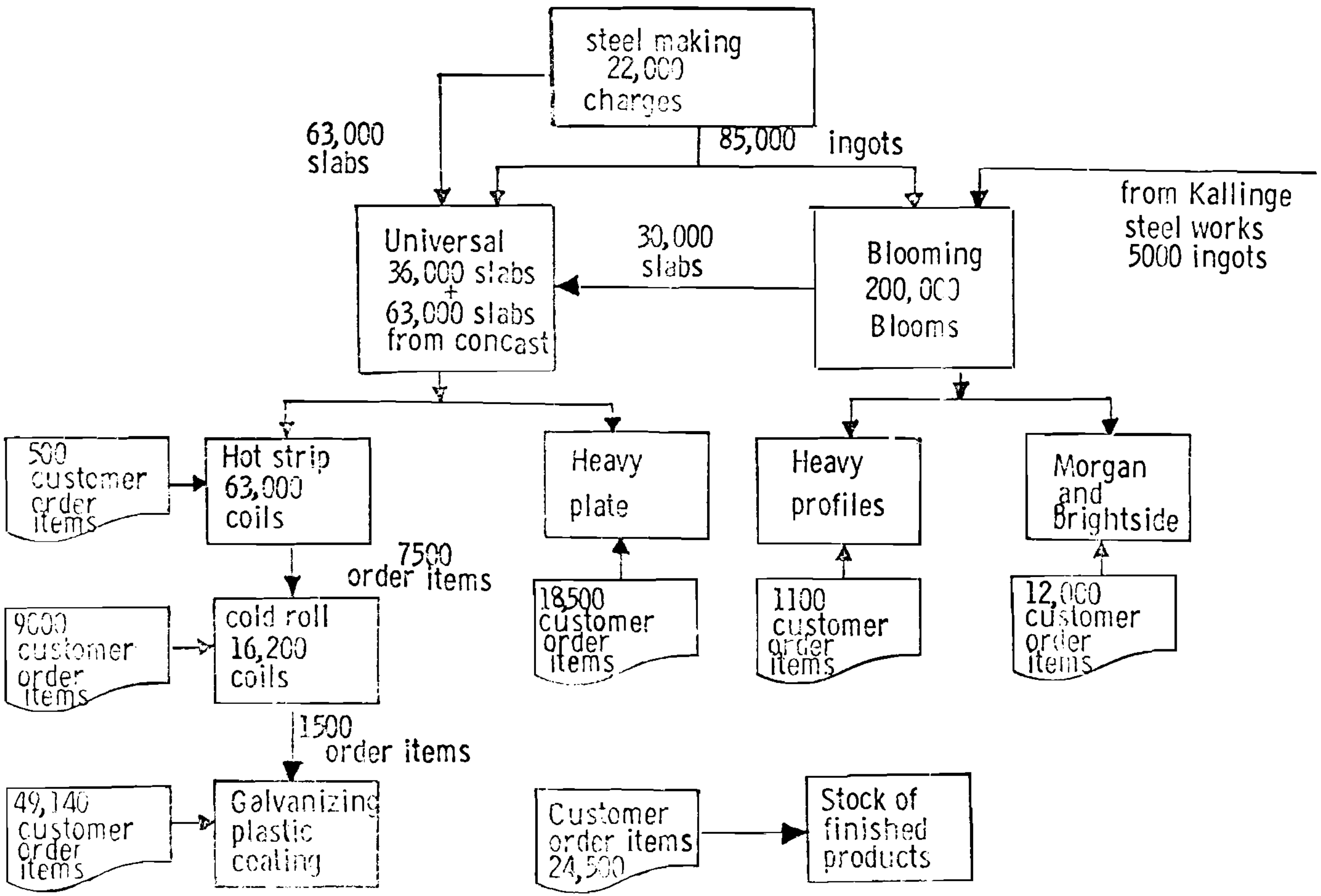


Figure 1. Facilities and transaction volumes, Domnarvets Jernverk.

percent higher than production based on ingots, and the universal rolling mill can now be relieved of ingot rolling in favor of rough strip rolling.

In 1968 Stora Kopparberg installed at Domnarvet a real-time information system (DORIS) composed of a duplex System 360--a System 360 model/40 with 128 K memory for batch processing, and a System 360 model/30 with 64 K memory. The System 360/40 also served as a back-up system for the model 30 which, in turn, was a dedicated system with a specialized IBM operating system PCMS (Process Communication Multiprogramming Supervisor). The System 360/30 controlled an IBM 1070 terminal network consisting of about 15 keyboards, 15 printers, 5 digital displays, and a large number of push buttons and signal lamps. DORIS operated 24 h/day, daily.

In 1970-1972, Stora Kopparberg investigated how to proceed with new integrated on-line applications and decided to build Domnarvet Information System (DIS), a database, data communication system based on general software.

In 1973, the System 360/40 was replaced by a System 370/145 with a 512 K memory. The operating system was changed from DOS to OS/VS1 and the data base System DL/1 was implemented. As System 370 is compatible with System 360, the model 145 could also serve as a back-up system for the model 30.

In 1974, the model 145 was expanded to 1.5 megabyte memory and Stora Kopparberg became one of the first users worldwide to implement IMS/VS.

In 1975, a System 370/158 with 1.5 megabyte memory was installed as an on-line production system. The model 158 replaced the model 30 and controlled both the new IBM 3270 network with about 80 terminals and the old IBM 1070 network. The control of the IBM 1070 network was done via a IBM system 7 used as a front-end concentrator. This was the simplest way both to create program support for the old IBM 1070 terminals and to achieve short response time for real-time transactions.

In 1975, Stora Kopparberg also implemented remote job entry to the model 145 mainly for application programming testing. By then the company was running the model 158 as an information management system (IMS) on-line production system 24 h/d, all days and the model 145 as an IMS on-line testing system, remote job entry system, and batch system.

THE FORMER DOMNARVET REAL-TIME INFORMATION SYSTEM (DORIS)

Application Overview

DORIS tackles several types of *application* within the production area. For example, material requisitioning converts customer order items into mill orders for each type of semi-finished product; facility scheduling defines the sequence of mill orders that are to be processed on each facility; and production reporting yields actual production data, which are compared against production schedules, thus enabling planners to reallocate out of specifications material.

The following is an example of the first stage of DORIS covering steelmaking in primary mills and production planning. Incoming customer orders are divided into product types and sent to the respective finishing mill planning groups, where they are worked into the production schedule of the finishing departments. This gives the slab/billet requirements of the finishing mills, which are then sent to the steel plant planning office. For each slab order, the computer allocates the possible mold types, and calculates the ingot weights for these types. The results are stored in the slab order record, and can be printed out in the planning office on request. A daily planning meeting is held at which the slab order listing is used to build up the cast requirement for the next 48 hours.

The shift planners decide the sequence of cast production within the limitations set by the day planners. To do this, they can request a printout of the cast requirement file, together with certain plant status printouts. When the planner decides to make a cast, he keys a reference number to the cast record via his keyboard. An order for this furnace is then printed out on a 1053 typewriter located near the furnace. The printout gives all the necessary data as to the analysis, the teeming temperature, etc., and the furnace crew can now start preparing the new cast. The planners must also decide whether to allocate this cast to the pouring bay, or to the continuous casting plant. As a help in making this decision they may request a pouring bay status list giving the situation for each pouring location.

The furnace crew reports when they have started a new cast. The computer system sends this message to the planners, who may check and in some cases alter the pouring bay or the continuous casting plant instruction. The furnace crew also reports when there is an estimated 20 minutes left until tapping time, and they report when the furnace is ready for tapping; for arc furnaces they also report when there is an estimated 50 minutes left until tapping. This information is relayed to the planners, who may use it to reconsider the cast allocation; it is also relayed to the pouring bay, or to the concast plant. As each message is received, the system calculates the expected future event times for this cast and also checks to see whether these events are going to produce conflicting crane requirements, if so the information is given to the planners who must decide which furnace to hold.

After pouring, the pouring bay reports the results, giving estimated weights for any ingots that have not been poured according to plan. This information is relayed to the planners who can now reallocate the cast or some ingots, if necessary. At this time the planners must consider the allocation of the ingots to the soaking pits. To assist in making this decision, they can request a printout of the soaking pit status. Their allocations are keyed in via the keyboard, and the message is relayed to the soaking pit controller, giving the charge number, the number of ingots, the type of mold, the pit allocated, and the heating instructions.

Cast analysis information is sent by teletype from the laboratory to the planners. This information normally arrives while the ingots are in the pouring bay. The planners now confirm the allocation of the cast. In the case of a miscast, they must consider the reallocation required; to do this they can request a printout from the slab/billet order file. Information on the new allocation is typed in via the keyboard.

Five minutes before the computed stripping time, a message is printed out to the planning department, which decides whether or not to go ahead with the stripping; this information is relayed to the pouring bay. When the ingots have been stripped and loaded onto ingot trains, the loading is reported to the system and relayed to the soaker controller so that he knows which ingots are coming down to the soaking pits. The soaker controller reports the pit loadings.

The soaking pit controller reports when a pit is ready to draw. There are three routes from the blooming mills, and for each a light, visible to the roller, is provided; the light is on when there is material available in the pits for this route. Information from the soaking pit controller that a pit is ready to draw is used to control the lights. The blooming mill roller has three push buttons, one for each of the routes from the mill. He selects the route he wishes the next bloom to go along, and presses the appropriate button. The system then allocates a particular ingot to be drawn for the blooming mill. Information on the cast number and the ingot number on a display is given to the soaker controller telling him which ingot to draw; a light is also set on over the relevant soaking pit. The soaking pit controller reports back which ingot has actually been drawn. This is normally a confirmation, but when he has drawn a different ingot, full details are given. The rolling instructions are now issued to the blooming mill roller, who reports back to the system when the ingot has been rolled.

The cutting instructions are also issued to the appropriate bloom shear operator, who reports on which cuts have been made. The ingots are weighed before entering the blooming mill, the weight being read automatically. This information will be used for determining the cut allocations issued to the bloom shears. The cutting result is reported back to the system. The inspection of the material takes place in the billet yard some days later.

File Description

Four basic classes of files were used in this system: order files, reference files or dictionaries, material tracking files, and plant status summary files. Some of these files are discussed below.

Order files represent the planned commitment of the plant. For example, FM contains all the slab/billet orders from the finishing mills; CH contains records for all required charges that have been built up with reference to the FM records. An example of the dictionary or reference files is RE, a quality dictionary containing records for each of the steel qualities made at Domnarvet. Material tracking files are used to track the location of the material within the plant. For example, the following files are kept for tracking ingots: GT--when an ingot is reported as poured, a record for the ingot is made in this file and remains on file until the ingot has been cut. (After deletion from this real-time file, records are moved onto a historical file where they are kept and used for statistics, etc.) To track the movement of the ingots through the plant, a series of indices are made to this file as for example GE which lists all the ingots that have been stripped but not yet loaded onto ingot trains for transportation to the soaking pits, and TP which references the loading of the ingots onto the ingot cars. The plant status summary files contain status information about the various plant facilities, and are used to compare the plant status printouts required by the planning department. An example of these files is SU which indicates the situations of the furnaces. There is a record in the file for each furnace, with three subsections for each record; the first indicates all the charges planned but not yet ordered on the furnaces, the second all the charges in the furnaces, and the third all the charges tapped but not yet poured.

Key Features of the Former DORIS

At the time DORIS was designed the following requirements were set up:

- The ability to process two types of transactions: simple transactions requiring a fast response time, and complex transactions with slower response time requirements.
- Shared access to data files from multiple message processing programs.
- A set of priorities for transactions.
- Testing procedures for new application programs, off-line tests and on-line tests.
- Errors in the application of programs must not affect the system.

- The on-line computer system must run 24 hours a day, daily. In case of a system breakdown, the terminal network must be switched over to the off-line system. The maximum allowable down time should not exceed 15 to 20 minutes.
- Logging file for transactions and restart procedure which enables the system to update data files after a breakdown.

DEVELOPMENT OF THE CURRENT DOMNARVET INFORMATION SYSTEM (DIS)

The present information system was established to provide both a common source for information required by users in different areas of the plant and up to date and reliable information for end-users. These requirements are met with the implementation of a DB/DC (data base-data communication) system. The so-called data base technology provides a means for easy storage and maintenance of information.

The reliability of information depends on the user's opportunity to communicate with the computer easily, and in a controlled manner. The usual combination of punched card input and error list has many practical limitations and demands much of the person reporting to the system. A good solution which provides end-users with up to date and reliable information is to locate such interactive terminals at display stations in users locations, enabling users to communicate directly with the computer and the data files.

One solution to the data base computer handling problem, adapted by Domnarvet, is to install a powerful control hardware system and a program package to assist data base and terminal handling. The hardware system, which has been previously described, consists of a duplex IBM/370 system made up of an IBM 370/145 and an IBM 370/158. The IBM program product IMS was used for terminal and data base handling.

Application Overview

The new DIS incorporates the old applications of DORIS with improvements, as well as new applications. There are four subsystems currently installed in the DIS: order entry, inventory control, shipping, and production planning and control.

Order Entry

The main objectives of this subsystem are:

- Registration of 70 percent of the orders on the same day that they are submitted by the salesman, with order acknowledgments being sent to customers the following day;

- A more complete and accurate processing of orders than previously;
- Less working time for processing orders;
- Accessibility of each order via the display screen at each planning office at all times;
- Printouts of orders ready for production, if needed by each planning office.

Operating Procedures

These procedures can be described in the following stages: the salesman prepares an order, and perhaps produces a draft; an order processor transmits the information arranged by markets from a 3270 keyboard; a control document is produced in a 3286 printer; draft and control documents are compared, amendments are entered and the market oriented processing approved; the order queues up in the system; the production-oriented processing starts; the delivery week promised is checked; the order is then ready for printout in the order acknowledgment, work order documents, etc. Each document is taken from its specific queue in the system.

Processing

Market oriented processing is done by means of a series of display formats. The first format concerns information about an order (e.g., name and address which is most often collected from the customer data base). In this format, the operator must also select some of the formats for the continued processing, which are used to register item information. Format OBJ, for example, corresponds to coated products. This format is repeated as many times as there are items to process. Most of the information remains on the display from item to item, and therefore only the differences between the items have to be keyed-in. The processing of items following the first one is therefore a very simple procedure. Once the order has been entered, the order acknowledgment is printed out either on a 3286 printer or on a computer room printer.

Production documents are also created. The production workshop concerned receives its orders in a queue per delivery week. The planners can therefore select orders for printout for precisely the manufacturing weeks in which they are interested.

Inventory Control for Finished Products

The main objectives are to: make on-line accounting for finished products; permit direct inquiries about these products from a display station; produce suitable inventory lists for customers, salesmen, and stores staff; and improve planning of loading.

As a result of *stock accounting*, which is done entirely on line, stock lists are printed out and adapted to the customer or to the salesman. Stock accounting transactions are keyed in to the finished stock office from documents produced manually in the store.

As a *sales support*, a stock inquiry can be made from a display station; a simple inquiry about just one product can be made. Usually the inquiries will probably be such that, for example, one can leave open (within a certain interval) the length, or the thickness, or both. The result of the inquiry is presented on a display station which also contains information on what is reserved and what is in progress as replenishment orders.

Shipping

Shipping documents are useful to do the following:

- Key dispatched material from the 3270 keyboard, and thereby make as much use as possible of the order information already stored in the system;
- Print 95 percent of consignment specifications on the computer;
- Provide quicker and more mechanical processing of invoices.

Shipping specifications are printed out on a 3286 printer. This document is distributed in many copies, and it is therefore copied on a copy machine. The *freight bill* for road transport is produced before the truck arrives at Domnarvets Jernverk, and is delivered by the weighing personnel as the truck passes through.

Production Planning and Control

The objectives are, among others, to:

- Improve the outdated system used on the IBM 360/30;
- Install display stations at the planning offices for direct access to essential data bases, such as customer order and production order data bases;
- Improve the charge planning;
- Improve control and management of the inventory for strip and heavy plate material;
- Improve production reporting.

Production Planning and Control Subsystems

The current Domnarvet information system (DIS) includes the following subsystems: (Figures 2 through 5 refer to material requirement planning and material distribution planning processes.)

- Material requisitioning from the finished product plant--e.g., combining customer orders with slab/billet orders, storing, modifying, and deleting slab/billet orders, and printing out planning documents for rolling mills and steel making shops;
- A steel ordering system for ingot casting;
- A continuous casting scheduling system that prints out slab orders for continuous casting, reserves material for continuous casting, prints out slab orders reserved for continuous casting, and stores cast orders for material to be used in continuous casting;
- A steelworks scheduling and management system--from furnaces, to teeming bay, to the shears, etc.;
- An analysis reporting system for recording steel grade and chartest specifications, listing steel grade and clear text specifications, analyzing, reporting, and controlling, reporting daily on analysis results, and controlling analysis results over a longer period;
- Slab yard control requiring a heavy plate mill and wide strip mill scheduling system for inspecting reports and printouts of inspection results, printing out stock lists, rescheduling, creating rolling mill schedules and reports, producing reports, and printing out work order documents for heavy plate mill;
- An ingot stock control system for recording movements in and out and listing ingot stocks.

Continuous Casting Scheduling System: A description of the former system will make it easier to understand the improvements to the planning system required for these installations. In the former system there were lists of slab orders for continuous casting, from which slabs were picked, noted on order forms, and sent to the cutting station in the continuous casting. Each form contained suitable to average cast weights. When the cast was teemed, it sometimes weighed too much and there was not enough slab on the order list. Slabs then were stored in stock. If the cast weight was too low, batches of slabs remained on the list and they were not reordered until the next day. Using this order system, which included manual selection of slab, the slab yield from continuous casting was not always satisfactory. The shear operator sent regular reports concerning cut slabs.

