INDUSTRIAL DATA PROCESSING APPLICATIONS REPORT

Applications	Steel Melting Process Control
Type of Industry	Steel Producer
Name of User	Lukens Steel Co., Coatesville, Pa.
Equipment Used	IBM 1710 Control System IBM 1713 Manual Entry Units IBM 1053 Print-out Typewriters

Synopsis

The steel industry's first computerized operator guide control for electric furnace steelmaking has been put in operation at Lukens Steel Co., the nation's fourth largest producer of plate steels. An IBM 1710 control system now guides production of carbon steels in the company's two electric furnaces, yet in doing so it activates no part of the steelmaking equipment. Instead, it issues instructions to furnace operators which provide them with precise guides, yet leave them free to exercise their own judgement and responsibilities.

Computer control operations are initiated by entry of a detailed prepunched order card and subsequent production of a heat work sheet. This document provides a complete description and sequential schedule for each heat. Input from IBM 1713 manual entry units begins with loading of charging buckets, each being identified to provide guidance for later furnace charging.

When proper temperature is reached in the furnace, the 1710 issues sampling and process instructions to the operator throughout meltdown. The climax of the control process is the 1710's calculations of the necessary alloy conditions necessary for the proper aim analysis. The operator get his information in both pounds and points. A signal tells him when he should make the additions and how long he should hold them in the bath before he begins to tape the heat. Once the heat has been tapped and poured, the system prepares a detailed heat report listing all events, times and consumption.

Expansion of the 1710 system's applications is being planned on a continuing basis. New applications now being developed include scheduling of facilities and scrap price and availability calculations. Other procedures are also being planned to further exploit the role of a practical operating tool, which the system plays in the melt shop.

"Every melter will admit that you can't make steel without him, and we go along with that," says L. P. McAllister, Luken Steel vice president for engineering and planning. His statement symbolizes the approach taken by the company when it decided to use an IBM 1710 system (see Fig. 1) for its two 100-ton electric furnaces in Coatesville, Pa. This is the first known on-line computer tie-in with large electric furnaces, but the operator has been left in complete control of the complex and often unpredictable steelmaking process. The computer acts only as a guide, giving instructions to the melter but leaving him the responsibility for following these instructions. As McAllister says, "The computer doesn't activate machines; it activates men."

Fig. 1 - IBM 1710 CONTROL SYSTEM at Lukens Steel (IBM 1620 processor shown here) implements the first known on-line computer tie-in with large electric steel melting furnaces.

The electric melt shop at Lukens annually produces 340,000 tons of carbon and low-alloy steel in big-end-down, slab-type ingots, varying in size from 5 to 75 tons. The hub of the operation is two 100-ton, top-charged furnaces, powered by 25,000KVA transformers. These furnaces are charged with 100 percent cold scrap and iron. A rigorous program of scrap identification, inspection and segregation is adhered to as a means of controlling residual chemistries. Most grades are melted in a single-slag process.

In addition to the furnaces, the main structure houses pouring and scrap weighing areas and a chemical laboratory. Supporting facilities include a mold preparation building, scrap storage yards and a stripper building.

The success of electric-furnace steelmaking at Lukens has been confirmed by the addition of a third 145-ton furnace to its original facilities and the installation of a $1-1/2 million, 150-ton vacuum degassing facility.

Background to On-Line Control

Before it went on-line, Lukens Steel Co. began a systematic study of the capabilities of computer systems. Key problems were scrutinized and proposals for suitable systems were made by representatives of control equipment manufacturers. The proposal selected on the basis of operating characteristics and cost factors called for the installation of an IBM 1710 computer control system in the electric melt shop. Following the placing of the order, company management and technical personnel initiated an active implementation program.

The program's objective was to develop a system that would:

1. Aid melting personnel in carrying out their primary task: the consistent production of the highest quality steel with maximum economy.
2. Provide a means of reporting timely, accurate and comprehensive data covering production, raw material consumption, operating technique and operating information for process refinement.

Fulfillment of these objectives was required to implement what has become the first known application of direct on-line computer control for electric furnaces.

