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Computerized control in a large electric-arc furnace shop

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SYNOPSIS

An account is given of the use of a computer to control the performance of three ultra-high-powered electric-arc furnaces in Iscor's steelmaking plant at Vanderbijlpark, South Africa. Several of the reports and graphs printed by the computer are reproduced.

SAMEVATTING

Daar word verslag gedoen oor die gebruik van 'n rekenaar om die werkverrigting van drie ultrahoëkrag-elektriese boogoonde in Yskor se staalvervaardigingsaanleg in Vanderbijlpark, Suid-Afrika, te beheer. Verskeie van die verslae en grafieke wat die rekenaar uitgedruk het, word weergegee.

INTRODUCTION

What is process and performance control, how do supervisors and managers control the performance of a particular plant, and what tools are available to them for making sound and effective decisions? This paper attempts to provide answers to these questions by demonstrating a practical solution for a steelmaking facility. It has been proved without doubt that the management information system described here has contributed largely to the high performance of Iscor's Electric Arc Furnace Shop in recent years.

THE ROLE OF A PROCESS COMPUTER

A block diagram illustrating the role of a process computer in controlling a process, as well as in promoting closer control at different levels of management responsibility, is given in Fig. 1.

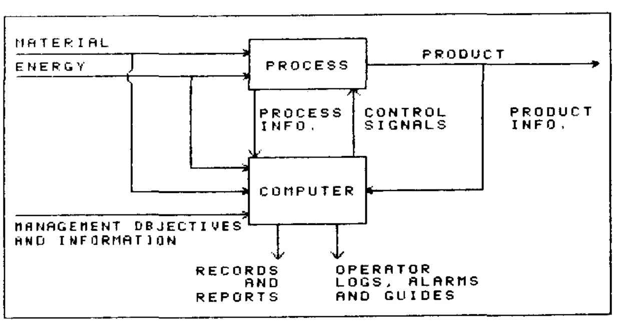

Fig. 1—A computer-controlled process system

The computer receives information from several sources, both automatically and manually, and, after appropriate analysis of the information, it prepares the outputs and presents them in the form of direct signals to the process itself, guides and reports for operators, and reports for staff of a higher level. The outputs for the Electric Arc Furnace Shop at Iscor are described below.

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DIRECT SIGNALS TO THE PROCESS

These signals are used, for instance, for closed-loop on-line process control (particularly control of the arc length and energy input) by means of a static power input program. Another example of their use is control of the total hourly Works maximum energy demand through control of the arc furnaces as a primary consumer of electrical energy.

Fig. 2 is a printout of important electrical parameters that are considered necessary for proper control of the melting process. Parameters in the power input program can be varied in order to optimize the melting process so that productivity (tons per hour) can be increased and major operating costs, such as those for the consumption of energy, electrodes, and refractories, can be reduced.

The melting process advances through a number of steps, and the computer changes electrical settings on-line for each step as it obtains data from the melting program. The on-line feedback from the process to the computer is consumed energy in kilowatt-hours. The computer provides the signal for changes in electrical parameters for each step, such as transformer tap setting and arc length reference (expressed in electrical signals).

Balancing of the three phases can be controlled by a comparison of the current readings for each phase and the accumulation of these values over a period of time.

GUIDES AND REPORTS FOR OPERATORS

The following are examples of these guides and reports:

(1) calculations of alloy additives for each heat,
(2) condensed heat reports for furnace operators,
(3) identification of delays, and
(4) control of the scrap input.

Calculation of Alloy Additives

The masses of alloys to be added into the ladle during tapping are calculated by the computer for each heat individually, and are displayed on the cathode-ray tube (CRT) in the furnace pulpit. The computer bases its calculations on the aimed-for analysis for a certain grade of steel and the latest available bath-sample analysis. The calculation is updated with each bath sample that

DATE 84/06/01	HEAT NO. 1E542	SCHEDULE 6	INTEGRATION TIME 6 MIN.											
			ARC				SECONDARY CURRENT				STEP AVERAGE			
TIME	STEP	TAP	REF.	MW	MVA	COS Φ	kA(A)	kA(B)	kA(C)	COS Φ	kA(A)	kA(B)	kA(C)	TIME
00:04	1	12	5	35	51	0.68	60.2	60.8	61.8	0.68	60.2	60.8	61.8	3min
00:07	2	17	12	45	60	0.77	59.3	59.9	60.9	0.77	59.3	59.9	60.9	4min
00:11	3	17	15	44	54	0.81	55.0	55.7	56.3					
				44	55	0.80	56.4	56.8	57.5	0.81	55.5	56.1	56.7	9min
00:20	4	17	13	45	56	0.80	57.2	57.8	58.4					
				45	57	0.79	58.3	58.5	59.0	0.79	57.5	58.0	58.6	8min
00:28	5	17	10	47	60	0.78	62.0	62.1	62.5	0.78	62.0	62.1	62.5	4min
00:32	6	17	8	48	63	0.77	65.3	65.7	65.9	0.77	65.3	65.7	65.9	3min
00:35	7	17	5	49	66	0.75	68.1	68.4	68.7	0.75	68.1	68.4	68.7	3min
CHARGING SECOND BASKET OF SCRAP														
00:42	8	12	5	34	51	0.66	62.0	61.8	61.9	0.66	62.0	61.8	61.9	1min
00:43	9	17	10	45	61	0.74	63.0	63.1	63.4	0.74	63.0	63.1	63.4	3min