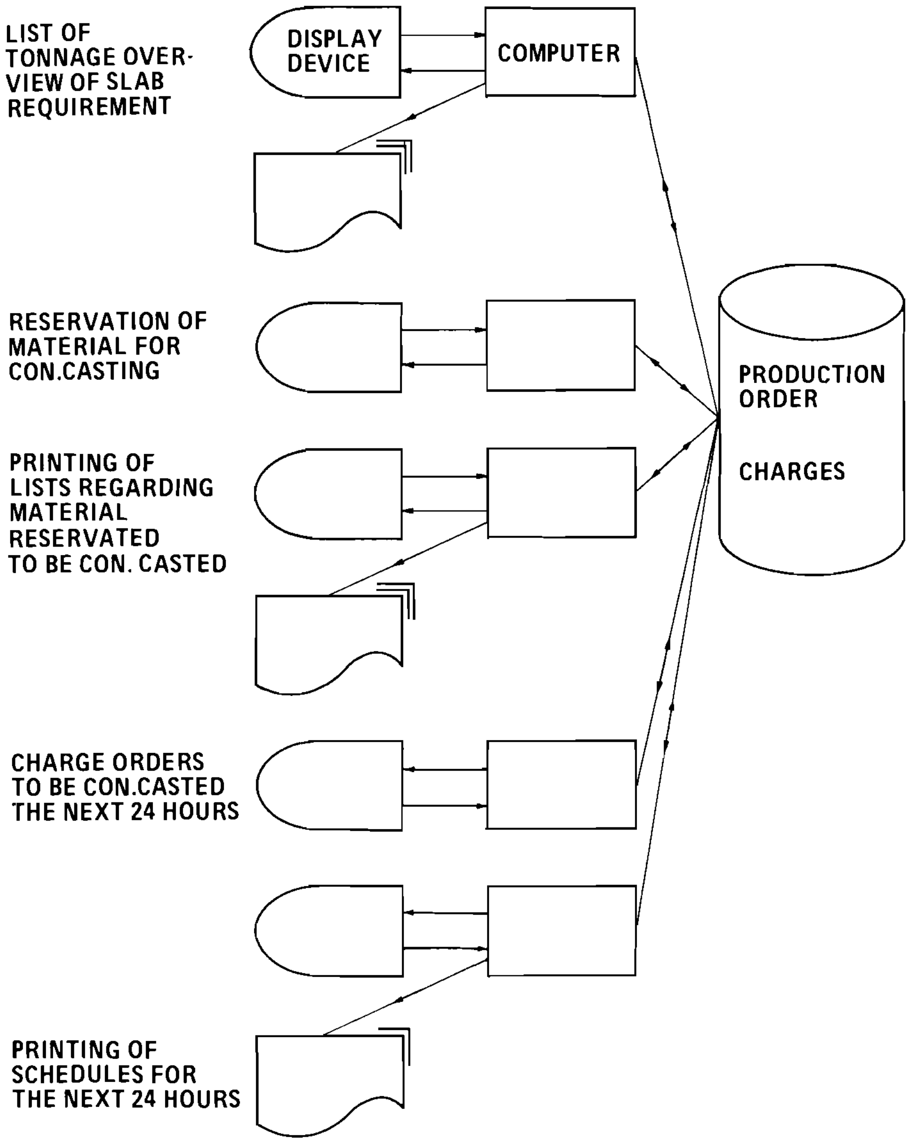


Figure 2. Charge planning for continuous casting.

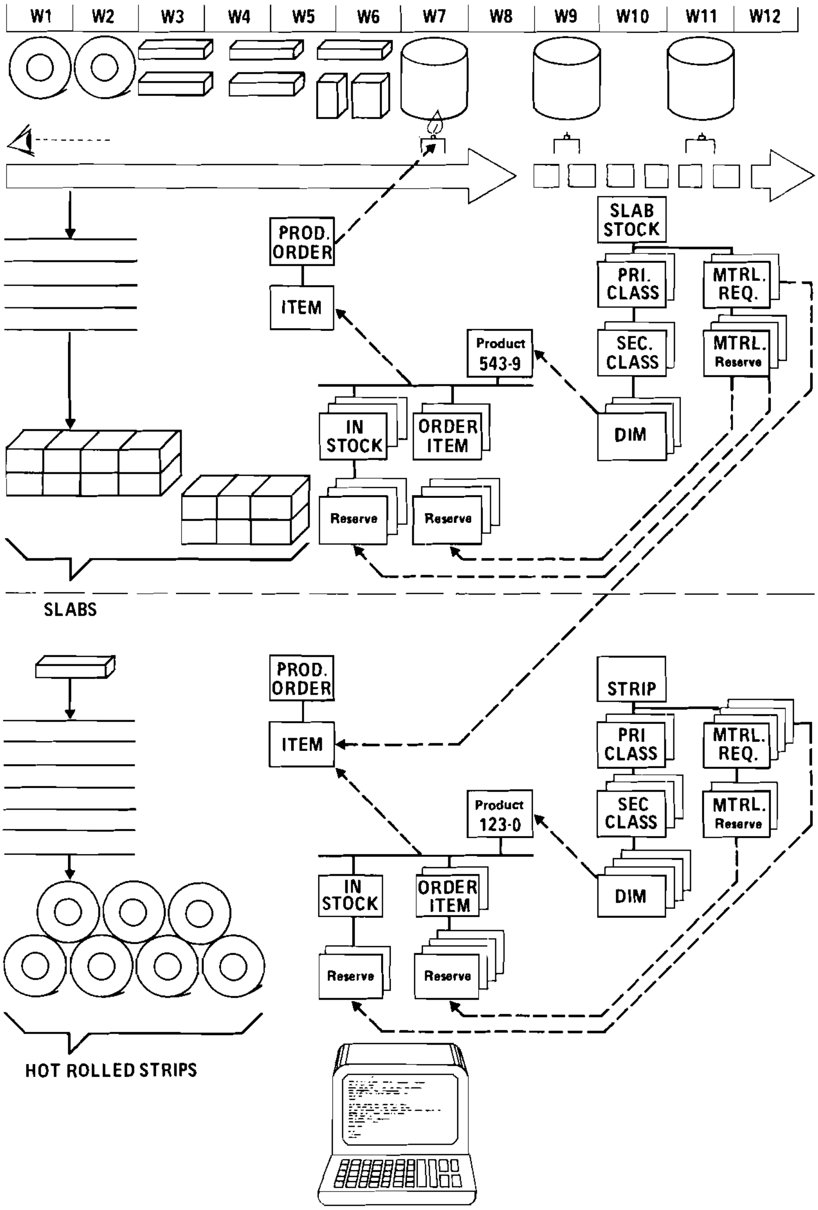


Figure 3. Material requirement planning.

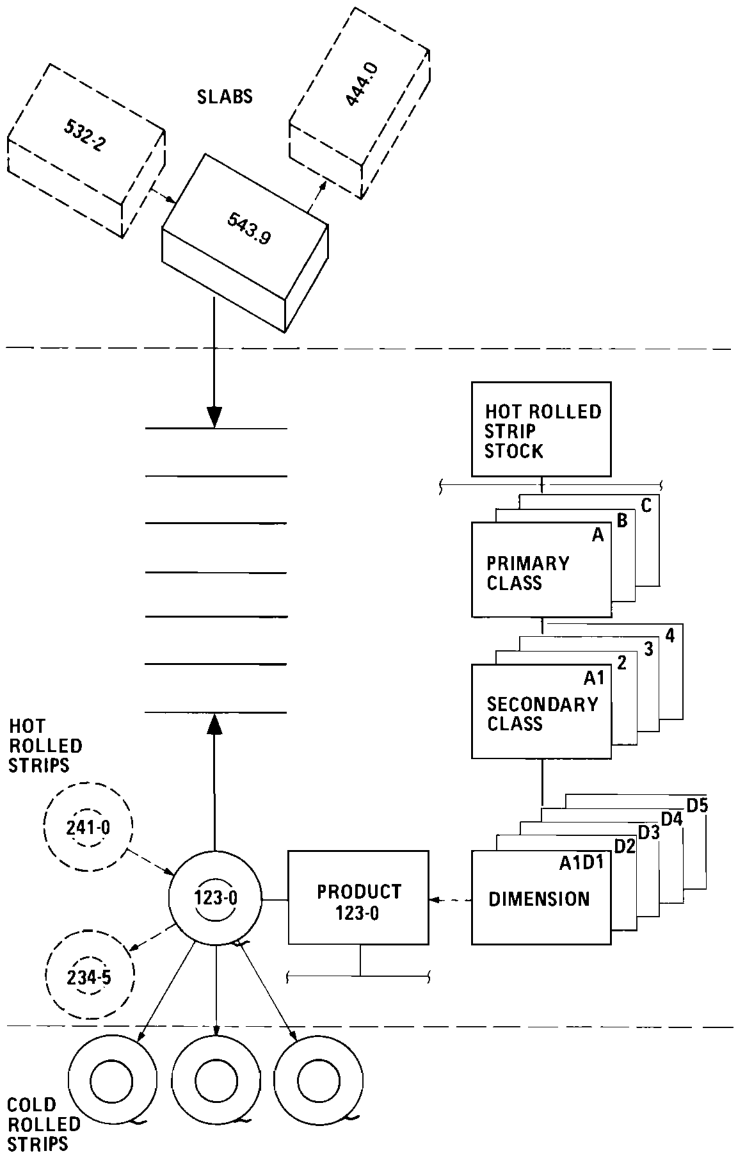


Figure 4. Product classification.

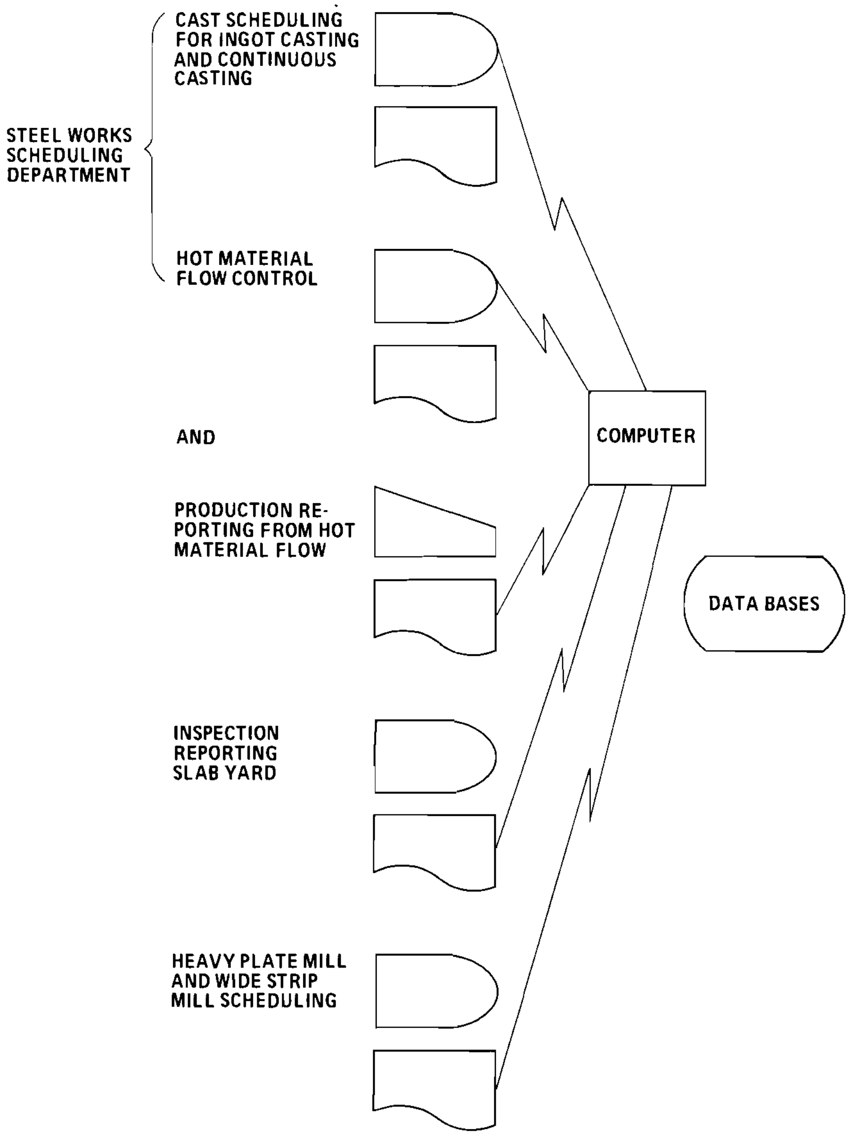


Figure 5. Material planning and tracking.

In the new improved planning system for continuous casting, these disadvantages have been eliminated. Planning for these facilities involves the use of a list of slab requirements. A request may be made for the list of slab requirements on which batches are arranged according to grade and rolling week. Other restrictions affecting the choice of casting mold to be used on the continuous casting strand can be added e.g., the weight of the slab, the width of the plate for producing heavy plates, and the width of strips for strip production. Details about the quantity of slab requirements of each grade can be obtained from the list of slabs for continuous casting of a specific mold. This information indicates the order requirements for the grade and mold concerned, broken down according to length and rolling week. This is transmitted to the display station, which reserves the materials for the casting operation.

Another advantage of reserving slabs is that the cutting list is obtained rapidly once the result of the continuous casting is known. Because a search does not have to be made among all production orders, the number of orders concerned is smaller. Slabs to be reserved can be selected on the reservation display. The maximum and minimum slab length limits must be indicated along with the desired rolling period. In this way, smaller amounts of different grades, considered as a single grade in the steelworks, can be produced. By making reservations for each grade in several stages, orders can also be assigned at different priority levels.

As for slab length, in general, only orders having a slab weight with lengths in the upper portion of the authorized range (1780 to 3000 mm) are chosen. Slab orders for the mold in question, leading to short batches, are either cast in another sized mold, or cast as ingots. In the latter case, they can be better sized during rolling.

When the reservation is made, a temporary file is set up in which the type of materials, casting mold, and grade are entered. The production order number and grade indications are given as well. During reservation, the number of orders reserved is subtracted from the number of production requirements. When the size of the mold is changed, the reservation can be cancelled by means of a specific transaction, and the new mold can be reserved as described above. It is possible to simultaneously have reservations for several molds for each continuous casting strand.

When recording cast orders for continuous casting the lists of reserved slabs can be used. Each list indicates the total quantity of slabs. These lists have also been designed for use when the system has a breakdown. In this case, cutting instructions should be sent by telephone to the shear pulpit.

Cast orders concerning grades for which materials have been reserved are given in the production form (list of cast requirements). Shift planners can request information about grades for which materials have been reserved and the quantities of these materials planned for the cast orders. They can also request an indication of the quantities that have been cut on the shears.

Normally, cast orders set up by day planners, allowing for reserved materials, are sufficient for the coming 24-h period. However, it may happen that the cast of a certain grade is poor and does not yield the expected tonnage of slab. If the shift planner is aware of the urgency of orders for this grade, he can send an additional cast order to the furnaces.

The major difference in planning ingot casting and continuous casting is in the moment at which slabs are allocated to orders. As for ingot casting, this is done at the time of cast orders, whereas for continuous casting this occurs only when the casting reports have been received from the continuous casting strands.

Rolling Mill Schedules and Reports

The creation of rolling schedules for a wide strip mill and a heavy plate mill used to be a complex manual job. A choice had to be made from among some 2000 to 3000 slabs in stock, according to a well established priority list, in order to respect the rolling cycle. Specific cycles had to be considered for a heavy plate mill and a wide strip mill. Other constraints in the operation of a wide strip mill included the maximum number of steps when changing thickness, the maximum length for a single width, the impossibility of combining certain grades, and the fact that certain products require rolling in special rolls.

Computerized preparation of rolling programs is carried out in the following way. The selection and sorting rules are first indicated on a display station showing the order; the selection rules indicate the stage in the cycle and whether or not only certain grades or a certain type of order, etc. are required. The sorting rules indicate whether the cycle concerned is in its upward or downward phase. The result of this preparation stage is a rolling schedule scheme which is listed on an on-line printer. This list is examined and any deletions, additions, or modifications to the sequence are noted. The next phase is a request for displaying the list under preparation, by using the reference number automatically assigned to the rolling schedule at the beginning of the preparation. The screen can then be modified with the changes noted on the previous rolling schedule proposal. Once all the modifications have been carried out, a request can be made to get the final rolling schedule. This schedule is then copied a number of times and distributed to the slab yard stock taker, to the reheating furnace loader, to the rolling mill personnel, etc. For the heavy slab mill, a work order (VK 2) is also prepared. By referring to the rolling schedule number, a request can be made for the display of all work orders that have not yet been distributed. Work orders are also distributed when the planning department receives the inspection report. At that time, a request can be made for the work orders of all the slabs included in the inspection report. This is done by indicating the report number. Later on, work orders of the rolling schedule are examined.

When the slabs have been rolled in accordance with the rolling schedule, part of the list distributed throughout the plant is returned to the planning department where it is completed with notes as to the slabs entered in the reheating furnace, slabs that have been sent back to the slab yard, and slabs that have been scrapped. For wide strips, the weight of the coil is indicated as well. In this way, reporting is possible on which slabs have been rolled. By means of the list number, the screen can be requested to display the list which corresponds to the current report. At present, no other report on original plates and wide strips is made after the rolling report.

Data Base Descriptions

At present, there are 22 data bases in the DIS system. The linkages of the most important data bases are shown in Figure 6 which has been simplified in order to give a picture of the central role played by the customer order data base.

There are actually two *data bases for customer orders:* the first for information common to large parts of an order in the so-called order data base, and the second for information that frequently varies among the items in the so-called order item data base. There has always been a file for orders, which formed the starting point of our planning routines. This information remains, and the addition now made consists mainly of clear text lines of variable length. Formerly, this information was difficult to accommodate in records of fixed length. Both data bases are HDAM-organized, with orders, or orders and items, as keys.

The *data base for production orders* reflects the manufacturing requirements for each stage of production. Subsequently, the requirements are switched backwards and forwards in the chain. The data base is HDAM-organized, with a production order number as key.

The *data base for storing finished products* fulfils several purposes. It contains the balance for all products for which orderly bookkeeping is required, and also information on orders tied to existing material and on those to be delivered from future production. Part of the stock is made up of standard stock consisting of products for which has been promised direct delivery. This part is now managed and controlled more accurately, by defining various stock-management parameters relating to reorder points, minimum production entries, etc. These parameters then control the generation of stock replenishment orders.