The first step in the program was to create a project task force of IBM personnel and employees from Lukens' operating, metallurgy, engineering, maintenance and industrial engineering divisions. Responsibilities for functions, progress reporting, administration, and maintenance of the system were defined and delegated.

It was determined that the computer system would best serve its purpose by functioning as an operator guide rather than activate any portion of the furnace facility. The system would issue guide instructions for the furnace operators to follow during the heat process. This operator guide feature emphasized the continued responsibility that the operator would have in the performance of his duties. The system's primary function would thus be to serve as a specialized tool to assist and guide the operator throughout the entire heat cycle.

Developing the control system required a vast program of information collection and data logging followed by careful analysis. The purpose of these efforts was to determine the significance of as many heat variables as possible.

Initially, data were collected by skilled observers recording and timing all events taking place during the production of a heat. Some 800 heats were studied. They were examined and classified by grade of steel, time required to melt down and refine, chemistry at various stages, flux and alloy additions and charged materials. Most important, they recorded the intangible, but very real difference in the practices of individual operators.

The poor heats, those that experienced excessive delays due to mechanical or electrical breakdowns, broken electrodes and the like, and those in which unusual operating conditions occurred, were eliminated. The balance of the heats was discussed with the operators, supervisors and metallurgists to determine if standard practices had been adhered to. Through these discussions it became evident that while the operators would produce heats within standard parameters, each operator's performance differed in some small way from that of the others.

The way in which some of the better operators accomplished certain functions yielded significantly improved results. These men were consulted and asked to explain the reasoning behind their actions. Some could give sound reasons for performing as they did. Others could only say that what they did worked. It took 18 months of recording, study and analysis to combine the best methods devised by operators, supervisors and metallurgists. The operating philosophies that underlay these methods were reflected in new programs, and computer equations were developed and inserted into the 1710 computer system.

At this point, the mathematical model of the operation and the related computer programs were tested off-line, using a heat simulator (a device that relays simulated instrument data to the computer). In this way, both the programs and the computer system were thoroughly tested out, and a relative performance level was established before on-line operations began. It was the culmination of nearly three years of preparation. It was felt that further efficiency could be built into the initial heat controls thus achieved. However, it was decided that the corrective refinements needed in the system could best be elaborated on the job through actual on-line computer guidance and data logging.

Before on-line operations began, furnace crews and laboratory and other personnel affected were briefed on the nature of the system and its basic workings. Ways of communicating with the computer system were explained to them. In addition, special attention was paid to the intensive training of maintenance personnel, particularly for instrumentation servicing and repairs.

The On-Line System

The IBM 1710 control system now installed at Lukens Steel was selected because of its adaptability to a process that can never be 100 percent preplanned. The system has built-in capabilities which permit it to adjust to existing heat conditions and take corrective action without losing control.

The system is centered around an IBM 1620 central processor with a basic capacity of 20,000 positions of alphanumeric core storage. It is linked to an IBM 1712 multiplexer through which all messages are channeled from or to manual input entry units and instrument sensors. The 1710's system configuration (see Fig. 2) also includes an IBM 1711 data converter which feeds

Fig. 2 - IBM 1710 SYSTEM CONFIGURATION is centered around an IBM 1620 processor (far right). Two IBM 1311 magnetic disc files (behind keypunch) expand mass memory. Linkage to instrument sensors and input units and conversion of analog signals are provided by IBM 1712 multiplexer (in corner against back wall) and IBM 1711 data converter (in front of 1712).

analog signals to the 1620 without need of off-line conversion equipment; an IBM 1623 core storage unit; an IBM 1622 card read-punch; and two IBM 1311 magnetic disc files.

The computer room (see Fig. 3) which houses the bulk of Lukens' computer equipment is close to the furnaces. It is air conditioned and pressure tight. A standby emergency air conditioning system is provided in case the primary system breaks down.