Fig. 2—Excerpt from a power-engineering log for one heat

becomes available.

Several tables of various kinds are stored in the computer for use in these calculations and are identified by such titles as 'steel grade' and 'secondary ladle treatment applied'.

The alloy yields vary with, among other factors, steel temperature, oxygen content of steel, tapping duration, and slag carry-over. Yields can be optimized either off-line by the use of historical data or by continuous updating by the computer.

Condensed Heat Report

A condensed heat report (Fig. 3) may be requested by the pulpit operator immediately after a heat has been tapped. Since arc-furnace steelmaking is a batch process, variations occur from heat to heat and should be closely analysed and controlled by the melter. All the heat data that are considered to be important to the operator are displayed, which enables him to judge his own performance.

Identification of Delays

As production delays can be very costly on high-output melting units, it is imperative that an efficient system of time management should be established. Delays have a negative influence, not only on production, but also on the three major conversion costs because of heat dissipation, electrode surface oxidation, and refractory erosion. The objective should be to have power on the furnace for at least 75 per cent of the available operating time.

A system has been developed at Iscor by which 'power off' periods exceeding 2 minutes are recorded on-line by the computer. The melter has to identify these off-times by keying in a predetermined code applicable to the specific delay. As shown in Fig. 4, there are nineteen main groups of delay reasons encompassing all the possible causes of delays. Each group is subdivided into sets of fully descriptive reasons.

Off-times shorter than 2 minutes are called 'unidentified off-times' and are summarized by the computer for each heat.

Details of the various off-times, including the necessary 'power off' periods for charging, electrode additions, tapping, etc., during melting of a heat are stored by the computer and printed as event logs for each heat. Further processing into assorted daily delay reports is also performed by the computer. The identification of all delays and

START HEAT 07 05	TAP/TAP TIME 2 07	DELAYS 9 min.	CAST NO. A102184
START TAP 09 12	NET MELT TIME 1 58	NECESS.POWER OFF 16min	AIMED GRADE SK7 26
END TAP 09 17	POWER ON TIME 1 42	ENERGY CONS. 496 kWh/t	FINAL GRADE SK7 26
MELTER BEHR J.	SCRAP CHARGED 169.8 t	FURN.YIELD 91.0%	PHASE BALANCE [kA]
OPERATOR VISSER G.	LIQUID STEEL 154.6 t	TEEM.YIELD 98.1%	A B C
	GOOD INGOTS 151.7 t		61.5 63.2 62.8

TEMPERATURES		TIME	ANALYSIS :	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
TAP	1621	09:11	MELT IN	17	15	6	28	-	6	7	3	2
LADLE	1565	09:19	TAP	08	11	7	19	-	7	6	2	2
TEEM	1555	09:28	PIT	18	95	7	18	5	7	6	2	2

Fig. 3—Example of a condensed heat report

GR.	DESCRIPTION	GR.	DESCRIPTION
01	MAJOR FURNACE REPAIR	11	SCRAP
02	PREVENTIVE MAINTENANCE	12	OVERHEATING
03	GUNNING / FETTLING	13	PREVENTIVE MAINT.(REFRAC.)
04	ELECTRICAL / MECHANICAL	14	SPONGE IRON FEEDING
05	ENERGY SUPPLY	15	MISCELL.(MAINTENANCE)
06	ELECTRODE BREAKAGES	16	MISCELL.(PRODUCTION)
07	ROOF	17	PLANNED-PROD. STOPPAGE
08	WATERLEAKS	18	NO DELAY CODE ENTERED
09	CHARGING CRANES	19	NECESS. POWER OFF PERIODS
10	TEEMING BAY / DEGASSERS		

Fig. 4—Identification of 'power off' periods

progressive summaries of delays during the course of a month make it possible for detailed investigations to be carried out as to the action needed to minimize delays.

Control of Scrap Input

Proper scrap blending and loading are most important for efficient steelmaking in an arc furnace. Many problems during the melting process have their origin in the scrap bay. The types of scrap used, and the order in which they have been charged into the buckets, must be known. These records are necessary for subsequent investigations into possible problems like electrode breakages, high sulphur or residuals, and poor yields.