A product in this data base can be reached in one of three ways:

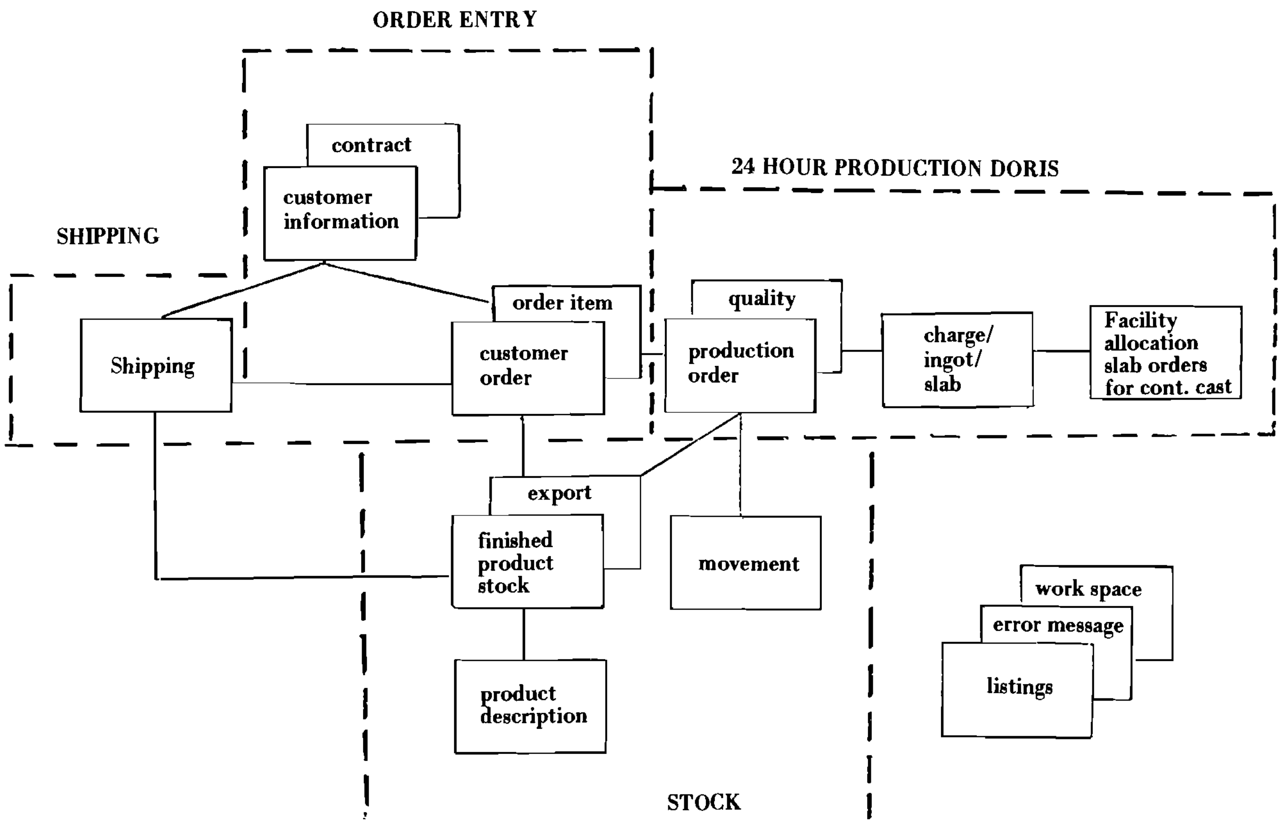


Figure 6. DIS - Data Bases: Main application usage.

- If the order item number of an earlier order for this product is known, this order item number can be employed.

- If a new product is created, a new product number is created and printed out on stock lists; later this can be used as reference.

- A new concept for product identity has been created, consisting of a four-digit code, which leads to a rough product division. The code, in turn, is the key to a variable sequence in which concepts such as length, width, thickness, quality, profile, color, and type of plastic can be entered. An inquiry to the data base is started with the four-digit code, and the answer is a reply with variables to be filled in for the product. After filling these in, a reply is received on the display screen showing the balance of the article. If, for example, a variable length for a product is possible, an inquiry may contain "up to and including" and "as from" a certain length. This also applies to other parameters in the product identity. The data base is HDAM-organized with the product identity as key and with the two other inputs maintained via cross-references.

The *data base for charge-ingot-slab/billet* entries are made by the automatic or manual charge combination that takes place in the system (Figure 7). Thereafter there is feedback to the system from steel furnaces, teeming bays, reheating furnaces, and the slab/billet yard, providing a record of production obtained. From this data base, the slab lists and rolling schedules for the wide strip mill and the heavy plate mill are then selected. The charge analysis results are also reported to the system, when this information can be used in planning. A charge remains on line in the data base while there is one slab left in the stock; thereafter the information goes on to magnetic tape. The data base is HDAM-organized, with the charge number as the key to the root.

The *data base for shipped material* gives an image of a shipment, which is defined as a delivery to the same place on the same occasion. A data base entry is made when a shipment is reported and has a life of about two months. The data base is used as a basis for putting shipping specifications and freight bills on printers located at the shipping department. The most important use will be as a basis for quicker and more automatic invoicing. The objective is to invoice on the same day as goods are sent or, at the latest, on the following day without having to increase existing staff. The data base is HDAM-organized, with the shipping number as a key.

The *data base for customer information* contains information about customers. All customers are registered, and a new order cannot be accepted by the system until the customer concerned is accessible in the data base. Special conditions concerning

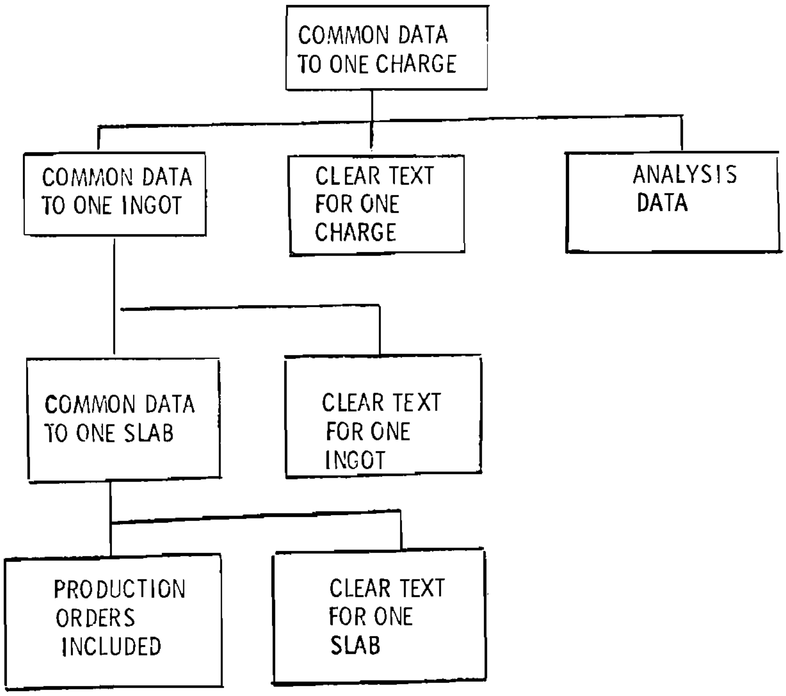


Figure 7. Data base for charge ingot slab.

customer deliveries are registered, and they are easily accessible for order processing. A reference to the order data base is available for all the customer's orders. The data base is HDAM-organized, with the customer number as key. An alternative way of reaching the root segments is via a cross-reference with a customer abbreviation as key. This is the normal way for an operator to reach the customer information.

The original DORIS system had a 15-digit direct-organized file. Upon consideration, we decided to create one *data base for the majority of files* rather than create a data base for each DORIS file. The key to the root is made up of the old DORIS key and a name for the dependent segment in which we are interested. The dependent segment has the same length and appearance as that of the DORIS record. Basically, the file design in the DIS is the same as that used in the DORIS system. The data base is HDAM-organized.

IMPLEMENTATION OF DIS

The time schedule for the integration of the DIS is shown in Table 1.

Table 1. Implementation of Domnarvet Information System.

May 1972	Domnarvets Jernverk decided to opt for a highly integrated information system (DIS-Domnarvet Information System) for production, administration, and marketing services. The plan was for the use of the latest data processing technique 24 hours operation, seven days a week.
October 1972	Decision to implement application subsystems: order entry, inventory control system for finished products, shipping, production planning and control including DORIS.
October 1973	Detailed system design of the subsystems.
November 1974	On-line start using customer and contract data bases in the order entry department.
February 1975	On-line preparation of the first product group. Successive start-up of the inventory control and shipping systems for the same product group.
May 1975	The new production planning and control system becomes operational. It includes functions for planner-computer (3270) combination at charges from the actual slab requirements.
December 1975	Order preparation, inventory control, and shipping system for all product groups operational.

Education

Over 200 people in various positions have been trained in DIS. About 100 of these were given courses in introduction to data processing, concept and features of IMS, and detailed application courses for terminal operators.

Availability

High system availability is essential to the successful operation of the steel plant. Domnarvet has designed and implemented several means to accomplish 24-h operation of the system. The target is to provide uninterrupted terminal service with a maximum interruption of 5 to 10 minutes. Availability considerations affect many areas of the data processing (DP) shop, including hardware, software, operation, and application development.

Configuration

From the viewpoint of system development and central processor utilization, the most important decision was to operate in a dual manner that allows testing of new applications or modifications on one system, while allowing the other system to handle the 24-h production load. In addition to this back-up capability the hardware configuration was designed to provide flexible alternative connections so as to reduce the number and duration of system outages in case of failure of an individual component. Examples of this hardware include the use of power isolation, string switching, and two channel switches for most I/O services.

Software

The use of IMS/VS software has been very successful. Important functions are the program isolation feature which supports automatic back out in case an application ends and thus reduces the operational activities to restart the system. Equally valuable is the "Write-Ahead-Log-Tape" feature of IMS/VS which ensures logging of all data base changes prior to performing the update.

In addition to these standard IMS/VS software capabilities, Domnarvet has included a minor modification, i.e., logging the last three log records on disk thereby helping to overcome recovery situations.

Recovery Procedures

Failure situations put heavy stress on operators, with most new errors being caused by improper operational (human) reaction. The recovery procedures were therefore designed to simplify the steps for recovery. A recovery handbook is at the operator's disposal and contains standardized procedures for various failure situations. The operators are highly trained in the use of the procedures. As a result, systems analysts are rarely needed to solve abnormal situations.

Planned Stop of 24-h Operation

To ensure a high responsiveness for recovery of messages and data bases, the IMS/VS system is stopped periodically to copy on tape the current status of this information. Also, during this period application modifications or new applications can be incorporated into the production system.

Considerable design and planning efforts have been made to limit the duration of and the human intervention in a planned stop. As a result, planned stops of about 10 minutes, are made five times per week, during which time the 24-h production data bases are copied. Reorganization of data bases has been done twice in a seven month period, the need for this being kept low by data base design considerations.

System Administration

During the implementation phase daily operations were monitored by a system administration group consisting of three people. Their function was to record and follow-up all operational problems, to coordinate modifications and changes to be included in the system, and to supervise the machine room. Their activities included reading the console sheet every morning and checking the corrections of the daily procedures. Weekly meetings were held, together with IBM staff, to review the current status. As a basis for discussion, the administration group has responsibility for preparing a weekly status report containing, for example, information on the most serious problems encountered, and system modifications done.

RESULTS OF IMPLEMENTING DIS

Users' doubts (and fears) when faced with a system in operation decreased as they became accustomed to data processing practices. There were many who, up to actual start-up of the operation, were highly critical but, after one month, became enthusiastic supporters of the new technique. A number of activities were simplified, operations increased in speed and quality over those procedures that required more manual handling.

Still there were complaints, e.g., the printers, in particular the 3288, were too noisy; the keyboard cathode ray display stations could not be set on conventional office furniture and required special adaptation of their own; the displays on the screens could be troublesome, often requiring a change in room lighting.

A major investment involving several subprojects carried out simultaneously and the extensive upgrading of the operating system (OS/VSI, IMS/VS--the first test site located outside the United States) have resulted in an ineffective effort. We would otherwise most likely have had to carry out tests with very simple applications to learn, with the help of IBM, how to use data bases and how to communicate with data through cathode ray display stations.

The customer department, which pays for the work carried out, must be in the forefront and have a managerial position. The user works in a project group and responds, among other things, to program and training modifications within each group. Technical specialists are assigned within each group, and together with the technical group, are responsible for the design documentation and standards applied to data bases and data communication.

Training of users and DP staff has been more extensive than planned. Data techniques cannot be solely placed within a technical group, and the best result will be obtained if the technical groups and the specialists have knowledge of the others' tasks and jointly design the data bases and data communication system.

Initially, availability was hampered by several circumstances, e.g., power failure, air conditioning breakdowns, and normal change over problems caused by the newness of the system. As more experience was gained, availability was improved by faster handling of recovery situations. For the second half of 1975, an overall availability of 97% was achieved, including planned stops.

About 700,000 DL/1 calls are executed daily, 90% of which are GET-calls and 10% UPDATE calls; 60% of all transactions modify data bases. The number of transactions per day averages 13,000 with about 80% during business hours (8.00 to 17.00). So far, a peak rate of 1 transaction/sec has not been exceeded.

The transaction load is handled on a priority basis in four partitions, to ensure satisfactory response time. These are:

- DORIS (production) Partition 1
- Order entry, inventory, shipping Partition 2
- Fast listing and long transactions Partition 3
- Long listings Partition 4

The system usage by application area is shown in Table 2.

Table 2. System usage by application.

Application Area	Transactions (%)	DL/1 Calls (%)
DORIS (Production)	46	81
Order Entry	28	7
Stock	14	5
Shipping	12	7

The response time is a function of the system/line loading and processing/transmission time of transactions. Most transactions in all partitions are handled in less than two seconds, while output transmission depending on line speed varies from 2 to 10 seconds.

Central processing unit (CPU) utilization averages around 30 percent, during peak load 60 percent utilization can be reached (370/158).

CONCLUSION

Based on the systems described above, we believe that all the conditions are present to further develop the production planning and control system for the steelworks up to the finished product.

The actual costs have not as yet been computed (system start-up is still too recent), but a rough estimate shows the savings realized through rationalization of the system, as estimated. An increase in the central processor capacity over what was originally planned has, however, proved necessary. The number of CALL/TRANS occurrences, for example, exceeds 30, whereas forecasts only provided for 5 to 10.

During 1976, projects for similar systems will be started up in the fields of heavy plates and coated products. Future developments are planned including maintenance of order entry, inventory control, and shipping systems placed the responsibility of a project group whose job will be to develop invoicing and marketing applications.

Discussion

A number of questions were raised about the reliability of the system discussed in the Holmberg paper. Holmberg pointed out that the reliability of the system was 96.7 percent. In 1976, for example, there were 502 stoppages. In one case there were 2104 runs; 0.7 percent were planned stoppages for hardware installations, and 0.67 percent were planned stoppages for software installations. In other instances, there were five stoppages in a week, approximately one stoppage per day. About ten minutes are needed to get the system into operation after a stoppage. He emphasized that there had been no production stoppages owing to computer system failures.

Replying to an inquiry about the system architecture, Holmberg stated that it is a very centralized system with 25 different data bases. The system currently includes about 100 terminals. Domnarvets Jernwerk is satisfied with the present level of system integration, and every control unit in the plant has a spare line.

Discussion then centered on the organizational structure of the data processing (DP) departments in steel plants. It was pointed out that often either the system department or the DP department is under the control of the Finance Director. The implementation of an integrated system has an enormous effect on the organization and redistribution of "power" in companies--power being defined as knowledge and information. The president or the board of a firm often delegates power that perhaps should not be delegated. In this instance, the finance department will only have control not only over where information is distributed, but also over what information is generated.

Other problem areas were mentioned. An example was given of a "completed" system--i.e., a system that has been designed, programmed, and tested with real data but not implemented, and is not a single module. One reason for this has been the difficulty in getting the design engineering department and the technical and the systems departments to agree on a simple point like coding a material catalogue. After eight months of discussion, no agreement has been reached on a coding system.

Opposition to implementing integrated management systems can be very strong. Although a system may improve the economic performance of a firm (perhaps to an extent that may not even be quantifiable), this fact is not important to many of the personnel. An example of another factor that must be considered involves the setting up of a data base. In the process of computerizing technical information, errors may be uncovered that had gone undetected for some time under the manual system, and understandably, managers may be unwilling to see these problems made public.

TOPS: Total On-Line Production Control System In the Kashima Steel Works

T. Toyoda and H. Tokuyama

INTRODUCTION

We named our system TOPS, because we aimed to make a Total On-line Production control System. I will give you the general picture of TOPS, and then describe the system of the heavy plate mill along the flow of the production processes.

Sumitomo Metal is one of the five leading steel companies in Japan (see Table 1). It produces about 13.4 Mt of crude steel a year. It has five works, three of which are integrated steel works; Kashima is the most modern (see Table 2) and is located on the coast facing the Pacific Ocean, about 100 km from Tokyo. It produces 7.4 Mt of crude steel a year, along with 11.5 Mt of heavy plates, U and O formed large size welded pipes, hot and cold strips, butt welded pipes, welded light gauge shapes, and large shapes.

Table 1. Leading steel industries in Japan in 1975 (million tons per year).

Company	Crude Steel Production
Nippon Steel Corp.	32.5
Nippon Kokan K.K.	14.7
Sumitomo Metal Industries, Ltd.	13.4
Kawasaki Steel Corp.	13.3
Kobe Steel Works, Ltd.	7.7

Table 2. Sumitomo Metals and its works in 1975 (million tons per year).

Capital ¥82,976 million ($284 million)

Employees 32,656 (Oct. '75)

Works	Pig Iron	Crude Steel	Main Products
Osaka	-	0.3	Castings & Forgings
Amagasaki	-	0.1	Tubes & Pipes
Wakayama	6.1	6.1	Plates, Tubes, & Pipes
Kokura	1.9	1.8	Wires, Rods, & Sections
Kashima	5.6	5.1	Plates, Pipes, & Shapes
Total	13.6	13.4	

The main facilities of the Kashima Works are as follows: three blast furnaces of the 4000 m^3 class, where the first furnace is currently under repair. Two steelmaking plants, one of which has three vessels capable of 250 t per heat. The other has two vessels of the same capacity. Two continuous casting machines and a universal slabbing mill produce slabs for the heavy plate mill, the hot strip mill, and the large shape mill. A certain amount of blooms for the large shape mill is produced in the Wakayama Works.

COMPUTER NETWORK

Figure 1 shows the outline of the computer network of our company. Computers of the Head Office and the Works are connected with the data transmitting lines to each other, and the data are transmitted once a day.

Daily operational systems consist of the:

- sales system of the Head Office which processes the information about order entry, order status, and submitting bills, and
- production control system of the Works which performs production planning and instructions, process control, and actual data gathering.