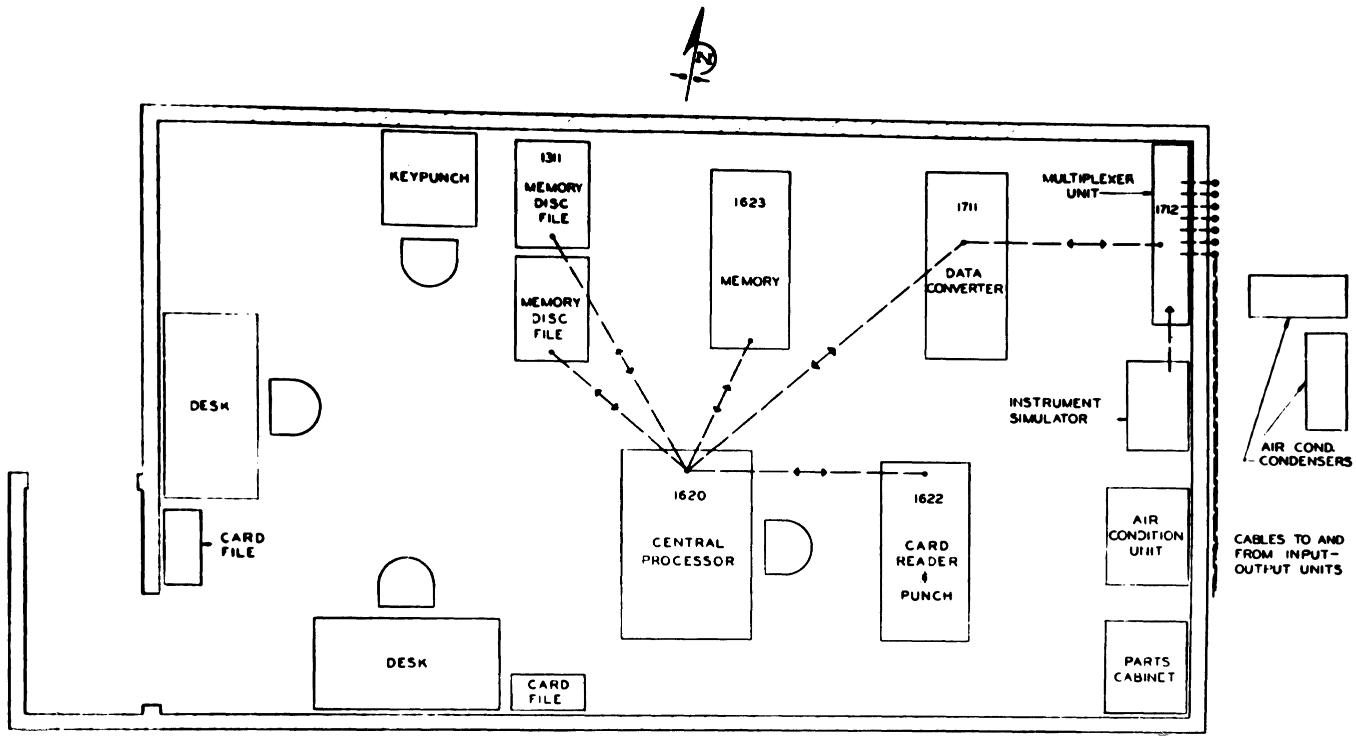

Fig. 3 - CONTROL SYSTEM COMPUTER ROOM, located close to the electric furnaces, is air conditioned and pressure-tight. An emergency air conditioning system is available on a standby basis.

Information is entered into the computer by several methods. Instrument sensors linked to the processor provide minutely detailed process data on bath temperature, oxygen injection, furnace pressure, power input and roof position. Information is also provided on slag-off and tapping as well as the position and temperature of the dust collection duct. Much of this information is transmitted to the 1710 on an interrupt basis. Some is scanned on a programed event-and-time schedule, such as every 3.6 seconds, to permit full computer servicing of priority control programs with maximum speed and efficiency.

Much of the other data input is entered as coded messages dialed through IBM 1713 manual entry units by furnace operators or heat analysts. These units are located next to each furnace, in the chemical analysis laboratory and in the shop office. Additional information is manually fed into the system through pushbutton consoles at each of the three electronic scales.