For this purpose, a log (Fig. 5) has been created to accurately record all details of the loading sequence. This log must be checked by the scrap operator on a heat-to-heat basis, and feedback from the furnaces may call for adaptations in the loading practices.

REPORTS FOR SUPERVISORS AND PLANT MANAGEMENT

Process information, once 'captured' on an on-line computer control system, can be used to keep management at all levels more closely informed about the process performance, and forms the basis of sound and efficient decision-making.

Iscor utilizes the large data-processing capacity of the

84/05/17 HEATNUMBER 3E265 CAST NO. 6335

SCRAP CHARGED:

BUCKET NO.11 SCALE NO.3			BUCKET NO.9 SCALE NO.5		
CODE	NO.	[t]	CODE	NO.	[t]
4	SHEETS,INT. RUSTY	20.1	4	SHEETS,INT. RUSTY	41.9
7	HECKETTS B	38.6	57	HEAVY CROP ENDS	36.0
42	MOULD SCRAP	9.9			
24	DRILLINGS	5.9			
23	MIXED,RUSTY	17.9			
		----			----
	TOTAL SCRAP WEIGHT	92.4			77.9
BUCKET ADDITIVES:					
92	LIME	6.0	93	COKE	2.5
95	FLUORSPAR	0.4			
96	RAW DOLOMITE	3.5			
93	COKE	2.0			
		-----			-----
	TOTAL BUCKET WEIGHT	104.3			79.4

TOTAL SCRAP WEIGHT 170.3
TOTAL Fe UNITS IN SCRAP 159.7

Fig. 5—Material-input log

process computer to supply immediate feedback of important control parameters to operators and shift supervisors for short-term analysis (i.e. on a heat-to-heat basis). Members of the plant management, on the other hand, require more-condensed versions of a variety of process data on a 24-hour basis (to be available early each morning) to enable them to evaluate the previous day's performance. On a weekly and monthly basis, they require even more-condensed information for medium- and long-term planning, budgeting, and decision-making.

Each manager should receive only sufficient information to enable him to control his own area of responsibility, as well as the areas that he has delegated to his subordinates (by using 'management by exception' techniques).

To ensure that the managers are not flooded with irrelevant data, their information needs must be derived from clear objectives or key-performance areas. One possibility in the establishment of what constitute the really important control parameters is the use of Pareto's rule (i.e. 20 per cent of the items contribute to 80 per cent of the total costs).

CONTROL PARAMETERS

In arc-furnace steelmaking, the following control parameters need close attention.

Yields

The ratio of prime steel produced to scrap input must be maximized. The same applies to expensive alloys and other raw materials such as lime and carbon.

Time

The availability and utilization of the melting units must be optimized by the minimization of delays, proper planning of preventive maintenance, and extended refractory campaigns.

Main Conversion Costs

The importance of the three major cost variables is clearly illustrated in Fig. 6.

Energy Consumption

Energy represents the largest single operating cost factor in arc-furnace steelmaking. Since the furnaces at Iscor were converted to watercooling, time utilization has become more important in preventing energy losses via the cooling system. The effective use of high-cost energy is possible only by proper control. Energy consumption in kilowatt-hours per ton of molten steel is calculated for each heat, summarized daily, and accumulated until the end of the running month. Any variation from the set standard (e.g. 480 kW·h/t) can be recognized in time to allow for corrective action such as adaptations to the power-input program and the scrap input.

Electrode Consumption

The consumption of electrodes can be controlled only if accurate records are kept.

Each new electrode is weighed and identified (with a running number), and the details are entered into the computer. When a new electrode length is added onto any of the three phases on the furnace, the operator has to enter into the computer the number of the new length and the phase to which it was added. The computer calculates exact consumption figures, in kilograms per ton, for each phase and each furnace (Fig. 7).

A large number of factors influence electrode consumption. Current settings (or arc length) in the melting program, heat times, and scrap blending have the largest effect and are therefore the factors most requiring optimization.

Refractory Consumption

There is an optimum relationship between guniting material and brick consumption, and the computer can plot this on a graph over the duration of a furnace campaign. With this information, plant management can decide during a campaign whether it would be economically viable to continue with the campaign, or to plan for intermediate brick repairs or a full relining (Fig. 8).