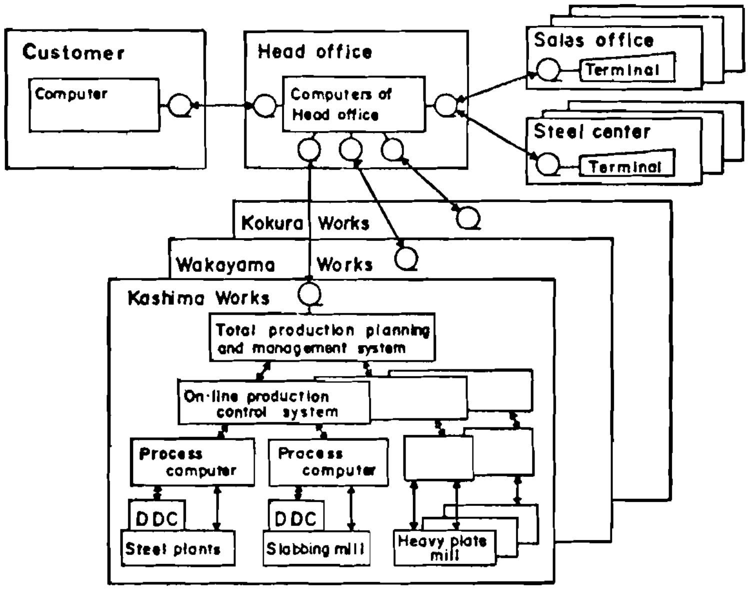


Figure 1. Computer networks.

These systems are supported by the management systems that process the information about purchasing, finance, cost accounting, personnel, and payroll (see Figure 2).

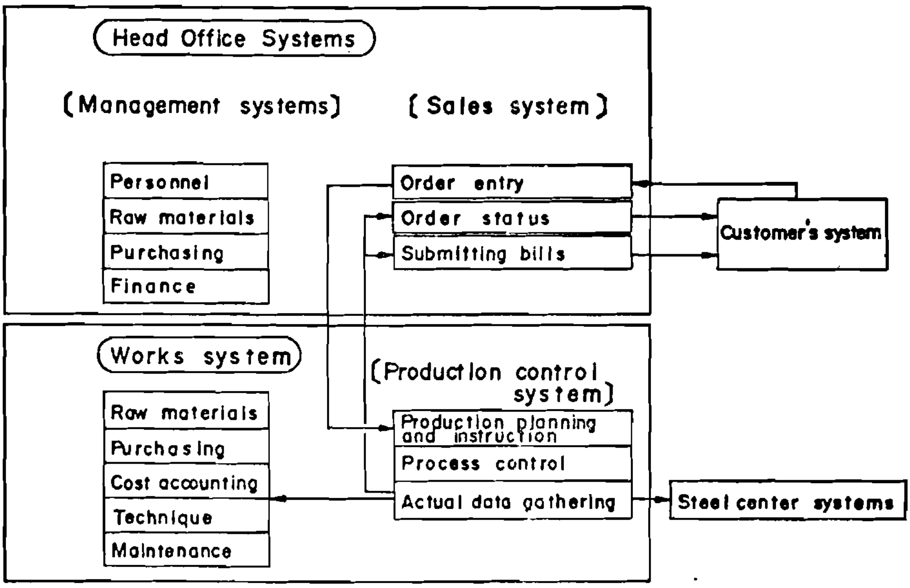


Figure 2. Functions of computer systems.

When the Order Entry System receives an order from a customer (see Figure 3), the system checks the specification of the order, and decides which Works is better able to produce this order regarding both manufacturing standard and mill load. Then the order information is transmitted to the Works. The Order Status System monitors the status of production progress in each works. The Shipping and Bills system submit bills when shipping information is received from the Works.

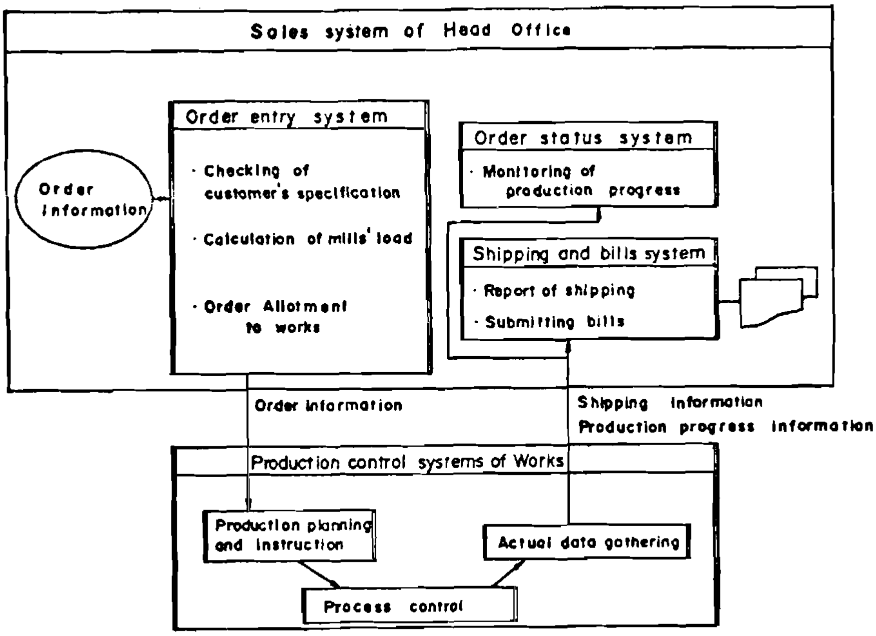


Figure 3. Sales system of Head Office.

CONFIGURATION OF TOPS

TOPS has three levels of hierarchy and these control all the flow of information and materials from order entry to shipping (Figure 4). Level 1 is the Production Planning and Management System, which consists of the following subsystems: order processing, production planning, production scheduling, shipping, reporting, cost accounting, and others. Level 2 is the On-line Production Control System whose functions are on-line operational instructions, rescheduling and actual data gathering, under linkage with the process computers. Level 3 consists of the Process Control Systems.

TOPS comprises six sets of data processing computers and 38 process computers (Figure 5). The system of the large shape mill has the most modern configuration.

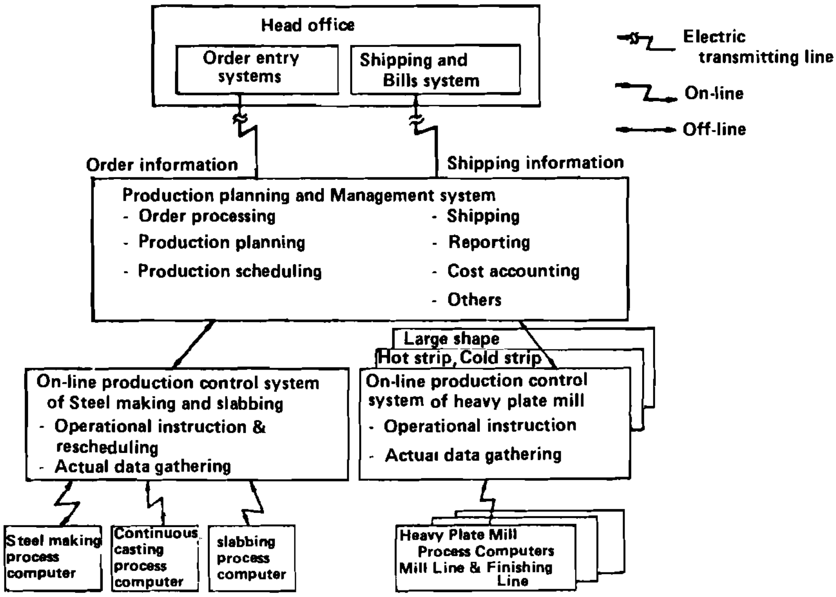


Figure 4. Tops of Kashima Works.

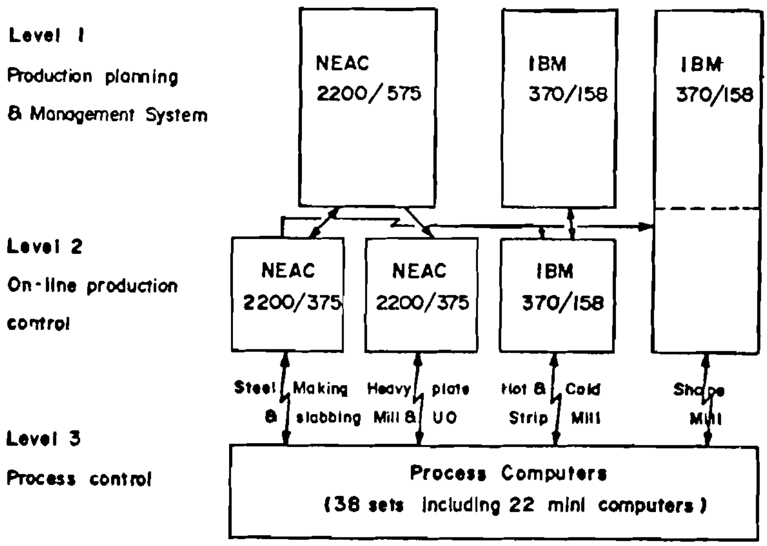


Figure 5. Computer configuration of TOPS.

In a modern steel works, facilities have become larger and larger. The number and varieties of orders have become greater, but the lot size of orders remains small. As the production process of steelmaking is of the breakdown type, it becomes very difficult to make a good production plan without the aid of computers. We have a short lead time coupled with a high throughput of modern facilities. Table 3 shows the lot arrangement problem of heavy plate production. To minimize surplus materials, the following items are essential: good sales (i.e. large lot sizes and many orders), good technical standards (i.e. flexibilities in planning), good operations (i.e. small allowance at the planning stage), and a good plan (i.e. flexibility to cope with changes in the actual operation). All these items, especially the last three, require a computer system (see Figure 6). As regards a good plan, we have endeavored to allocate orders logically to surplus slabs or to new heats. We established an on-line reallocation system to adjust for any change in actual operation, e.g. a misblowing in the basic oxygen furnace (BOF).

Table 3. Lot arrangement in heavy plate production.

	Heat	Ingot	Slab	Plate
Lot size	250t	25t	6-7t	2-3t
Constitution of lot	10 ingots	4 stabs	3 plates	-

Nos. of Order in Heavy Plate Mill

8000 orders/month

200 items/order - - - - - - - - - - -Items - Quality of material

2500 characters/order - Shape

- Dimension

(30,000 orders/order master file) - Delivery time

- Delivery place

- Production process

- etc.

PRODUCTION CONTROL SYSTEM OF HEAVY PLATE

Figure 7 is a diagram of the integrated production control system of heavy plates. I will introduce to you the functions of this system, going along with the flow of orders and materials from accepting orders to shipping products.

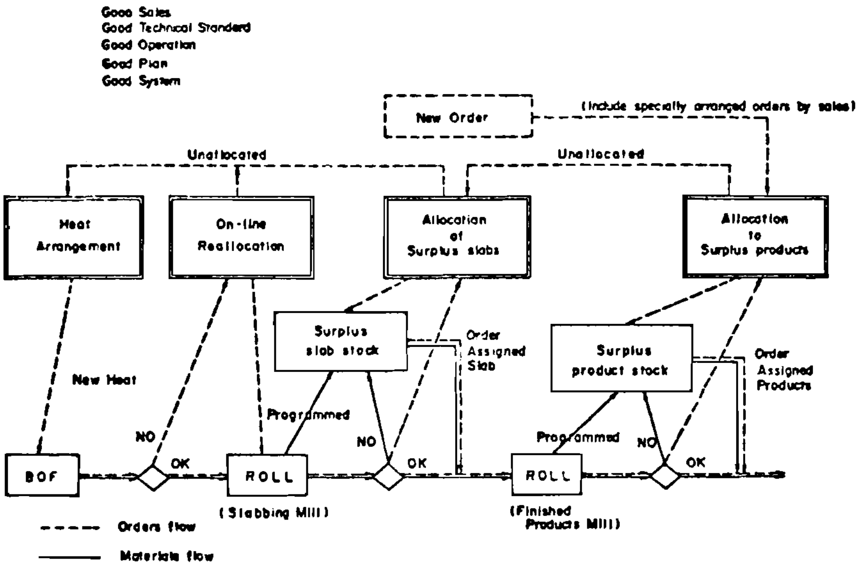


Figure 6. System to minimize surplus materials.

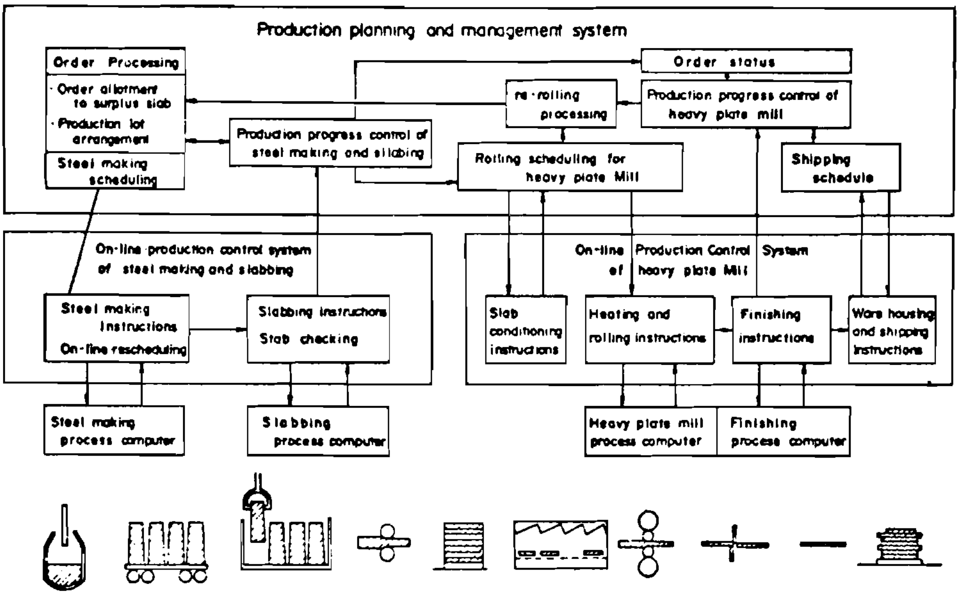


Figure 7. Schematic diagram of the integrated production control system of heavy plate.

Order Processing

The computer checks the errors in the specification of each accepted order, and in the case of no error and no special specification, decides the manufacturing specification of the order which consists of about 200 items (see Figure 8).

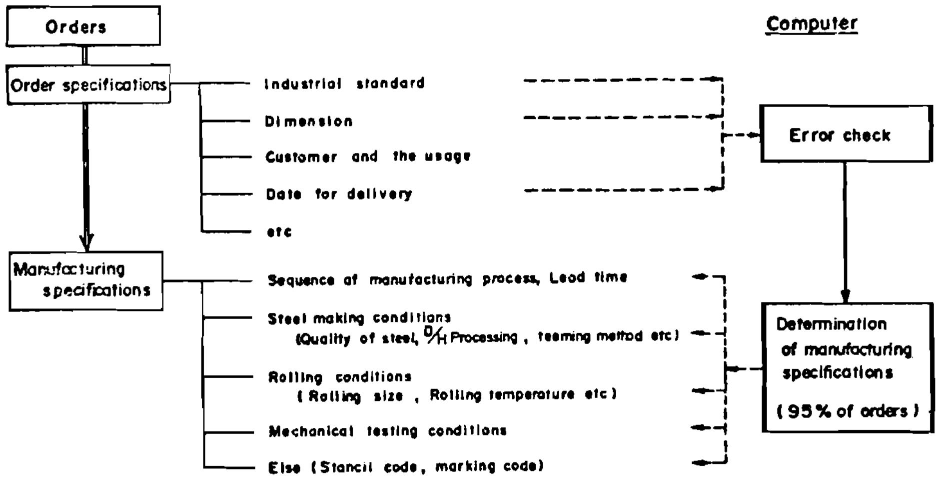


Figure 8. Order processing.

Order Selection

The computer checks the delivery date of each order stored in the order files, and decides which orders must be assigned to the daily production planning.

Order Allocation to Surplus Slab

Orders are checked against surplus products and slabs for quality of material, dimension, and yield.

Production Lot Arrangement

As mentioned above, the production process is of the breakdown type--the computer classifies orders and arranges them into heats, ingots, and slabs, according to quality of material, dimension, yield, productivity, delivery date, and so on. As this processing is critical for the efficiency of production, we will consider this production lot arrangement problem again later (see Figure 9).

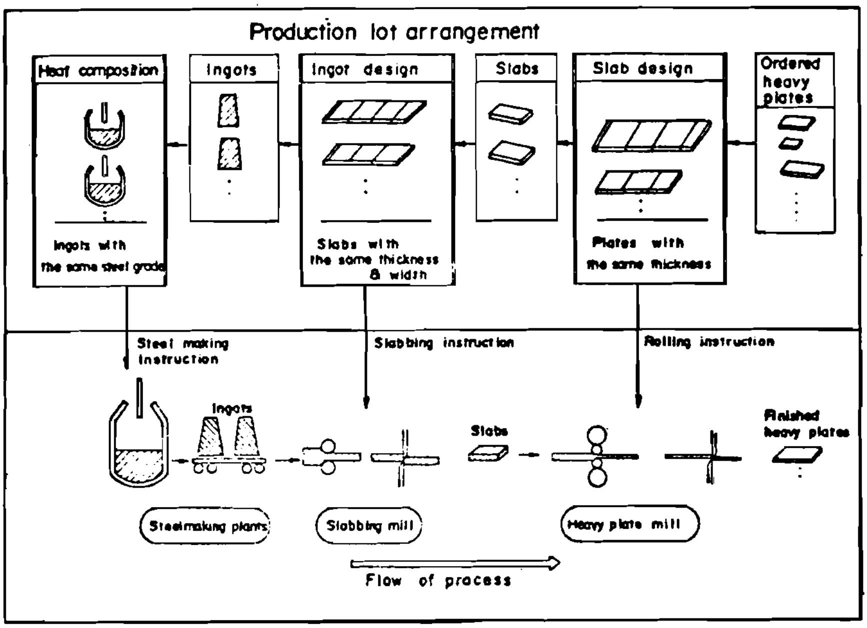


Figure 9. Production lot arrangement of heavy plates.

Steelmaking Scheduling

According to the production lots arrangement, the melting shop program is prepared by man-machine communication using the cathode-ray tube (CRT) in the control center.

On-Line Steelmaking and Slabbing Instructions

Operational instructions for steelmaking and slabbing are transmitted to process computers of both steelmaking and slabbing in accordance with the melting shop program.

Process Control of Steelmaking and Slabbing

The steelmaking process computer and the slabbing process computer are applied to both process and production control. The functions of process control are (for the steelmaking process computer) the control of amount of raw materials, end-point control of BOF, and steel composition control, and (for the slabbing process computer) prediction of ingot heating time, charging and drawing schedule of ingot at soaking pit operation, mill pacing, pass scheduling calculation, and shear gauge control. A finished slab is transported to the place in the slab yard indicated by the electrical character display.