The scales, used for weighing scrap charges and alloy and flux additions, automatically relay material weights to the computer. The material's number code and heat sequence number are entered for positive identification on the pushbutton console. These data provide computer input for heat control calculations. They are also stored for later production of reports and checked against predetermined materials control standards.

The IBM 1713 manual entry unit (see Fig. 4) is equipped with 12 rotary switches, an execute button and a signal light which indicates computer acceptance of data entered. The furnace operator feeds specific information into the system by dialing number codes and then executing the message. Much of this information is entered by the operator in response to guide instructions issued by the computer. Other entries are made to indicate delays or to permit the operator to override computer instructions, if conditions dictate it.

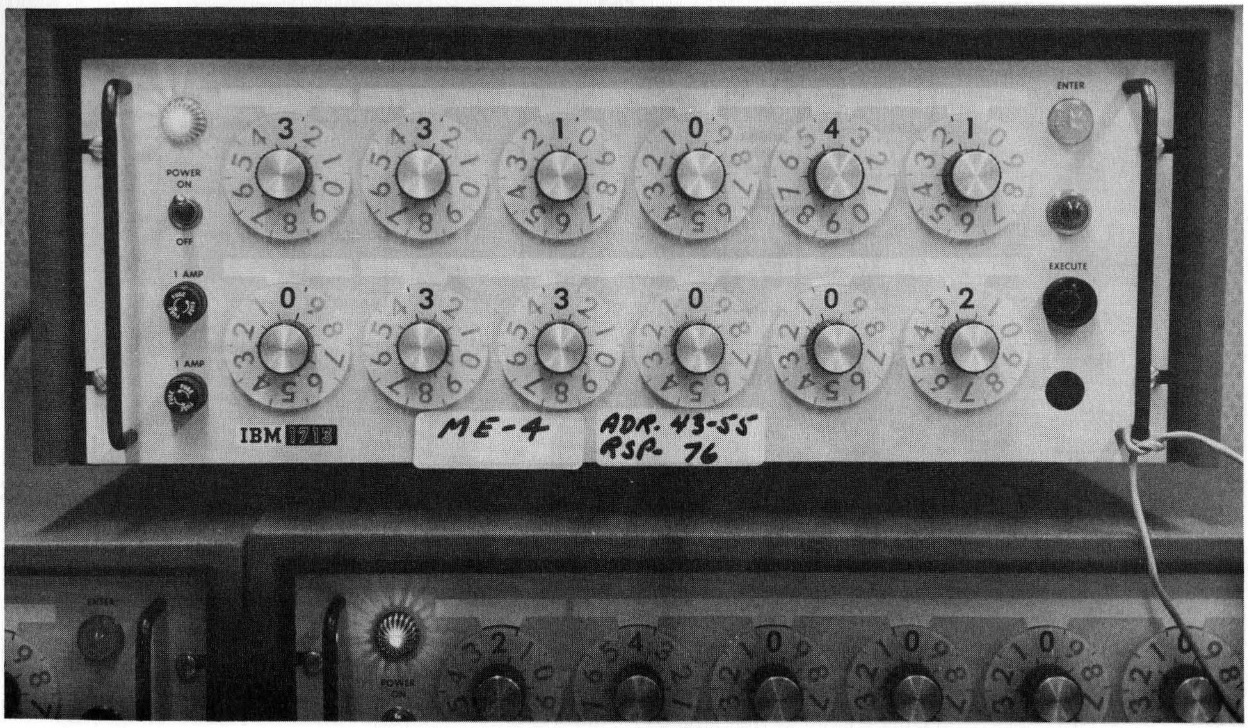

Fig. 4 - IBM 1713 MANUAL ENTRY UNITS, located near furnaces, in the chemistry laboratory and in the shop office, are equipped with 12 rotary switches to permit direct entry of process information and management requests into computer memory.