Performance

After having established the most important control

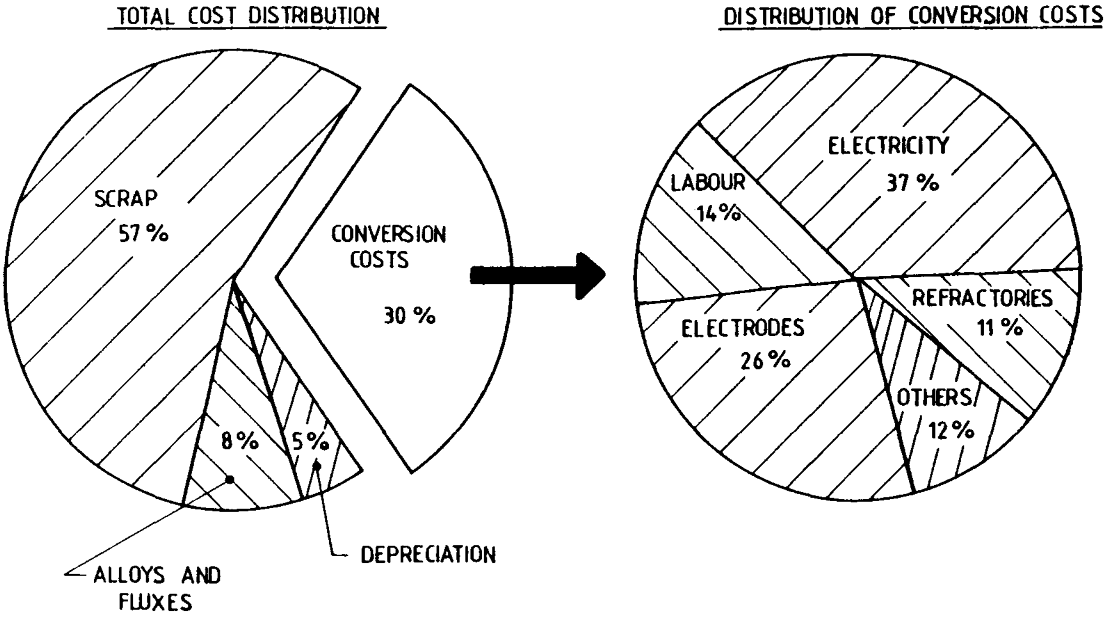

Fig. 6—Distribution of arc-furnace costs

PHASES	A	B	C	TOT./AVER.
NEW ADDITIONS	104	94	98	296
ADDITIONS INCL. COLUMNS				317
BREAKAGES	10	15	8	33
kA (AVERAGE)	63.6	64.6	62.9	63.7
NUMBER OF HEATS				648
SPECIFIC CONSUMPTIONS (kg/ton)				
NEW	1.30	1.23	1.26	3.79
NET	1.22	1.15	1.16	3.53
GROSS	1.28	1.22	1.24	3.74