On-Line Rescheduling of the Melting Shop Program

When the aimed steel grade is not obtained because of misblowing, the computer searches the melting shop program and reallocates the heat to other suitable orders in order to minimize surplus ingots and slabs. If the computer fails to find a suitable one, a request for human judgment is displayed on the CRT in the control center. Much improvement of the order-assigned slab ratio has been achieved by this means.

Slab Checking

The computer receives actual data of produced slab from the process computer and judges whether it satisfies the specifications or not. If not satisfied, the computer requests human judgment in the control center.

Production Progress Control of Steelmaking and Slabbing

The production planning and management computer receives actual data on steelmaking and slabbing once a day, and refreshes production progress status files. The orders for which specifications were not satisfied are fed back to the production planning for the next day.

Rolling Scheduling for the Heavy Plate Mill

According to the information of slabs produced for particular orders, a rolling schedule is made giving date for delivery of order, slab heating conditions, rolling conditions, and finishing conditions. Based on the rolling schedule, slab conditioning instructions are output at the terminals in the slab yard pulpit. After conditioning, the weight of the slab is checked to see if it satisfied the required amount or not. If not, the rolling schedule is modified, and rejected orders are fed back to rerolling processing. The rolling schedule involves rolling size, finishing and testing specification, and so on.

On-Line Rolling and Finishing Instructions

According to the rolling schedule, the on-line production control computer transmits rolling, shearing, marking, and inspection instructions in a timely manner to the process computers through the direct data linkage line.

Heavy Plate Mill Process Control

In the mill line there is one process computer, and in the finishing line two; all are linked with the on-line production control computer. Further in the mill line, there are two sub-computers exclusively for calculation of the draft schedule and another one for position control linked with the mill line process computer (see Figure 10).

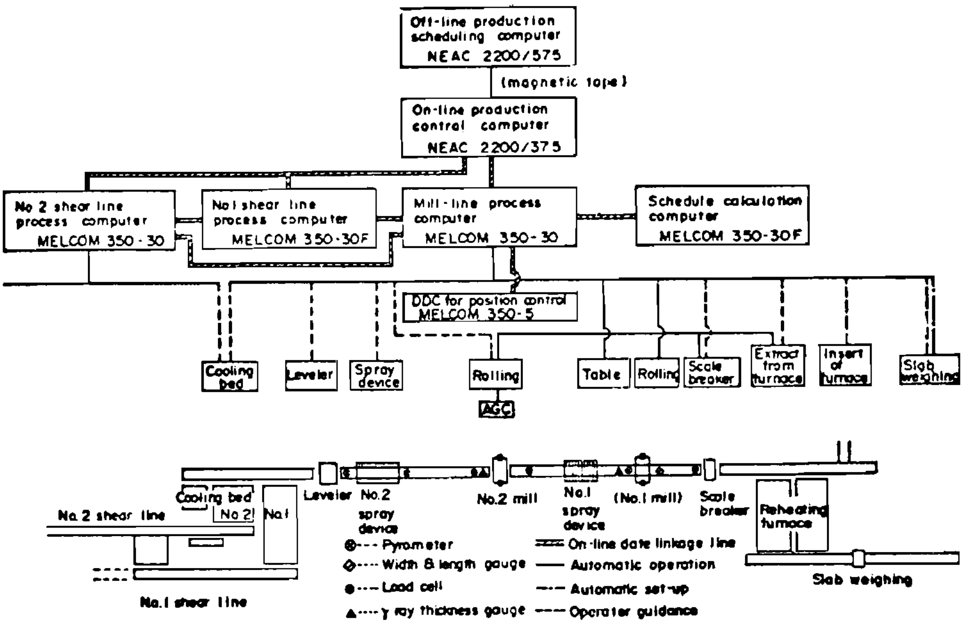


Figure 10. Computer control system (mill line).

Mill Line Computer

When the slab is positioned on the slab scale at the entrance of the furnaces, the function of slab tracking is initiated by the input of the slab identification number from the CRT key and then the process computer accepts all the data required for process control and operating instructions from the on-line production control computer. The progress of the slab is tracked by hot metal detectors from when it appears out of the furnace, until it arrives at the cooling bed. The computer transmits the data gathered in the mill line to the finishing line process computer. The instructions for operations in the mill line are all performed by the process computer on line.

The tracking conditions and the operating instructions can be confirmed by the operator with the CRT of the pulpit and the tracking board. Process control functions of mill line computer are width control, thickness control, flatness control, and automatic reverse rolling.

Finishing Line Computer

At the finishing line of the plate mill, the series of works are processed including dimension measuring and marking, cutting or flaw inspection of the plate. The finishing line arrangement is shown in Figure 11. The finishing line computer receives the operational instruction corresponding to the plate rolled in the mill line from the on-line production control computer.

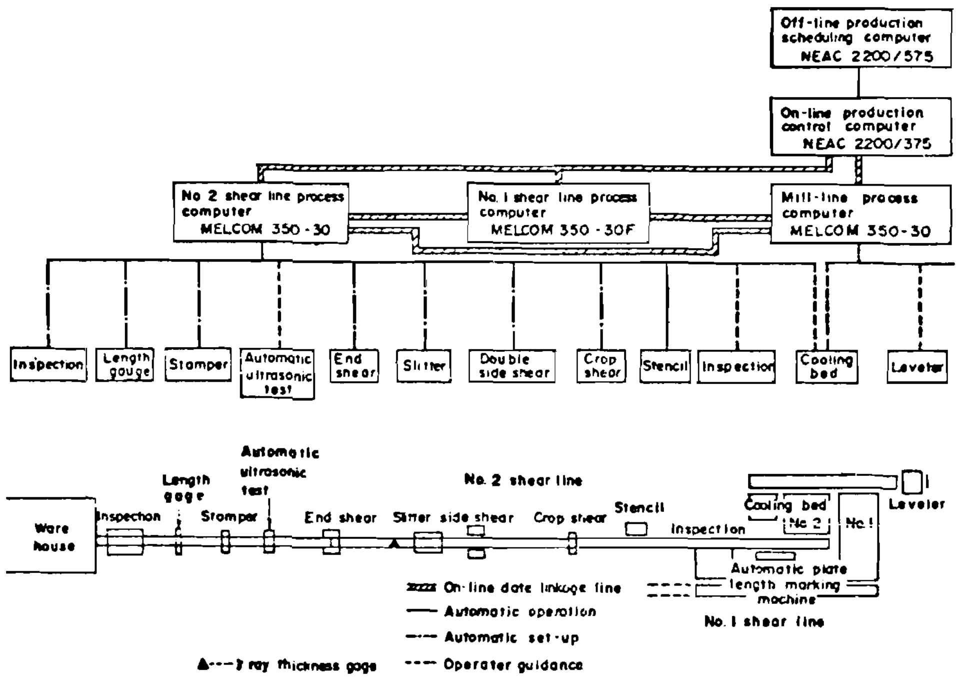


Figure 11. Computer control system (finishing line).

The plate rolled in the mill line is next cut into several sheets of finished products, the cut length or marking of each piece is different so tracking in the finishing line is more complicated than in the mill line (see Figure 12). For efficiency and man-power saving in the finishing line, we have developed the automatic tracking system by computer. With a color CRT and indication board at each pulpit of the finishing line, the arrangement is that the computer issues timely instructions to the particular work pulpit where they are needed.

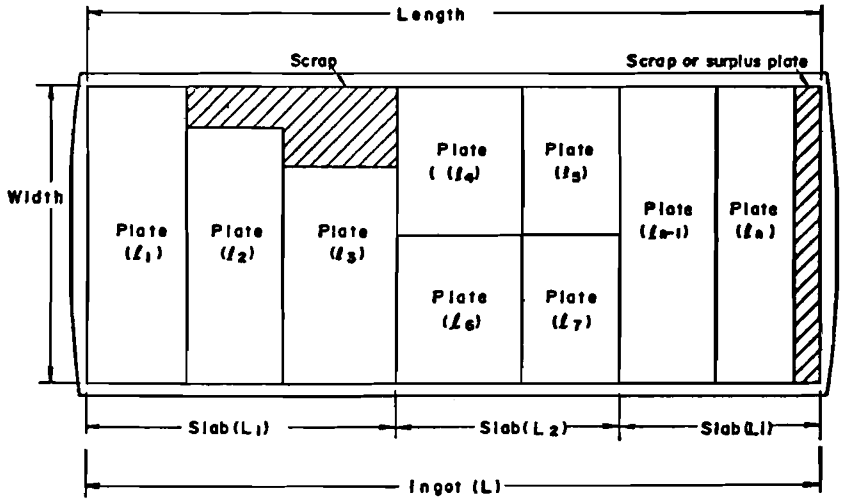


Figure 12. An example of ingot-slab design.

Automatic Plate Length Marking

The plate, rolled in the mill line, is next cooled on the cooling bed and transferred to the shearing line. For cutting the plate into the finished products (in sizes as ordered), the size is first measured and marked; conventionally, an operator marked the position to be cut with chalk for each individual piece of the order. Now this work has been automated by the automatic plate length marking equipment shown in Figure 12. In brief, the traveling cart incorporating the traveling position-setting equipment and marking spray travels to the marking point according to computer command. The accuracy of position setting of this traveling cart is within 20mm. The computer receives from this equipment the effective length and determines how many pieces of the product in the required size can be obtained from the as-rolled plate; it performs the marking.

Automatic Stenciling

On the marked-off as-rolled plate, the stenciling (of customer's name, dimensions, standard, etc.) is performed on each piece of the product automatically. The equipment compiles the stenciling pattern according to computer command and cuts the pattern on paper. The stenciled plate is cut into the piece-plates by the crop-, side-, and end-shears according to the conditions set by the computer.

Automatic Stamping

Next comes the stamping on each piece ordered. This work is done by an automatic stamping machine. This equipment selects the letters in accordance with the command from the process computer.

Automatic Inspection

The finished product, cut in the shearing line, next passes through the automated inspection process. This is effected to a great extent by the close combination of various inspection equipment with the computer.

Ultrasonic Flaw Detection: The plate dimensions and flaws are inspected by the automatic ultrasonic flaw detection equipment in which the detection elements are arranged at 100mm pitch in the cross-wide direction above the line. The computer logs the inspection.

Plate Thickness Inspection: This, the center and the edges, is measured throughout the length with the two units of the gamma-ray thickness gauges which are also linked with the computer. The computer notes from the gamma-ray thickness gauge the variation of the plate thickness and judges the plate thickness inspection.

Plate Width Inspection: Along with the command for setting of the cutting width of the side shear, the computer accepts the actual value of the width to confirm whether or not the plate is cut correctly.

Plate Length Inspection: Each piece of the plate has its length measured with the touch-roller type length gauge, which is fed to the computer for judgment. When the inspection of a plate is completed, the process computer sends actual data about the plate to the on-line production control computer.

Warehousing Instructions

Finished plate is transferred into the warehouse by roller conveyor. The computer determines where the plate should be stored in order to be convenient for shipping, and displays this on the CRT in the pulpit of the warehouse and the electrical character display device from which a crane operator makes his operation.

Production Progress Control of the Heavy Plate Mill

The production planning and management computer receives actual data on heavy plate production and updates the production status files. If there is an order for which the specification was seen not to be satisfied by the inspection and/or mechanical test, the computer puts a warning on the CRT in the control center.

Information Processing for Shipping

The mill sheet of finished products corresponding to each order is printed out. The shipping schedule is made by man and computer with consideration of the date of delivery and the operational plan of shipment. Actual information of shipping is transmitted to the Head Office in order to submit bills.

Order Status

As the production progress information of each order is stored in the order status file, it is always possible to display it on the CRT in both the production control center of the Kashima Works and the sales division of the Head Office. Inquired key words are order identification number, work number, slab identification number, plate identification number, address in the warehouse, and so on.

Production Lot Arrangement Problem

As regards the production lot arrangements, in order to get the total optimization through the steelmaking, slabbing, and heavy plate rolling, we have developed the new algorithm which consists of the arrangement of a heat and the ingot and slab design.

Arrangement of a Heat

In the matrix shown in Table 4, L_1, L_2,...are groups of orders with the same steelmaking specification and M_1, M_2,...are kinds of steel grades. The availability of each steel grade for a group of orders is shown by a double and single circle mark. The steel grade marked with single circle is available, but not so desirable from the viewpoint of cost. So, we call it an applicable steel grade. The size of the matrix is about 100 rows and 150 columns. The ordered quantities of steel are distributed among the available steel grades so that the number of heats can be minimized, priority is given for orders with early delivery dates, and the amount of applicable steel grade used is minimized.

Table 4. Problem of production lot arrangement. The matrix of material quality which can be used.

Ordered lot (same in steel-making specification)		Material quality that can be used for ordered lot							
Kind of lot	Ordered amount	M_1	M_2	M_3	---	---	---	---	M_j
L_1	t_1		O		o		o	o	
L_2	t_2			oij O	o				
L_3	t_3	O		o	o	o	o		
:	:					O	o	o	o
:	:		o	o	O	o	o		
:	:		O				o	o	o
L_i	t_i								O
Total amount	$\sum t_i$	P_1	P_2	P_3	---	---	---	---	P_j
Necessary number of lots		$\left[P_1/250\right]$	$\left[P_2/250\right]$	$\left[P_3/250\right]$	---	---	---	---	$\left[P_j/250\right]$

Ingot-Slab Design

Orders are arranged into ingot and slab simultaneously (Figure 12) with a view to minimizing the slabbing dimension of ingots in the same heat, good yield rate, and suitable thickness of a slab corresponding to that of any heavy plate ordered. Consideration is taken of the constraint over the length of a slab caused by the size of the reheating furnace (over 2300mm, under 4000mm). High priority is given to the cutting pattern which provides high productivity and yield rate (Figure 13).

CONCLUSIONS

We would like now to review some characteristics of TOPS. It uses an on-line system extensively, and adopts hierarchical configuration. Many computers, including process computers, are used and pertinent allotment of junctions among computers and men are made. The computers are extensively linked with the data communication lines. It is being planned to extend this network not only intra-Works, but externally to the Head Office, other steelworks, subcontractor's factories, and external stock yards for distribution. The order status of products can be monitored by the Head Office through on-line terminals. Data exchange between the Head Office and the Works, and intra-Works are being done through point-to-point communication lines.

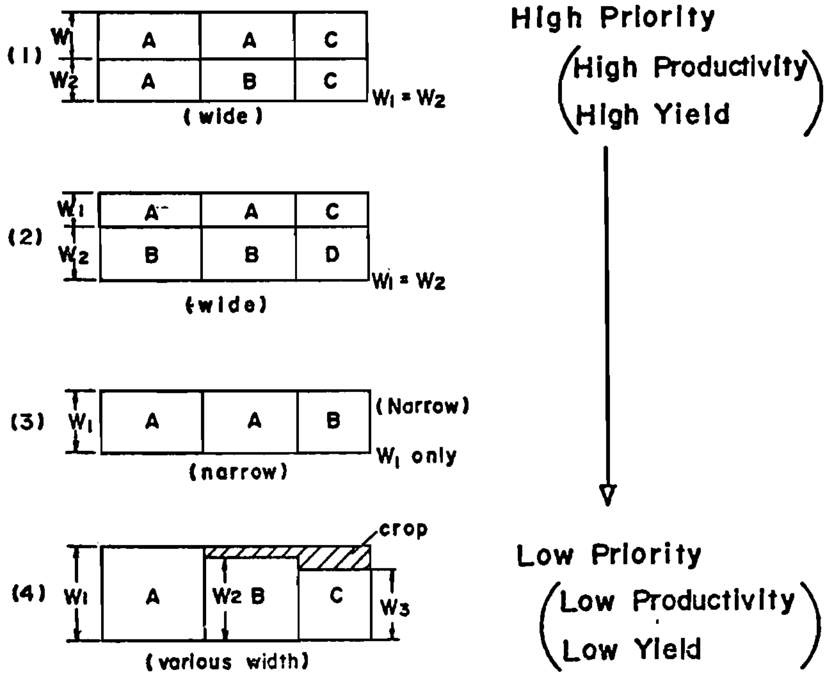


Figure 13. Two dimensional cutting stock problem. the combinatorial rule of heavy plate ordered.

TOPS adopts computer oriented planning system extensively, such as order allocation system, on-line reallocation system, and on-line scheduling system.

It is a totally integrated system. The data gathered through any subsystem come to the management system of Kashima within 24 hours. Here we can examine the correlations between quality data from the steelmaking area and finishing products areas even though physically they are far apart. A wide variety of inquiry systems are provided to aid human decision. On the other hand, most of the judgments which can be made logically are done by computer--e.g. recording the results of the mechanical tests to prevent careless mistakes--to save manpower, and to shorten lead time. If some trouble, e.g. faulty product claims, occurred for a plate, we can search the history of the production rapidly using the data base and resolve the problem.

GENERAL CONCEPTS OF INTEGRATION

The Need to Formulate Integration Strategies

H. Hübner

INTEGRATION AS AN ORGANIZATIONAL NECESSITY

Integration is the essence of organization. It normally has rationalization as its objective and involves a multilevel and multidimensional complex of problems that have not received adequate attention so far. This paper takes as its theme integration problems specifically associated with the processing of information--in particular from the viewpoint of availability. Integration used in connection with automated data processing usually means data processing with large computers including a data bank. But there are some questions. What will be integrated in this matter: data, departments, tasks, men, or something else? Can integration within an organization only come about through the use of large computers, coupled with an enormous effort to establish a central databank? From where do the needs for any integration come, and are there significant limits to the integration?

The starting point for integration in information processing is the great variety of tasks connected to a variety of data--a relationship not confined to time-related data (often called flow or movement data). Survey of data within an enterprise yields the following classes.