The IBM 1713 manual entry units, save the one in the chemical laboratory, are also equipped with an IBM 1053 print-out typewriter (see Fig. 5), capable of printing 888 characters per minute. Both units are protected by special air-filtered, pressurized housings from the severe dust and heat conditions which are common in melt shops. A heavy-duty plastic window provides visibility, and access panels permit servicing of the units, replacement of paper rolls and insertion of forms.

Coded messages fed into the computer are translated and reproduced on the typewriter. Computer instructions similarly appear as typewriter print-out. This unit thus provides communications from the computer to the operator.

Punched card data are automatically produced during a heat's course, thus providing a second method for information recording within the system. Information thus retrieved can be used for analysis and updating of control equations, development of mathematical models for new grades of steel, analysis of grade costs, investigation of metallurgical control factors, or for raw materials inventory control.

On-Line Procedures

Computer heat control begins as soon as the system receives a prepunched order card with all necessary heat information: customer, quality, grade, chemistry specifications, ingot sizes, deoxidation schedule and heat sequence number. Up to 100 heat requisitions at a time can be loaded into computer memory.

The next step is a heat work sheet, computer produced upon receipt through the manual entry unit of a shop office request. Besides the information from the order card, this document lists the specified amounts of scrap to be charged, the order in which the ingots are to be poured, and the types and amounts of alloy additions and fluxes that are to be preweighed.

The scrap weigher then loads the charging buckets as soon as he receives the heat worksheet. Each bucket load is identified, and scrap types and weights are instantly entered into the system. Every bucket is identified by the computer to prevent mixing of scraps within heats. The furnace crew similarly follows the heat worksheet listing as flux and alloy additions are weighed and information transmitted to 1710 memory.

The 1710 begins to log data as soon as the furnace operator notifies it that the furnace is ready for charging for a given heat sequence. As it is now programed, the 1710 acts only as a data logger during the charging and meltdown periods with such notable exceptions as the identification of buckets. This information collected during weighing is now used to check that buckets are charged in the proper sequence. The operator notifies the computer before he charges each bucket, and the system promptly advises him, via the automatic typewriter, of any errors he may have made.

When the charge is about 85 percent melted, scrap is usually pushed back with the charging machine to clear the doors. Shortly after the computer has been notified of this, the first bath temperature can be taken. As soon as the first immersion thermocouple reading has been taken by the operator and that reading exceeds 2790° F, the computer starts to guide the melter. The output typewriter prints out end of charge and meltdown and shows total melt and kilowatt hours.

Then, the computer starts issuing its instructions: take samples for carbon pin, sulphur pin, alloy tests, slag. Based on the original bath temperature, the 1710 calculates the power setting and approximate time at this setting. When the power is back on, the system automatically senses the tap and rheostat settings and prints them out, telling the melter how to get to the next stage in the meltdown cycle.

After the melter has determined the steel's carbon content, he enters it directly into computer memory. The balance of the chemistry is established through spectographic analysis in the chemical laboratory and entered into the system through the manual entry unit located there. The 1710 relays these results to the operator and also uses them in heat control calculations and heat records. It then prints out the amount of oxygen which should be blown into the bath and the rate at which it should be introduced. After the operator has complied with these instructions, the computer monitors his performance and prints out a record of events.

Similarly, the operator and the system continue to communicate during the entire refining period. Information which the computer receives from the operator and instrument sensors is checked, processed and stored to provide the basis for issuance of new guide instructions. Each event taking place during the heat is noted by the 1710 at the exact time that it occurs. In addition, a record is made of all deviations from guide instructions on the part of the operator.

The climax of the control process is the computer's calculations of alloy additions necessary for the proper aim analysis. The melter gets his information in both pounds and points. A signal tells him when he should make the additions and how long he should hold them in the bath before he begins to tap the heat.

Fig. 5 - **IBM 1053 PRINT-OUT TYPEWRITER,** located in the same console as the 1713 manual entry unit (at base), reproduces computer instructions at a rate of up to 888 characters a minute.

Once the heat has been tapped and poured and the final chemistry determined, the computer prepares a heat record on shop office command. In addition to grade, quality and similar information, the system prints out a real-time log of all primary events, calculated alloy efficiencies, charge summary, addition materials, power consumption, electrode and oxygen usage yield figures and a heat time summary. The computer at this time does not print information regarding pit pouring details. This information is filled in by hand by office personnel.