Fig. 7—Monthly record of electrode consumption

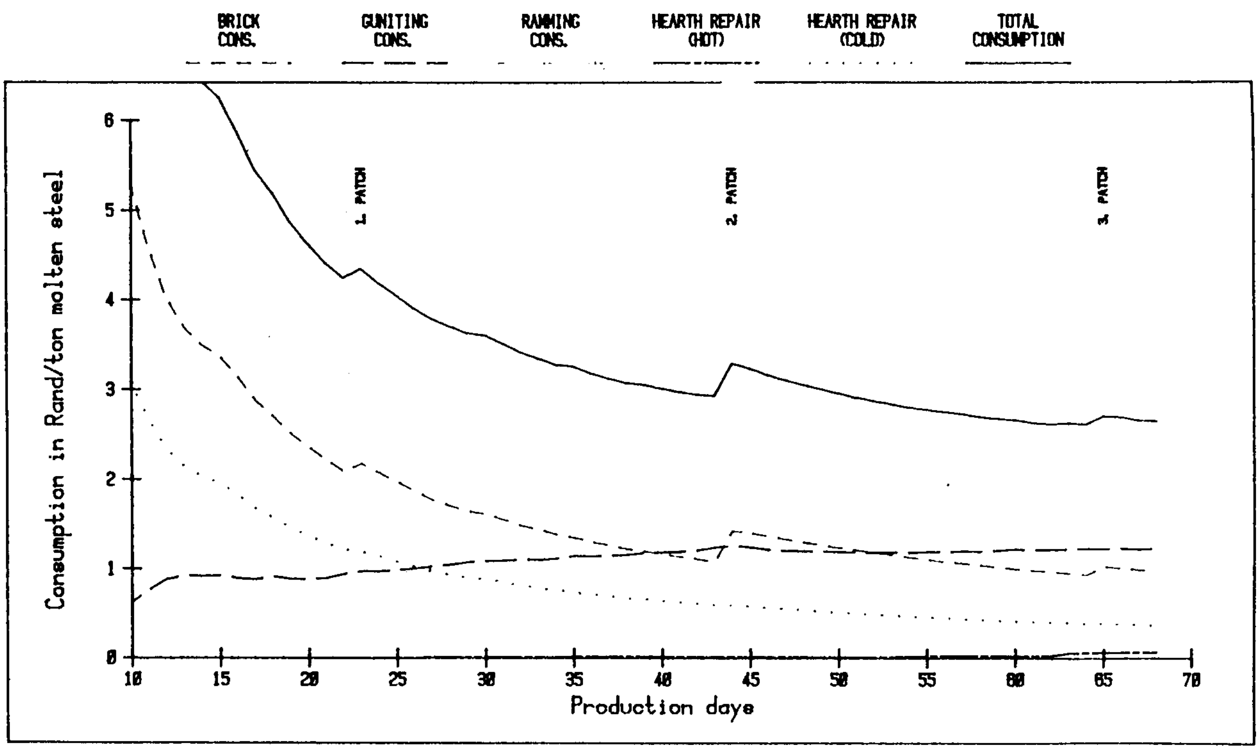

Fig. 8—Graph of optimum cost for refractory consumption

parameters and how they are processed by the computer, one must go a step further and develop meaningful reports for the different levels of the plant hierarchy.

A number of summarized daily reports have been developed at Iscor, which provide supervisors and plant management with a means of identifying deviations from the set standards. Important parameters relating to yields, time management, productivity, and major consumptions are printed in one line for each heat. By comparing the columns, one can immediately detect deviations from standards (Fig. 9). If more details are required, one refers to the detailed logs of events or the heat logs for specific heats.

The Plant Manager looks up only the daily averages and cumulative trends. Fig. 10 shows these for the total plant, but they are also available for each individual furnace.

All the important control variables are plotted in the form of trend graphs on a monthly basis (Fig. 11). If the trends show that the envisaged objectives will not be met at the end of a particular period, these early indicators trigger action plans (or specific objectives) to bring them into line with the target objectives.

Historical data are averaged over yearly periods, and the previous three years are indicated in histogram form on the left side of the graph for comparison. The values for the preceding six months, always beginning in January or July, are drawn as a line to show the trend, and the values for the current six months are drawn on the right side of the graph next to a target value with which they

HEAT NO.	GRADE	SCRAP LOADED	Fe IN SCRAP	LIQUID STEEL	GOOD INGOTS	BUTT	MOULD TYPE	TAP TEMP	LADLE TEMP	TEEM. TEMP	TAP/TAP TIME	NET.MELT TIME	POWER ON TIME	kWh/t
3E063	SK7 29	161.8	150.7	154.6	151.3	2.7	DM	1621	1576	1558	1:43	1:39	1:27	452
2E184	SK7 12	172.2	161.9	158.5	154.8	3.4	XA	1607	1564	1553	2:02	1:39	1:28	464
3E064	R3 01	161.6	151.9	148.7	144.2	4.0	W	1607	1580	1568	1:50	1:46	1:25	463
2E185	R3 01	170.9	160.0	164.4	163.5	-	WT	1621	1575	1561	1:45	1:35	1:23	418
3E065	R3 01	159.7	148.3	154.4	149.6	3.6	XA	1627	1589	1559	1:59	1:53	1:30	462
2E186	SK7 66	171.6	162.5	159.9	156.0	3.9	DM	1620	1573	1563	1:50	1:43	1:33	487
3E066	SK7 65	159.6	147.1	154.3	152.9	0.8	DM	1608	1572	1558	1:50	1:45	1:33	488
2E187	SK7 47	170.6	158.7	155.7	150.8	3.9	DT	1608	1565	1555	1:50	1:43	1:24	441

Fig. 9—Excerpt from a daily production report for supervisors

INPUT / OUTPUT		AVERAGE CONSUMPTION		AVERAGE MELTING TIMES		AVERAGE YIELDS	
LIQUID STEEL :	3858 t	NO. OF HEATS	: 25	POWER ON	: 1 hr 33 min	FURNACE :	90.8
GOOD INGOTS :	3763 t	OXYGEN CONS.	: 22.2 Nm^3/t	NET MELTING	: 1 hr 48 min	Fe :	95.6
SCRAP LOADED :	4237 t	ENERGY CONS.	: 485 kWh/t	TAP / TAP	: 1 hr 57 min	TEEMING :	97.7
Fe IN SCRAP :	3983 t	ELECTRODE CONS.	: 3.1 kg/t			TOTAL :	88.8

Fig. 10—A daily production report for supervisors, the yields being expressed in percentages (Nm^3 = normal cubic metres per ton of liquid steel, and t = tonnes of molten steel)