Data categories describing states:

- Historical data (e.g. turnover in past years),

- Basic data (e.g. suppliers, customers, products),

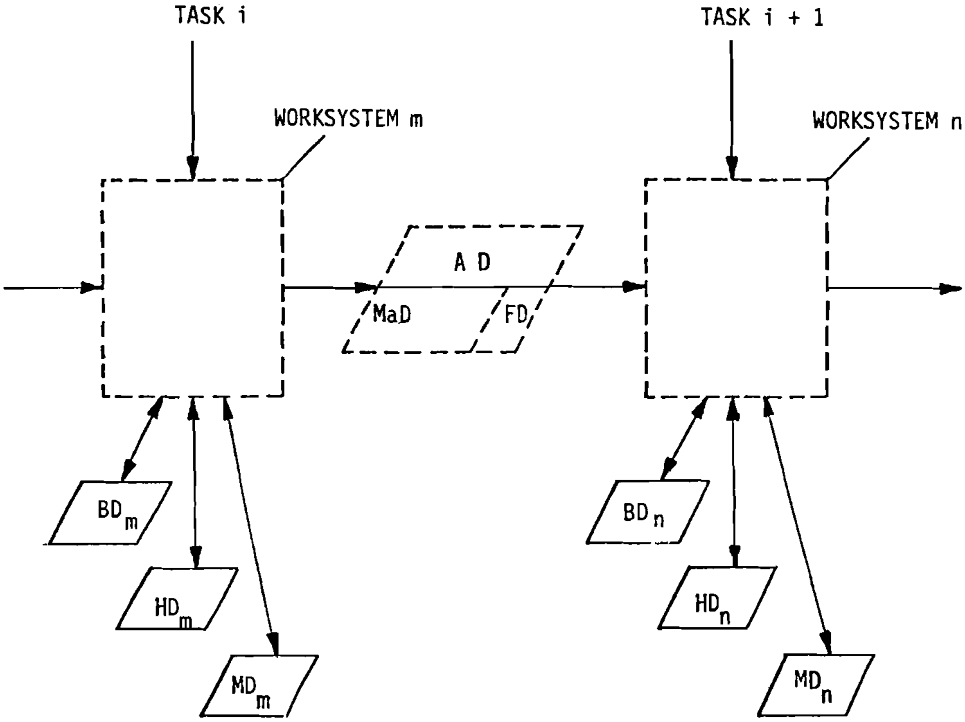
- Data on methods (e.g. definition of a method to determine batch-size).

Data categories describing flow volume (action data):

- Management data not directly affecting active operation (e.g. unfilled orders, unpaid accounts),

- Flow data with immediate active effect (e.g. changes in delivery dates of supplies demand immediate consideration of consequences arising and possibly leading to revision of plans).

All these data categories offer a possible foundation for task integration as shown in Figure 1. The precondition for integration is partial or full agreement between data (from one or several categories) required by different work systems and/or those charged with carrying out specific tasks, for all of whom these data must be made available in the required manner. If, for instance, the basic data (Stamm-Daten) BD_m and BD_n agree either partially or completely, then integration based on these basic data for task systems m and n is possible.



AD = Action Data
MaD = Management Data not directly affecting active operation
FD = Flow Data with immediate active effect
BD = Basic Data
HD = Historical Data
MD = Data on Methods

Figure 1. Data-categories as possible foundations for integration.

INTEGRATIVE PROCEDURES RELATED TO DATA PREPARATION

General Integrative Procedures

The general procedures relate primarily to content and management of data (and data banks) and involve:

- Reconciliation of the common data (particularly with regard to content, arrangement of data elements and logically related data units, as well as origin of data); and

- Assigning responsibility for maintaining identical data on one particular work system. Assigning responsibility to one particular point for maintaining the records of similar data, fulfills one of the most important objectives of integration, namely avoidance of repeated performance of tasks and/or partial tasks).

By these measures we make sure that for work systems using similar data, the responsibility for recording them lies with one department.

Specific Integrative Procedures

The specific procedures concern the way in which data are made available for the different task systems and/or those responsible for carrying out specific tasks. Two types of integration can be identified:

- Integration by interlacing (interaction), and

- Integration by common use of data banks.

Both methods ensure, in different ways, data availability in respect of:

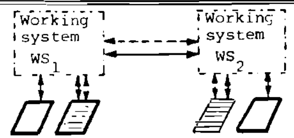
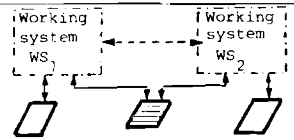
- Existence of specific physical data stores,

- Allocation of data to individual task systems,

- Access to the data, and

- Availability of the data.

The two types of integration are briefly explained below with reference to Figure 2, which shows the conditions resulting from the two types of integration. Brief comments on these conditions are attached to the diagram.

PRECONDITIONS TO REALIZE SPECIFIC INTEGRATIVE PROCEDURES	TYPE OF INTEGRATION	RESULTING CONDITIONS	CONDITION - DESCRIPTION: Existence of specific physical data stores	Allocation (of the identical data)	Access (of the identical data)	Availability (of the identical data)	Relationships between the work systems
1. Partial or full agreement between data for work system WS_1 and WS_2	INTERLACING (Interaction)		at each working system	direct to each working	only for one working system	through/by the one working system	- designing relationships and - working relationships
2. - Reconciliation of the identical data - Assigning responsibility for maintaining identical data on one particular work system	INTEGRATION BY USE OF COMMON DATA		one	basically not to any specific working system	direct for all working systems considered together	through/by more working systems	- designing relationships

WS.......Working system (task)
▱.......Data used only by one working system which is responsible for their maintenance
▱.......Identical data for both working systems, responsibility for maintenance by the specific working system
▱.......Identical data for both working systems, duplicate not maintained by the specific working system
◂- - -▸.......designing relationships ("Gestaltungsbeziehungen")
◂——▸.......working relationships

Figure 2. Conditions using the two different types of integration (related to data preparation).

Integration by Interlacing

The procedures for integration by interlacing concentrate on the definition of how availability of the common data to the different task systems is to be determined and ensured. This is done simply by the provision of duplicates (of the common data) by the department responsible for maintaining them. To define the form and timing for making these copies available, links between the task systems involved--so called "designing relationships" (in German: "Gestaltungsbeziehungen")--are needed.

Independently of these links, another network of relationships is required to ensure that the common data are transmitted at regular (or irregular) intervals. These are work relationships and their requirement forms both the basis and background for defining the concept of "integration by interlacing".

Integration by the Common Use of Data Banks

With this type of integration, the process involves specifying means of ensuring direct access to the common data without the need for keeping data available separately for each work system. By common use of identical data, the transmission of common data is made unnecessary. Specification of and ensured access for the common use of identical data requires only relationships of the designated type. Inasmuch as no further relationships are required, one can (since working relationships are not called for) say that integration by common use of data carries a certain element of "dissociation".

THE NEED FOR FORMULATING INTEGRATION STRATEGIES

Recent developments in the field of information technology permit, in theory, comprehensive integration based on the common use of data banks, with the ultimate objective of storing all data required by a variety of tasks only once, thus avoiding redundancy. The problems* and consequences involved however make the practical achievement of such an ideal a highly doubtful proposition since, the organizational consequences are largely unknown.

Two examples from the technical literature make the point:

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*Selected aspects mentioned by Wedekind (1972) include: Lack of qualified experts, and impossibility of complete formalization of relationships. Cost considerations, grave intrusions into organization structure, and the long period required for development, taken together, prohibit any realistic approach to the consideration of total systems.

> The shaping of administrative organization in enterprises in line with the concept of automated administrative systems ("total business system integration") requires all enterprise, data processing and information requirements to be combined withoout regard to the existing vertical and horizontal subdivisions. (Hartman, 1971.)

> The slogan of "integration" having created a great stir in information processing ten years ago, is today felt to be in bad taste if not a "dirty word" in professional circles. (Oettli, 1976.)

The substantial and so far largely unexplored problems yet awaiting analysis that comprehensive integration dependent on singular data storage involves make it inappropriate to interpret the term "integrated data processing" as meaning an all-embracing centralized system of all tasks and data. That insight necessarily leads us to consider the formation of subsystems of optimal size, for which integration can be realized on the basis of using common data banks. This integration can be organized by "interlacing" (or intertwining) in a way allowing the subsystems to function substantially independently of one another, an aim which can be realized by deliberate (but limited) redundant data storage.

Subsystem (or partial system) refers here to an area comprising those tasks for which integration is established by common use of data; we shall consider such a task area to be an "integration field". As far as the application of electronic data processing (EDP) equipment is concerned we take as our starting point that integration by use of common data is realized for task areas covered by user-oriented software programs. Thus, if EDP equipment is applied, the integration field is identical with the task area covered by a particular user application software program. The creative forces called for are primarily systems analysis, systems design, and programming, with hardware merely a tool.

It is therefore necessary, prior to the selection of user oriented software, to form appropriate integration fields.* Optimal structuring of the total enterprise with reference to data availability must be based on an integration strategy that defines those aspects specific to the enterprise, and that govern its subdivision into specific integration fields. Higher level integration of these fields is subsequently achieved by interlacing while keeping them--from an EDP technological point of view--as independent as possible by providing deliberately for partial multistorage of data.

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*An integration field is not identical with a given task area to be handled by EDP equipment application. It is essential to design and define integration fields for that task area.

DETERMINING AN INTEGRATION STRATEGY

Integration strategies are formulated on the basis of determinants whose specific form must be established for each particular undertaking in the light of consequent organizational effects. Four dimensions require consideration:

- Direction of integration,
- Size of area to be integrated,
- Type of integration area (in the case of horizontal integration), and
- Level of integration.

Direction of Integration

Integration may take two directions:

- Horizontal: consideration of tasks at a single organizational level, and
- Vertical: consideration of tasks at different organizational levels.

Horizontal integration leads to differentiation between different functional areas, whereas vertical integration takes place mainly at the operational, tactical, and strategic levels.

Figure 3 shows the horizontal and vertical structure of an undertaking in these terms and shows how integration may be structured vertically or horizontally. Realization of a vertical data-technical integration (common use of identical data) encounters a number of problems, namely, structural difficulties (such as tasks carried out only once), confidentiality of certain data, etc. The principal problem, however, is the fact that tasks carried out at different hierarchical levels require data at different levels of aggregation.* This need for aggregation makes use of common data impossible, which explains why the market offers hardly any software for multiple use suited to vertical integration.

The problems associated with the use of data of varying degrees of aggregation may also be encountered in horizontal integration but if so to a lesser degree. This means that the direction of any integration sought must be precisely defined theoretically with reference to the aggregation of the required data and that horizontal integration comprises tasks of equal degree of aggregation. Figure 3 shows the possible course horizontal integration might follow.

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*Aggregation may involve time, quality, or quantity (Poths, 1969).

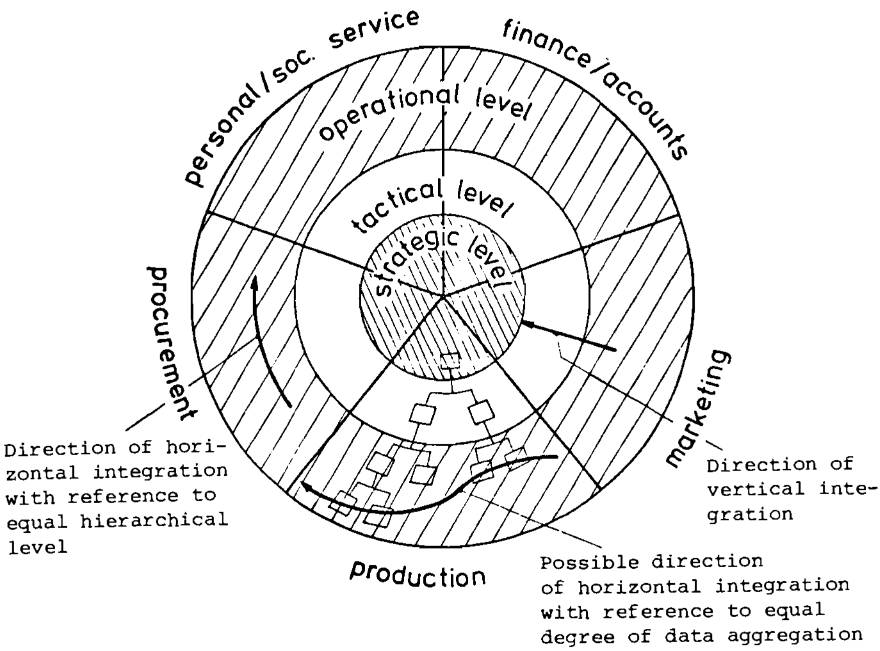

Figure 3. Horizontal and vertical structure of an enterprise.

Size of the Integration Field

Use of EDP equipment permits the formation of comparatively large fields of integration. Current (theoretical) approaches accept the maximization principle, i.e. making the integration field as large as possible. However, the exposition that follows is based on the concept that in setting up integration fields, the principle of optimization--seen from the viewpoint of the organizational consequences--must be adopted.* This approach is relatively new and, therefore, still the subject of research (Hübner, et al., 1977).

Determination of possible fields of integration must start with consideration of the tasks of the undertaking as a whole. There is, of course, an inverse proportional relation between the size of fields of integration and their total number. Figure 4 illustrates this relation by reference to the two extreme values:

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*Total integration cannot--if the organizational consequences are taken into account--be achieved, even when EDP equipment is employed. "Total integration" must, therefore, be taken as a purely theoretical concept defining a purely abstract limitation of action.

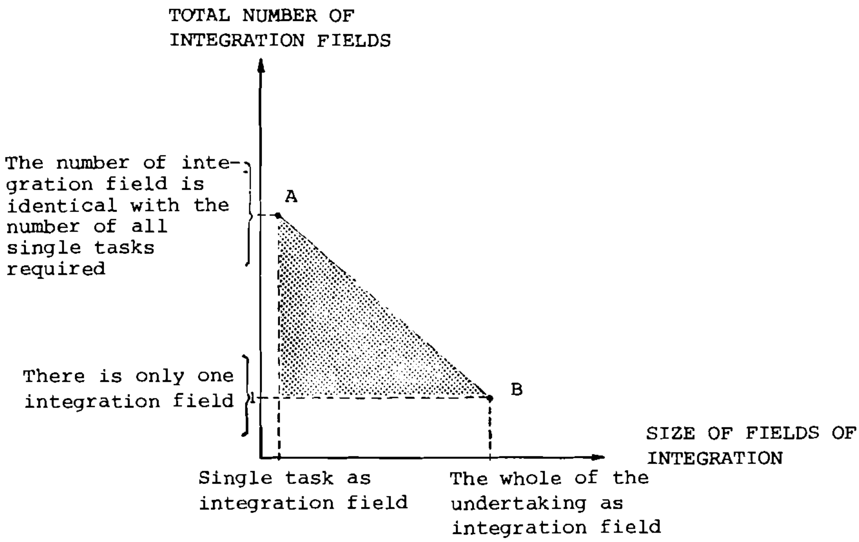

Figure 4. Relation between size and total number of integration fields within an undertaking.

- If a single task is considered as the smallest integration field, then the total number of different integration fields is identical with the number of all the single tasks required (A).
- If the whole of the undertaking (i.e. all single tasks) are considered as one integration field, then, of course, only one such field exists (B).

The larger the individual integration fields, the smaller is their number.

Our definition of integration implies that it is achieved by common use of data, while the various fields of integration are themselves integrated by being interlaced. Hence, determination of the size of the integrative fields also decides the extent of fusing of both types of integration since increasing size of integration fields (and with it decreasing numbers of integration fields) causes the proportion of "integration by use of common data" to rise and the converse equally applies.

This is illustrated in Figure 5 with seven tasks which use identical data. The following three strategies are shown in respect of size of fields of integration:

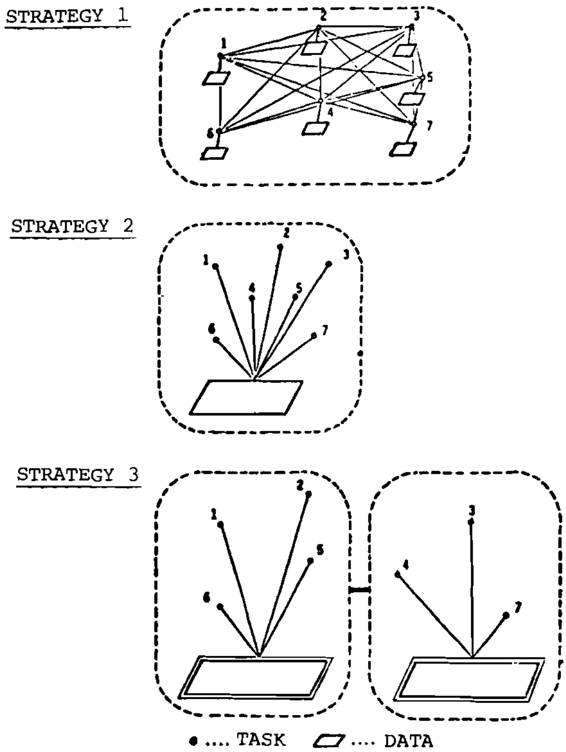

Figure 5. Several integration strategies referring to "size of integration field" (example for 7 tasks).

- Integration field size corresponds to a single task (the number of integration fields thus corresponds to the number of single tasks (7) and integration is effected entirely through interlacing).

- The integration field comprises all the seven individual tasks under consideration (therefore, only one integration field exists, and the integration operates entirely by use of common data).

- One integration field is set up for three tasks and another for four tasks. This means that two integration fields come into being and integration uses--if all 7 single tasks are taken into account--both types of integration (interlacing and common use respectively).

The single task as integration field represents an extreme case. In practice the following classification appears to be appropriate: single task area, several tasks area, sectional area, sectional areas, functional area.

Task areas or sectional areas to be integrated may fall into different functional divisions (e.g. production/procurement). The point of membership of integration fields in different functional divisions is covered by the criterion "integration field category".

Integration Field Categories

Membership of tasks within one integration field to one or several functional divisions is covered by developing categories of integration fields. For the undertaking considered here, the functional divisions responsible for achievement of performance, namely the three basic functions: procurement; production; and marketing, plus finance and accounts and personnel/social services (see Figure 3). Dependent on whether tasks from one or more functional divisions are integrated, the following five* integration field categories can be differentiated:

- Integration of tasks within one functional division (e.g. production),
- Integration of tasks from two functional divisions (e.g. production, procurement),
- Integration of tasks from three functional divisions (e.g. production, procurement, finance/accounts),
- Integration of tasks from four functional divisions, and
- Integration of tasks from five functional divisions.

Level of Integration

Dependent on whether integration applies to one or more categories of data, different levels of integration can be established. Exposition of the relevant background would, however, take us well beyond the limits of this paper. Reference to the level of integration as one of the determining factors in integration strategy design is made here merely for the sake of completing presentation of these determinants in the light of our present level of knowledge. These determinants and their various specific formulations in particular undertakings are presented comprehensively in Table 1.

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*This classification of an undertaking into five functional divisions is only one possible way of dividing the total activities. They might equally well be classified by using different criteria.

Table 1. Dimensions of an integration strategy.