Results and Future Plans

From the start, the IBM 1710 control system has operated on a round-the-clock basis, providing guidance during the refining period of carbon steel grades. "We have found that the programs for oxygen injection rate and volume, for heat input and power settings, and for alloy additions have performed in virtually perfect fashion since start up," says Daniel O. Gloven, Lukens superintendent of melting. As a result, it was decided to extend computer guidance to all phases of the process.

The big gain from two-way computer/operator communications, Gloven continues, is uniformly high quality. C. H. Alexander, a one-time melter, who is now assistant to the plant manager, adds to this reaction by pointing out that examination of a random assortment of heat records shows no more than one point or two of the aim point in either carbon or manganese for any heat.

"A company like ours has got to do it this way," he adds. "We used to give a melter a range of carbon or manganese - say 5 to 10 points for carbon and maybe 20 points for manganese.

"Customer specs are a lot tighter today. We can't afford that kind of range. Now the melter gets an aim point, and we want to help him make it. It's the only way to be sure you're controlling tensile strength and yield point."

Perhaps as important, the initial success of computer control has created an atmosphere of confidence among melters and crews which cannot but aid the project's final success. Similarly, by incorporating the best known steelmaking practices into the computer program, Lukens is upgrading all crews to consistently high performance levels in several refining areas. The maintenance of closer tolerances on carbon removal rates is a notable example. Furthermore, the automatic collection of heat data via computer output cards is providing process information for off-line analysis. This permits the continuous improvement of the electric melting process. This same information also permits close analysis of each crew's performance.

The biggest problem so far encountered at Lukens is in the area of instrumentation. The need for extreme accuracy in the sensing instruments which supply information to the computer is a vital one and continuous improvements will have to be made. Similarly, improvements will continue to be sought for programs now on the air to refine them and make them still more effective. Each program is being reviewed in detail and revisions are being made, where applicable, for greater practicality and accuracy. Beyond this, other development projects involve guide controls for charge and meltdown, melt-in carbon predictions and refining of low-alloy grades.

Beyond the attainment of the company's immediate goals, Lukens executives foresee a great number of problems for which the 1710 can be used in its present configuration or in an expanded version. An example is the effective scheduling of facilities, an off-line computer application which has already been successfully implemented in several steel plants.

Since the melt shop at Luken is basically a job shop, the company's problems in this area are unusually complex. Manufacturing a specialty plate product requires the use of some 20 different mold sizes and the pouring of approximately 300 different chemistries. With a constantly changing product mix, mold sets cannot be rotated according to any predetermined plan, even on a relatively short term basis. In addition, with the company's expansion and the application of new steelmaking technologies, planning of day-to-day operations is becoming progressively more complicated. It will thus become more difficult for shop management to arrive at the same effective and consistent decisions. A computer routine would being consistency to solution of scheduling problems.

The cost of the metallic charge is another factor that vitally influences the profitability of a melting operation. A cold charge operation is obviously more sensitive to price fluctuations in the scrap market. Yet, price alone cannot dictate the charge. Material availability and metallurgical and operating restrictions must also be taken into account. Ever since mid-May 1963 Lukens has been using an off-line IBM 1620 computer system to develop charging strategies. At regular intervals - usually every four weeks - all pertinent variables are fed into this off-line unit, and the scrap mix to be used for each grade is determined.

Although the 1620's calculations are precise, a situation exists there in which many of the conditions are subject to frequent change. Scrap price, availability and product requirements fluctuate. A computer at the shop level, programed to absorb a constant flow of current information, will permit the continuous attainment of maximum charging economies.

There are other examples of the manner in which computer capabilities can be applied to melt shop problems, and Lukens executives confidently foresee their implementation. Their attitude is exemplified by that of Gloven who says, "our initial experiences have demonstrated that a computer system.... has a place in a modern melt shop, not as an oddity, but as a practical operating tool."