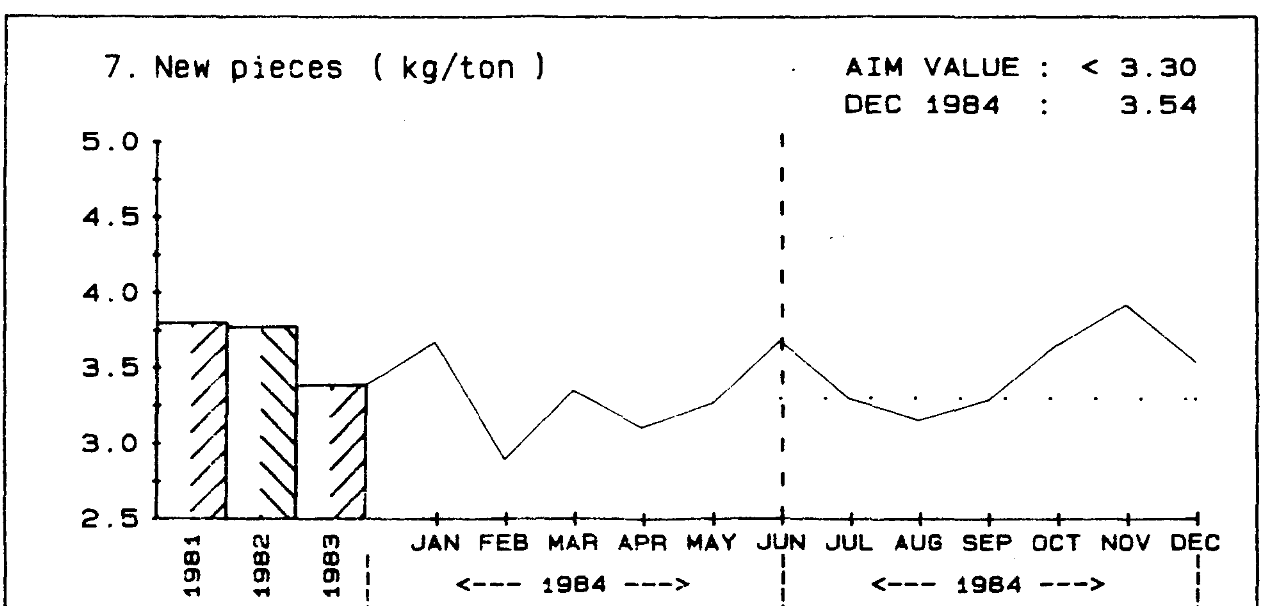

Fig. 11—Example of a trend graph for an important cost parameter (electrode consumption)

can be compared. The computer program automatically takes care of all the changes required, and updates the graph at the end of a six-month period.

The control computers can also be used in the preparation of desired production summaries based on operating unit (to distinguish between the performances of the three furnaces), on product (different steel grades), on shift, and on operating crew (represented by the first melter) at weekly or monthly intervals. An example of a monthly comparison between products of different types is shown in Fig. 12. Because of additional refining activities and a higher amount of alloy additions, killed grades must be tapped at higher temperatures and take longer to melt. The yields are normally higher.

Operational control concerns not only the measuring of outputs, but also the appraisal of workers and the improvement of their efficiency by proper training and retraining. This is impossible unless all the factors pertaining to the achievement of improvements are evaluated and presented in such a way that workers can have access to them, can understand them, and are able to act on them. Healthy competition between shifts and operating crews has been found to be a valuable tool in the achievement of workers' participation and continuously improved performance.

A performance coefficient has been introduced, taking into account energy consumption, power-on time, and net melting time. The computer calculates this factor from each of these important variables by comparing the melter's performance with the shop average for the particular month, taking into account the product mix he produced (Fig. 13). A factor of less than 1,0 means that the furnace crew did better than the shop average, and of more than 1,0 that the crew performed worse than average. One can immediately see where improvements are possible, and whether the crew needs further train-

GRADES	RIMMING	SEMIKILLED	KILLED	TOTAL
NO. OF HEATS	184	392	72	648
				AVERAGE
MOLTEN STEEL [t]	152.8	154.8	157.6	154.5
GOOD INGOTS [t]	148.6	151.1	152.6	150.6
SCRAP [t]	169.1	170.3	171.7	170.1
Fe IN SCRAP [t]	159.5	160.3	162.7	160.3
TAP / TAP	131	133	137	133
POWER ON	99	103	107	103
NET MELT	117	121	125	120
ENERGY (kWh/t)	493	512	529	509
OXYGEN (Nm^3/t)	24.5	20.3	19.1	21.4

GRADES	RIMMING	SEMIKILLED	KILLED	AVER.
TAP TEMP. [C]	1612	1623	1662	1624
LDL. TEMP. [C]	1564	1567	1596	1569
TEEM. TEMP. [C]	1554	1550	1540	1550
IDEAL TEMP. [C]	1556	1550	1539	1550
FURNACE YIELD [%]	90.3	90.9	91.8	90.8
Fe YIELD [%]	94.8	95.6	95.9	95.4
TEEM. YIELD [%]	97.3	97.7	96.8	97.5
TOTAL YIELD [%]	87.9	88.8	88.9	88.5
BUTTS [t]	2.6	2.4	3.3	2.6
SLAG INGOT [t]	1.7	2.3	2.0	2.1