Dimensions of an Integration Strategy	Possible "Values" for the Dimensions
Direction of integration	Vertical Horizontal
Size of area to be subject of integration	Single task area Several tasks area Sectional area Sectional areas
Type of integration area (field)	Type I Type II Type III Type IV Type V
Level of integration	Phase 1 - 4

CONCLUSION

The far-reaching and partly euphoric concepts of Management Information Systems (MIS) which stress primarily vertical integration of information have not found acceptance in administration (Grün and Maier, 1976). The need to take into account goals and conditions specific to particular undertakings requires integration strategy to be formulated specifically for each enterprise. Formulation of such a strategy must take into account that its realization ties up personnel and resources in the medium and long term and is likely to produce consequences which may, in part, be irreversible.

Scientific penetration and clarification of the interaction between integration strategies and more especially their organizational consequences--taking into account the application of various EDP equipment--must form the subject of further research.*

*"Integration in Organization" currently forms an important focal point for research at the Institute for Innovation Research at Innsbruck University. Constructive contributions from science and practices will be warmly welcomed.

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Discussion

The participants pointed out that integration in a computer system should reflect integration in the production system. The integrated system should maintain the interconnections between different departments within the production system.

The concept of integration originated in the USA where the production systems are highly complex. The current trend is to fuse the production systems, and in this connection, the integration of the management system is of great importance. It was stated that in a number of cases the realization of integration is very difficult.

Discussions also focused on whether the decomposition of goals in an integrated management system is an art or a science, and most participants felt that it contained both elements. The decomposition depends very much on the objectives being considered, and the goals must be formulated by those who know the system.

Furthermore, an integrated management system is an effective tool for integrated decisionmaking. For real-time decision processing, it is essential to present the decisionmaking technique in a formal manner. This gives rise to the problem of organization, which the participants felt deserved study.

Information Flow and Large-Scale Integrated Manufacturing*

F. Muller

The development of large-scale integration in the semiconductor industry has brought about new ways of designing logical systems for data handling and information flow. The subject of logical systems has developed into an independent branch of computer technology for circuit designers for *internal* computer hardware structure, and it becomes more and more apparent that the findings and solutions reached in this field might also be applicable for improving the *external* information flow that constitutes the man-machine computer interface. There is a "parallel world" inside the computer that shows great similarity with the structure of a large-scale enterprise and its information flow. It might be worthwhile to analyze the logic within the system and try to utilize it to determine a significant decision framework of a model for the industrial process itself. Thus one could think of *building a computer that directly plays the part of the model* rather than existing as a numerical tool to be employed on a model constructed from a system of differential equations.

The cooperation and coordination aspects between elements of the oxygen steelmaking system are of the same priority as the structure of the elements themselves. This has not yet been sufficiently underlined and too little research is being made in this area of large-scale industrial systems. The individual process control systems are developed on their own as individual elements and interaction between the process control system's elements is only slowly progressing, if at all. In computer terminology there do not exist yet software protocols for defining the type of cooperation between the system's elements.

The main findings of a recent publication on "Systems Engineering Methodology for Interdisciplinary Teams" are that when professionals from many disciplines form a team to design or analyze large-scale man/machine systems, many of the problems arise not from mathematical, physical, or scientific considerations but from the *methods* employed. In order to make progress in this direction, the basic structure of the production process has to be defined in terms of information flow and information processing functions within and between the system's elements.

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*Summary of a paper distributed at the Workshop.

Because an industrial large-scale implemented information system cannot be exclusively hierarchical, or centralized, the internal structure of the oxygen steelmaking system's elements should be of a modular, distributed, multi-access nature, at least as far as the communications within the elements (i.e. management, process, EDP) are concerned. Such a configuration is becoming more and more popular because of the great advances made recently in multiple access bus techniques and cable television technology. The resulting data communications system called "cable bus" thus gives modular, decentralized control, in conjunction with the use of microprocessors distributed throughout the plant, an ever increasing potential.

Interlinkage between the oxygen steelmaking system's elements can be divided into three main systems. The most comprehensive configuration of the interlinkage is an "all inclusive" configuration, where each constituent of each element would be accessible to each constituent of another element. Advanced methods used for "structured programming", such as Petri-networks should be adopted for structured interlinkage between the different elements. Necessary construction rules for and decomposition rules of logical networks have to be formulated (recursive construction, syntax analyses, etc.) as in computer construction. Centralized and/or distributed organization architectures will evolve, depending whether sequential or parallel subnetworks are involved. Functional information flow is primarily sequential and requires centralized configuration, whereas the computational information flow centers are of a parallel nature and require a distributed organizational architecture.

This proposed structured approach for building the information flow system not according to the existing hierarchical structure of the industrial process but according to the nature of the information, has the great advantage that the methods used for building the natural logical structure of computer hardware can be applied for developing a similar logic system of the organization of the production process as regards the data flow. This, however, does not mean that the physical hierarchical structure of a given industrial process is overthrown, only that the means are provided to improve its information flow as the need arises.

Algorithms of Decisionmaking Under Conditions Of Functional Integration*

A. Kopelovich and E. Maslovsky

Scientific, technological, and organization difficulties arise with the computerization of control systems for large-scale plants, particularly for the continuous and discrete production processes in steel plants. An interdisciplinary, analytical approach is needed to solve these problems.

The authors point out that the computerization in the steel industry began in the mid-1960s and that by the mid-1970s, over 1000 computer control systems had been implemented in industrially developed countries. These systems are at various stages of integration:

- Isolated, autonomous systems installed at one level--e.g., for control production processes for real-time processes; about 80 percent of the steel plants are at this stage.

- Partially integrated systems covering two levels--both scheduling and production planning; about 15 percent of the steel plants are at this stage.

- Fully integrated systems covering three levels--scheduling, production planning, and technological process control; only about 5 percent of the world's steel plants have reached this level of integration.

Because total plant control problems are complex, it is necessary to break these down into local and coordinational control problems, and to design multilevel hierarchical structures for decisionmaking. The primary aim of the authors' research is the development of practical methods for designing coordinated subsystems, and for establishing a general control structure for steel plants. They discuss the various structures that must be taken into consideration in designing a system, and provide some guidelines for using mathematical models to achieve systems control.

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*Summary of a paper distributed at the Workshop.

Computer Based Integrated Management Systems For Large Companies

F. de Jong

INTRODUCTION

Integrated operational systems with large storage capacities, multiprogramming capabilities, direct access to data and operating speed became a possibility during the mid-1960s when third generation computers were first marketed. Even at this time, technical problems of systems integration would have been difficult to overcome without the enormous contribution of software houses and hardware manufacturing companies to the development of application software.

Industry recognized these developments as an opportunity to solve its short- and medium-term resource planning problems, which are inherently of an integrated nature. Nevertheless, many manufacturing companies still struggle with problems of integrating management systems.

Industry in both the developed and the developing world can be divided into two major groups. The first is composed of companies that make extensive use of computers for operational systems (payroll, inventory control, routing, etc.); these systems usually operate independently of each other. The second group consists of those companies that are or will soon be involved with computer systems. Although the latter group may lack systems design experience, in the long run they may be better able to realize integrated systems. This paper discusses some reasons for this.

Difficulties in realizing a concept that seems obvious and relatively easy to comprehend appear to be more of a human than a technological nature. The process of realizing integrated management systems is largely one of reorganization and user education. This is a slow and time consuming activity, that requires almost a fanatical conviction to carry it to completion.

Hardware and software manufacturers, often faulted for overselling, cannot really be blamed for these difficulties. They have provided both the soft technology and the equipment that make modular, data-base oriented, integrated systems possible.

The following sections deal with the development of integrated management and information systems in a number of different social and industrial environments, and review some of the methods that have proven most efficient in dealing with integrated systems implementation. Problems in this area appear to be universal; the solutions, however, depend largely on the nature of the enterprise, its management organization and style, and on the social environment in which it is operating.

PLANNING

Ideally, the desire to create an integrated manufacturing control and management information system originates at the top level of the company. The reasons for this may be a realization that current operational systems do not provide adequate information to support decisionmaking, that duplication of information storage is either expensive or creates too many discrepancies, or that the growing complexity of the business environment demands a more complete approach to the systems problem. However, this is rarely the case. More often, management views its systems and computer operations as a quicker way to do what has been previously done. Operating departments often demonstrate a possessive tendency towards their operational systems. The idea of giving up sole access to their files is generally not popular.

More frequently, the idea for systems integration originates with the systems department. If they, and not the top management, conceive the idea, they are faced with the problem of its realization. Since integrating operational systems involves cutting across departmental boundaries, pure systems design and programming knowledge is not sufficient. The systems department will have to enlist support from both managers and users.

Experience shows that operational systems developed without the idea of future integration are often not suited for data base orientation. Data base structure requirements underlying such integration usually result in massive program changes such that the task of redesigning the systems is often simpler than that of conversion. This may be advantageous for those companies that are attempting an integrated system but who do not have a developed computer system.

The development of such a system requires careful planning. Many manufacturing companies who, for example, would not consider changing a floor layout without the involvement of technical and administrative personnel at all levels and without careful time and resource planning, often leave the realization of an integrated management system entirely to a systems department.

The first task in the planning process is to educate top management as to what is involved in integrated systems design, what their continued involvement in integrated systems design should be, and how they can control the various activities that lead to implementation. This should result in a management directive launching the project and giving it the necessary authenticity to be recognized as a component of the company's development objectives.

In large, multidivisional organizations, the systems activities are often decentralized and disjointed. The corporation's headquarters may have a management services group concerned with problem solving and systems analysis. At the company level there are usually groups of analysts and programmers involved in day-to-day operational problems; also, some of the larger departments may have personnel who unofficially devote their time to systems design. This has proven to be a weak basis for integrated systems design. The uniform approach required for such systems almost prescribes the project team approach. Going back to the earlier example of a major change in plant layout, it would be inconceivable for plant engineers to undertake such a project without the use of project control techniques and without some form of centralized control. Because of the long time period usually required for implementing integrated systems, the use of these techniques is recommended.

Thus it is essential that management take an active part in determining the organizational structure of the project team and in assigning objectives and tasks to permanent team members.

Because the integration of a management system affects the organization and activities of the company, it is advisable to involve initially top executives and line managers in the control and management of the project. Because of its specialized character and its staff position in an enterprise, the systems department has neither the overall view nor the decisionmaking power required for this task. Moreover, because an integrated system must be user oriented, line managers should be members of the design team; eventually they would become advocates for the new system in their own working environment. Access to user personnel can be obtained more easily when their superiors are themselves involved in the management and control activities of the system project.

The interrelationships of all business activities have not been invented by systems designers or behavioral scientists; they have developed partly through a process of evolution and partly by means of a preconceived company organization structure and the resulting communication network (official and unofficial). The process tends to change slowly the original structure of many interrelationships in an enterprise, often to such a degree that it is difficult to recognize the original intent after many years of operation.

One objective of designing an integrated system is to reflect this interrelationship in the company's decisionmaking and control activities. As a basis for defining the problem and designing a new system, the project team should study initially a number of activities that give a general picture of the enterprise's present system, and administrative and control conditions.

FEASIBILITY STUDY

The feasibility study should result in a master plan for the new integrated system which will provide a basis for further systems efforts. On the basis of these results management can decide either to continue with an integrated systems project or to abandon it as too expensive or too complex to be carried out within the present organization. The master plan is to be viewed primarily as decisionmaking tools; in the presentation of the plan to management, only those aspects of the plan that most clearly assist decisionmaking should be emphasized.

A typical master plan might include the following:

- A general statement of systems objectives;
- A brief description of the user organization;
- A preliminary requirement definition;
- A general outline for the integrated systems design (the systems architecture);
- Preliminary hardware and software specifications;
- An overall schedule for the continuation of the systems design and implementation effort;
- Clear recommendations to management whether or not to start the actual integrated systems design effort, and if these recommendations are positive, the measures to be taken.

Analyses are required, beginning with that of the efficiency of present systems. If the effort is left entirely to the systems department, this may take the form of self-analysis and self-criticism. The need to obtain an unbiased view of the systems efforts to date, both manual and computer-based, is another reason for organizing an independent team charged with the task of introducing integrated systems into the enterprise. Especially in companies that already have a number of operational computer-based management systems, it is a problem to convince the systems department that these systems cannot or will be very difficult to incorporate into the new integrated system.

Responsibility for the feasibility study cannot be delegated downwards. Since the study will involve an examination of the company's management practices, there should be constant management direction and involvement in this work. Ideally, the management participants in the study should outnumber the systems technicians on the team.

For the manufacturing control and planning part of an integrated system, use should be made of *application packages*. The design of an integrated data base structure, a retrieval system, and the operational modules making the entire system serviceable is a task usually beyond the capabilities of the average systems department in a manufacturing enterprise.

Integrated manufacturing control packages are the result of many years of application experience in a wide area of manufacturing. They are adaptable to the special output requirements of any company, and thus contribute greatly towards limiting the time needed to develop the system.

The feasibility analysis problem can be approached from different directions. First, given available hardware and pertinent application packages, one could study all details of these packages and the extent to which they might solve present company problems. Another approach is to analyze the organization, the problems defined, and thereafter determine how existing packages can be used to solve present company problems. Likewise, one could start by analyzing the organization and problems, and thereafter determine how existing packages could be adapted to satisfy the information requirements of the enterprise. The latter approach is recommended strongly, based on the premise that after the feasibility study has been made, management will have to decide either to continue with the actual systems design and implementation or to abandon the effort for technical or financial reasons. If the project is abandoned, the results of the study will still justify the costs.

After an analysis has been made of the company's present systems, its information flow, product flow, problem areas, and decision information requirements, the feasibility study team can begin to design a new systems architecture.

SYSTEMS ARCHITECTURE

The systems architecture is a preliminary general description of the new system, its division into modules, and the data base files. This description is based on an evaluation of the existing product and information flows in the organization, taking into account shortcomings and duplications.

The system architecture divides a new system into a number of logical modules and determines the relationships between these modules and their supporting files as well as those among the files. Although a suggested priority sequence with respect to developing the systems modules should be part of the systems architecture, the actual development sequence is to a certain degree predetermined by the need to develop the data base files, thereby making information available for operational purposes.

The entire system could thus be divided into a number of major parts or components, each in turn built up of a number of submodules: data base creation, manufacturing control modules, planning modules, management information retrieval, and decision support modules (simulation, "what if" questions).

SYSTEMS DEVELOPMENT PHASES

When management decides that development of an integrated system is justified, the actual systems design and implementation work can begin. This work can be broken down into the following phases: general design, detailed design, programming and testing, and implementation and evaluation.

It has been customary to leave what can be classed as systems design work to a group of specialists such as analysts and programmers usually attached to the systems departments. However, their orientation of systems development activities seems to be in direct contradiction with the user-oriented modern hardware and with the need for line management control over major changes taking place in the enterprise. From this point on, it is essential that managers and users be involved in the activities of a systems project team.

A first task should be to organize this involvement. For example, a small group of senior line managers could form a committee for controlling the activities of the systems development group. The development task should be carried out in accordance with a well-defined plan indicating where management decisions are required in order to continue the work. As a result of its involvement, the committee is continually familiarized with the systems development activities and with the shape of the future system. Not only do these managers have the power to make the decisions required for acceptance of the systems, they are also responsible for the management changes that may result.

The management control committee should establish a project team and assign team members on a full-time basis. The project team should bring together the personnel from departments affected by the project and the systems specialists in order to ensure optimal cooperation and coordination. The composition of the team at any given time depends on the stage of the project; the team as such, however, functions from the start of the project, until the implementation and evaluation phase is completed.

The formation of this project team is another crucial stage in the systems project. It will be difficult for both the project managers and the management control committee to obtain firm manpower commitments from line managers. Even when line managers make these commitments, they may not assign their best people for this work. However, it is exactly these qualified people who should be on the project team. Considerable tact and powers of conviction are required of the project team manager in order to avoid having a surplus of personnel from the line departments or personnel for whom a function has to be found just prior to their retirement. The "user-oriented" members of the project team will be most involved in the implementation phase, when the system is passed on from the system team to the users; they may also nurse the system through its first period of parallel running. Obviously, only user personnel who perform key functions in their departments could be successful in this task. Note that it is usually at this stage that the first serious human objections to the development of the system are encountered.

Those assigned to work on the team should be relieved of their normal duties and, if necessary, given suitable training. It is important that all team members have a clear understanding of the purpose and scope of their assignment, and be familiar with the schedules and constraints of the systems effort applicable to their work.

Although ideally systems development should proceed according to a module priority selection, there are certain limitations on the freedom one has to make this priority selection. To achieve an integrated system, the first modules to be approached are those associated with the creation and updating of the data base. At the outset of the systems project, the project team is faced with one of the more difficult areas (from a systems point of view) of the enterprise.

The creation of a manufacturing data base starts with the company's product structure, from which an item master file is created, followed by technological data, labor standards, and costing information. Most data required to develop these files can be obtained from the enterprise's design engineering department. This is an area that forms essentially the technical core of the company, usually operating along lines that have evolved during the life of the company. The approach used in collecting the department's base information in a set of central interacting files prescribes a specific discipline for preparing source data and handling engineering and cost changes. This discipline is unique, and usually results in considerable changes in operating mode and responsibility distribution within the department.

Experience shows that it is difficult to obtain cooperation for the systems efforts. While the department staff may not understand the objectives of the new system, they do realize quickly that the transfer of manually updated bills of material and routing files to a central disc file can mean an enormous amount of work for the department. If the system is designed properly, the data entry modules will contain a number of precise validation and data checking routines. The result will be that all existing shortcomings in the company's documentation show up and have to be corrected before the new system will accept them.

The entire system effort can stand at this point, unless the engineering department is involved in the analysis and design task. It is worthwhile to develop a comprehensive educational package for this department.

The problem of ensuring the active participation of the user departments in the systems development task will remain throughout the project's duration. Because of difficulties encountered in solving this problem, it is essential to have only phased implementation of integrated systems. The simultaneous implementation of new systems in an entire company would require so many major organizational changes that no systems department could be expected to cope with the task.

A possible method for dealing with the problem of enlisting the users' cooperation is the development of a user education program. Responsibility for developing the user education program should be given to a small subteam of the project team consisting of systems specialists and user representatives. Part of the user education program should be progress and activity reports presented to the management control group, and another part in the form of class room presentations to the user department personnel. The actual systems development activity taking place in an enterprise represents ideal case history material for such a program. The users will find it easier to identify with the material presented during the program when it is drawn from their own working environment.

During the implementation of a recent large systems project, it was observed that not only the users but also many of the staff in the systems department benefited from such in-house training. Whereas the systems development team had initial difficulty in selling the idea of implementing the new system, eventually it was the user department staff that wished to accelerate the development pace.

Obviously, one reason for the slow progress in integrated systems development in industry is that there are few vehicles to support a system of transfer of experience and proven technology. In particular, medium-sized and small companies embarking upon such a project go through the process of reinventing the wheel. The reluctance to engage outside help in a project of these proportions is found to be more a matter of professional pride than of finances. The systems department, which plays a large role in an integrated systems project, feels that it has the knowhow to carry out the project. It is difficult for any systems department to have firsthand knowledge of difficulties experienced in other companies in the process of convincing users and managers, an outside "prophet" may receive more recognition than the company's own familiar faces.

Transfer of knowhow and technology is not necessarily effected only from highly developed to the developing world. On a different scale, similar problems exist in technology transfer between highly developed industries and within the industrially developed world.

Discussion

The setting up of a data base was singled out as an important problem. Data collection should be a function of those working in the plant and not that of the operational research group.

The view was expressed that while the capability existed in most enterprises to establish these bases, costs were a critical factor. The size of the computer will depend on the size of the enterprise, and in particular on the number of basic data elements to be processed. Normally about 2000 essential data elements are involved in such work. Setting up an efficient information flow will in the long run be a cost saving activity for an enterprise, and will justify the initial expenditures for creating this system.

Several problems were mentioned in this connection: the lack of techniques; changes in user requirements once the collection process has begun; and human errors in processing data.

One participant informed the Workshop that in Japan, as a rule, two separate departments were responsible for the design and implementation of management information systems: large-scale data processing and computer application were handled by the Systems Department and the electrical engineering department was responsible for the process control computer. This arrangement eliminates the problem of an imbalance of power.

In some companies in the USA, there is either a special information group or a vice president for corporation information responsible for making policy for EDP design and implementation. In some steel companies, the process control computer is part of the production section, and the systems personnel are under the Financial Department. Many participants expressed the opinion that a special systems department and a vice president for information would be practical in steel companies.

General Discussion

Surguchov opened the session, suggesting that discussion focus on only those subjects not covered in the Workshop presentations. He asked for an evaluation of the organization of the Workshop and for constructive proposals for future ones.

Kopetz pointed out that the integration of the process control computer for continuous casting operations was not discussed at the Workshop. He felt that the coordination and cooperation within the different parts of steel mills is a subject that deserves some attention.

Kuwabara proposed discussing at a future workshop a topic connected with ingot making and integration within a steel plant. The reason for this is that ingot making has not progressed very much as far as computer application is concerned, and work in this area is needed. Another possible subject is the relationship between continuous casting and ingot making. Nippon Steel Corporation (NSC) is conducting such a study. A questionnaire on this topic was sent to a number of Japanese companies; the results indicated that in 1990 the technology of continuous casting will still be in use in about 50 to 55 percent of the steel plants, which means that about one-half the steel must be teamed in the ingot-making plant.

Lanzer indicated that this solution will depend mainly on the features of each plant. Anderson agreed that communication between the steelmaking production unit and the continuous casting one is a major problem area. Several questions arose in this connection. Where does overall responsibility lie? Will one manager be responsible for both plants or should there be separate managers for each of the plants? If there is a separate management, how are priorities set and what communication system should there be between the two units? Surguchov added that integration between different production units may be vertical as well as horizontal, and this aspect of managerial integration should also be discussed.

Oberparleiter inquired about the data requirements of such an integrated system. The main jobs are data transfer and interpretation of data. There are usually many problems--as for example data storage, and it would be useful to discuss the different jobs and ways of creating an integrated system from individual data banks.

In the discussion of the general problems of integration, Hübner added that it would be of interest to all participants to learn about IIASA's activities in this area. Commenting on technical communications in steel plants, Muller stated that there were problems not only within steelmaking plants but also within the "boundary regions"--between BOFs and continuous casting units or between continuous casting units and rolling mills, etc. The basic concept for solving these problems is that they can be applied at any level. A seminar or a workshop on such boundary conditions should be considered.

Kopetz, while agreeing with this viewpoint, stressed an inherent danger. If the problems of boundary conditions are abstracted and treated as such, the concrete aspects may be forgotten so that one is again talking about the abstract. This may result in the real problems not being addressed and solutions that may not be usable.

de Jong elaborated aspects of IIASA's approach to the organization of research. He referred to Dr. Levien's comments at the beginning of the Workshop. The Institute is concerned with problems of a universal and global nature. The work of the Management and Technology area includes studies of the impacts of integrated systems not only in the steel industry but for industry as a whole. He welcomed the suggestion to create a group to study integration problems in BOFs, and in the steel industry as a segment of the economy. The study could be followed up by meetings with steel makers and steel users or planners. Although planning ministries exist in only a few countries, there is enough experience to permit a fruitful exchange of information.

Gifford stressed that most of the participants were from industry, which is evidence of the latter's support for IIASA's work. It is important to keep in mind that industry's support will, however, be maintained only if the emphasis is on the concrete. Surguchov also stressed the importance of industrial contacts. The most optimal ways to establish these is through case studies such as the one on steel.

Lanzer suggested that future topics and participants at workshops be chosen with care.

Kuwabara made several statements. With regard to the dynamic control of BOFs, after listening to the Workshop discussions, he still believed that dynamic control by the sublance method was one of the best solutions. He added that his company planned to combine the sublance, sound meter, and waste gas analysis; if this new technique was successful, it would be an improvement over the existing one. The second point he commented on concerned computerization. Although he was not a specialist in this field, he had studied the problem of integration. With the knowledge obtained at the Workshop, he felt he could hold valuable discussions with his project management in Japan. He had learned much from the Workshop, and would return to Japan to apply this new knowledge. Thirdly, he suggested some subjects for future workshops, adding that he hoped more participants from the USA would be in attendance as well as more representatives from East

European countries. Both Gifford and Lanzer agreed that it would be interesting to make contacts with those operating management control systems in East European countries.

As regards the use of the sublance method, Anderson said that in the UK, and perhaps also in other European countries, the problem is that a universal point has not been reached and a wide spectrum of transitions still exists; however, an end point is hoped for in the near future. While Japanese companies may have achieved good results from the introduction of the sublance in the last minutes of blowing, this was not the case in the UK.

Ogawa supported Kuwabara's view on the use of the sublance for determining carbon content and for temperature measurement. Important information is needed in connection with slag formation, and here sound intensity is implemented for measurement. Most plants in Japan have implemented the sublance method, and are developing an integrated computer system which appears to be different from the European system in operation.

Referring to the presentation of de Jong, Rollé stressed the importance of involving line managers in an information system. He suggested that IIASA consider studying various techniques used to define an information system. de Jong agreed that IIASA could play a role in this area, but that funding for this task within the Management and Technology area was limited.

Rollé observed that since most companies have developed their own techniques to define a system, it would be interesting to hold discussions on this topic. He felt that IIASA would find support among industrial firms for a workshop on this subject.

Gifford stressed two points. High quality, reliable computer software should be available, and users should not have to make modifications to the packages. For this to occur, a dialogue should be set up between suppliers and users. His second point concerned the operators and other personnel in steel plants. In his opinion, the success of the Japanese steel firms had to do with the quality of the key operators and the way they were selected, trained, and motivated. This factor should not be overlooked by countries studying the Japanese experience; he stressed the need to examine it in more detail.

Kopetz referred to the previous statement about supplier packages, stating that he felt, for example, IBM makes considerable efforts to tailor their software packages to user requirements. The real problem is that systems are too complex, and have to be broken down into a number of smaller subsystems in order to be handled. He invited comments on this subject from a representative of IBM.

Rollé replied that there was always room for improvements; new technology offers opportunities in a decentralized systems approach. He agreed with Kopetz that users should not develop their own hardware. IBM has much experience with installations where users have not taken standard software. Surguchov added that it is important to remember that software is approximately 80 percent of the cost of the whole system.

Anderson commented on the personnel factor in steel plants. Life is becoming more automated, with complete control facilities based on the computer. As a result, operators find it difficult to have job satisfaction. Moreover, there is often a communication problem between operators. Lanzer agreed with this observation. At Mannesmann, he stated, there are only four people on one shift, working at different places, and during one shift they may see one another perhaps only twice. Referring to the BOF process, he noted that formerly the operator had contact with the process; now, however, he is only reading signs and reporting results by telephone. At Mannesmann, operations are only made automatic when absolutely necessary, and as much responsibility is left with the personnel as is possible. He felt that IIASA could play a contributive role by studying these problems.

Müller pointed out that the International Federation of Automatic Control had formed a working group to study the social effects of automation. As a member of this group, he welcomed the Workshop's comments on this and advised that he would transmit them to the next meeting of the group, to be held in June.

Kuwabara cited several examples of how Japanese firms are dealing with the human factor in automated systems. He agreed that this topic would be a good one for a future workshop.

Rollé pointed out that at IBM job satisfaction forms are completed annually, and the company was aware of the need to solve this problem. He agreed that it was a common problem to all industries.

Holmberg raised the subject of data bases, stating that they were an excellent tool to help management look into the future. De Jong gave an example of how data base had been used in the USA to predict trends in the automobile industry. He felt that data bases played a major role in forecasting.

Lanzer expressed several points. He supported Kuwabara's statement about the use of the sublance for BOF control. Other information about waste gas analysis and sound measurement should also be used. He stressed the importance of computer application for maintaining quality control in steel plants. The computer, he opined, was only a tool for solving concrete problems, and other methods should not be overlooked.

Miska pointed out the need to develop a model for an integrated steel plant, and Tokuyama stressed the need to examine the problems of total optimization of steel plants from the points of view of productivity, energy conservation, etc.

Both Weiler and Burghardt expressed their satisfaction with the Workshop discussions, adding that they had learned much from the exchange of information among the participants from different countries.

Speaking on behalf of the Management and Technology area, Straszak stated that based on the discussions he felt there was sufficient interest for IIASA to continue its efforts in these directions. IIASA hoped to strengthen its contacts with industry, and in particular to establish good relations with those working on specific problems of mutual interest. He hoped that at future IIASA workshops there would be more representatives from the Soviet Union, Poland, and Czechoslovakia. He wished to express his thanks to the participants for their contributions. Special thanks were given to VÖEST-Alpine, without whose help the Workshop would not have been possible. He hoped that contact would be strengthened since the company was international in scope. He also expressed thanks to IBM for their considerable contribution to the Workshop. He suggested that a small working group be set up, composed of representatives from industry and IIASA.

Several participants offered comments about the organization of the Workshop. Lanzer, Miska, and Muller suggested limiting the length of presentations to allow more time for discussions of real problems. It was unanimously agreed that the Workshop had provided an excellent opportunity for information exchange.

Conclusions

G. Surguchov

IIASA's approach to solving scientific and technical problems may be characterized as *international*, *interdisciplinary*, and *applied*. Research on the application of computers in the steel industry, on the control of basic oxygen furnaces (BOFs), and on the integration of management systems in large plants has proceeded along these lines.

Steelmaking is a universal activity that is of *international* importance, as evidenced by the participation at this Conference of representatives of some ten countries. The BOF is the most widely used steelmaking technology in most developed countries and in a number of industrializing countries. Computer application for the control of this process and for the development of an integrated management system can improve the techno-economic indexes of this technology.

The need for an *interdisciplinary* approach to problem solving in the steel industry has been discussed at this conference within the framework of the IIASA matrix (see Table 1). A number of related subjects were identified for applying system analysis: the man-computer interface, organizational structure, social aspects of computerization, model development and verification, adaptation and optimization techniques, etc. Most of these fall within two research areas at IIASA: Management and Technology, and System and Decision Sciences.

Experience has shown that computer application in the control of BOFs has achieved effective utilization of resources (e.g., materials, energy, labor, capital). For example, a comparative analysis of resource demand of BOFs and of other steelmaking techniques (e.g open hearth) has shown the advantages of the BOF technology. Also, the steel industry is a major environmental polluter; computer control of BOFs has decreased pollution, as for example, by decreasing and preventing slopping.

As to the *applied* aspect of this research, let me point out that industry has always expressed interest in discussing problems of computer control of BOFs, and has been active in supporting and organizing conferences like this one. The discussions following the presentations have been industry-oriented.

A number of technical points were made at the Conference which could be useful to steel industries in different countries. Among the major points are the following:

Table 1. Selected topics connected with the problem of computer application for the control of basic oxygen furnaces.

RESOURCES AND ENVIRONMENT	HUMAN SETTLEMENTS AND SERVICES	MANAGEMENT AND TECHNOLOGY	SYSTEM AND DECISION SCIENCES
ENERGY PROGRAM: Evaluation of energy demand for BOF steelmaking technology as compared with other technologies.			
- Evaluation of resources needed for steel production: ore, coal, water, etc. - Analysis of pollution in the steel industry, steelmaking in particular	- Job conditions in the steel industry - Human settlements in the industrial area	- Man-computer interface - Integration of management systems - Organizational structure - Efficiency of computer application - Social aspects of computerization	- BOF's model development - Adaptation and optimization techniques - Data banks - Computer linkages

- The current trend in computer control of BOFs is to combine a static computer system with a sublance for measuring carbon content and temperature. This is possible as a result of recent developments in obtaining direct information on metal conditions.

- During the past ten years there has been no significant progress in developing and implementing dynamic systems for waste gas analysis sound measurement, and similar activities, owing to inaccurate indirect information.

- For the control and management of BOFs as part of an integrated steel plant, it is necessary to have a computer system that coordinates all production and management activities.

- The implementation of a fully integrated management system has taken place only in new plants that were designed and implemented jointly with control and management systems. The integration of computers in established production systems is a more comprehensive process since many old firms concentrate their efforts on developing a local subsystem that might be needed in the short run.

- There is a lack of communication between customer and supplier in developing and implementing an integrated systems, particularly in developing software packages. One way to overcome this is to use standard packages developed by software houses, and to involve the user's software facilities in order to adapt them to particular conditions.

- Evaluating the economic efficiency of computer systems is difficult for a number of reasons, including the small changes in the parameters of the production sphere, and the fact that effectiveness in the managerial sphere is difficult to determine owing to a lack of evaluation techniques.

- The role of man in operating computer systems remains a key one. The computer-based management system is only a tool to help decisionmaking at all levels, starting from the process control operator up to the top management in a steel plant.

Solutions to problems in areas such as computer systems configuration, software package development, and systems adaptation, are of great importance to the steel industries, worldwide, and this experience could be useful to other industrial sectors as well.

APPENDIXES

Appendix 1

FUTURE DISCUSSION POINTS*

Iron Analysis

How to achieve consistent iron analysis: raw material, contracts? How to achieve reliable analysis figures for BOF plants? Sampling techniques and analysis?

Weighing

What are the recommended techniques? What is the accuracy required and achievable? What are the calibration, checking, and routine maintenance techniques? Is there any radio transmission of crane weights?

In-blow Measurement

Are indirect methods better than direct methods? Are direct methods alone a waste of money?

Models

Should static models be used versus dynamic models? What are the main features of each type? Are iron, scrap, O_2, additives, ladle additions, temperature, and bath height data taken into consideration in the model?

Key Operators

What are the key jobs and how are selection and promotion methods carried out? What is the educational level and payment/motivation system like?

Information System

What type of information is used and what is the size of the network and its configuration?

BOF/Concast Link

Is computer modeling necessary? Are the decisions manual or computer?

Implementation

Are standard supplier software packages good?

*Proposed by representatives of British Steel Corporation.

SUGGESTED TOPICS FOR FUTURE RESEARCH*

Process and production control in the ironmaking area.

Production control in steelmaking and continuous casting.

Production and production control systems in rolling mills.

Optimal level or limit of computerization in the steel industry.

Economic efficiency of computer application in the steel industry.

Total optimization for large-scale steel plants.

Role of computers in the steel industry in the year 2000.

Techniques for defining urgent needs for an information system.

Computer penetration in operating production systems.

Realization of integration using different hardware categories.

Integrated control and management systems: limitations, current trends, perspectives.

Problems of organization and computer application for applied industrial research.

*Proposed by the Workshop Participants.

Appendix 2

Agenda

<u>Monday, 9 May</u>

10:00	Opening Remarks	R.E. Levien
10:15	Computer Application in BOF Technology - A Systems Approach	G. Surguchov
	Discussion	
11:15	Thermodynamical Considerations in LD-Process Modeling	J. Weniger
	Discussion	
14:00	Dynamic Control of Basic Oxygen Furnaces	T. Kuwabara
	Discussion	
15:30	Investigations for Dynamic Operation of the LD Method, A Model of End-point Control	W. Lanzer
	Discussion	
16:45	Economic Aspects of Computer Application in BOF	L. Surguchova
	Discussion	

<u>Tuesday, 10 May</u>

09:30	Adaptation Methods in Investigations, Monitoring and Control of the Oxygen Converter Process	R. Simsaryian
	Discussion	
10:30	The Application of Computer Technique to Process Control of Bottom Blown Oxygen Converters in the GDR	H. Burghardt
	Discussion	

11:30	Integrated Computer Control System for Steelmaking Plants at Mizushima Works	M. Ogawa and Y. Iida
14:00	Integrated Computer Systems in Large Steel Plants: Experience at BSC Teeside and Scunthorpe	J. Gifford and D. Anderson
	Discussion	
15:00	The Computer Control System at the Steel Plants in Wakayama Steel Works	H. Tokuyama et al.
	Discussion	
16:00	Standard Communication Subsystems for Steelwork Application	R. Oberparleiter
	Discussion	
17:00	Total On-line Production Control System in Kashima Steel Works	H. Tokuyama and T. Toyoda

Wednesday, 11 May

09:30	Production Planning and Control at Domnarvets Jernverk	K. Holmberg
	Discussion	
10:30	Strategies for Data Integration	H. Hübner
	Discussion	
11:30	Computer Based Integrated Management Systems for Large Companies: A Design and Implementation Approach	F. de Jong
	Discussion	
13:30	General Discussion and Conclusions	

Appendix 3

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Systems Analysis Applied to Hot Strip Production. A. Cheliustkin. (rr75-046) $5.20/AS95.

The Bratsk-Ilimsk Territorial Production Complex. Proceedings of the 2nd IIASA Conf. on Case Studies of Large-Scale Planning Projects, March 1976. H. Knop, editor. (cp77-003) $14.20/AS255.

The Tennessee Valley Authority Experience. H. Knop, editor. (cp76-002) $41.40/AS745.

Integrated Systems Control in the Steel Industry. State-of-the-Art Review and Proceedings of the Conference June 30-July 2, 1975. I. Lefkowitz, A. Cheliustkin, editors. (cp76-013) $14.40/AS260.

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