Fig. 12—Monthly report on important control variables (based on different grades of steel) for May 1984

GRADES	R's	SK's	K's	FeSp	STORE
HEATS	23	69	14	3	3
kWh/t	484	509	530	549	532
POWER ON	94	101	107	108	109
NET MELT	116	118	125	132	130

TOTAL HEATS	112
AVERAGE CURRENT	63.9 kA
ELECTRODE BREAKS	3
ELECTRODE ADD.	54

AVERAGE FIGURES OF IMPORTANT VARIABLES :	kWh/t	POWON	NET MELT	TAP/TAP
	508	101	120	132
	OXY.REF.	OXY.TOT.	P.ON/N.M	P.ON/T.T
	6.9	21.0	84.4	77.0

PERFORMANCE :	kWh/ton	Power on	Net melt	Total
	.999	.986	.999	.984

REFRACTORY CONS:	GUNITING	ROT. GUNIT.	HEARTH	TOTAL
(kg/ton)	2.08	0.38	0.28	2.74

AVERAGE VALUES USED FOR PERFORMANCE :	R's	SK's	K's	FeSp	STORE
kWh/t	490	508	529	552	522
POWON	98	103	107	108	105
NET MELT	117	120	125	129	124

Fig. 13—Monthly melter performance

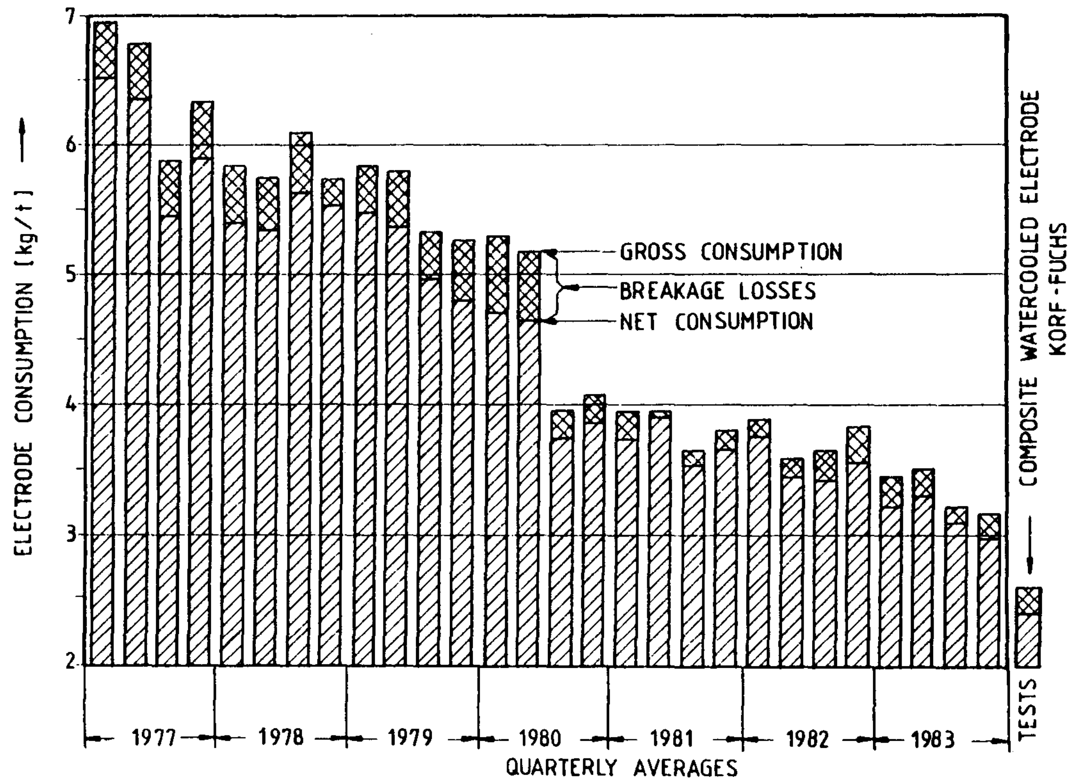

Fig. 14—Reduction in electrode consumption, 1977 to 1983

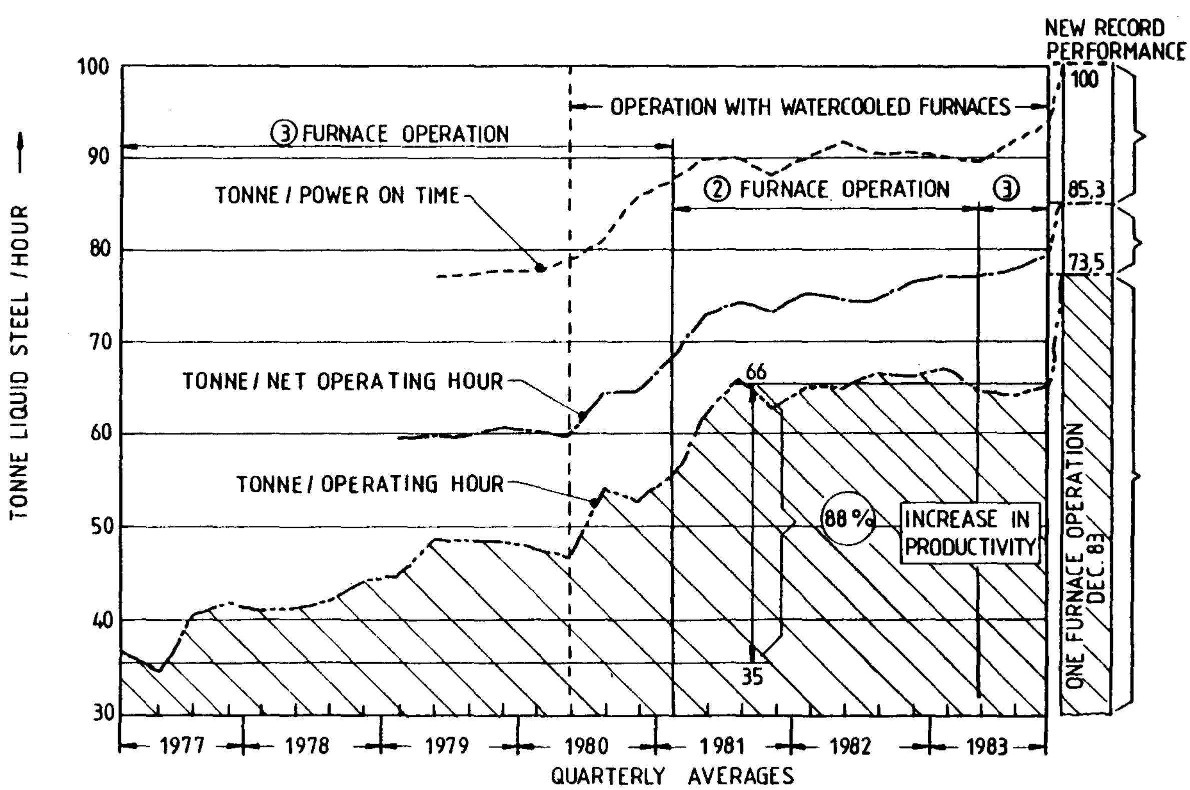

Fig. 15—Increase in productivity, 1977 to 1983

ing. This information is also used as a basis for objective appraisals of performance. Efficiency figures such as time utilization and skill factors are also calculated.

The results from these performance reports are discussed at least once a month between the shift supervisor and his subordinates, and between the shift supervisor and plant management.

SUMMARY AND OUTLOOK

Reliable information on which important decisions can be based is a vital resource to the supervisor and plant manager, but the information must be accurate, complete, timely, and accessible. At Iscor, possibilities have been provided for the correction or deletion of erroneous inputs at the man–machine interface terminal. These computerized decision-support systems have contributed immensely to the continuous improvement of process control, productivity, and cost reduction in the Electric Arc Furance Shop. Figs. 14 and 15 show only two examples of the many improvements that have been achieved: reduction of electrode consumption from 7 kg/t to below 3,34 kg/t, and increased productivity from 35 t/h to 66 t/h.

Because of ongoing developments in arc-furnace and computer technology, new ideas are continuously being introduced into the system.

The examples given here of computerized data analysis to support decision-making illustrate the dynamic development that has taken place within the steel industry. They also show that the functions of a process computer can be extended from the on-line control of melting units to the provision of an integrated management information system.

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Shot peening

The Third International Conference on Shot Peening is to be held in Garmisch-Partenkirchen from 12th to 16th October, 1987. This Conference should once again provide delegates from all over the world with a comprehensive overview of the current state of knowledge, research, and technical applications in the entire field of shot peening.

The themes of the Conference are

- Basic aspects of shot peening
- Technology of shot peening
- New applications of shot peening
- Quality assurance by control of the peening process and of the peened material
- Economic aspects of shot peening
- Changes in the state of the material by shot peening
- Improvement of the behaviour of materials and construction components: fatigue strength, behaviour under fretting corrosion, stress-corrosion cracking, rolling contract and wear conditions
- Consideration of material changes in design and strength calculation
- Shot-peening forming
- Stimulation and optimization of the effects of shot peening by means of computing processes
- Modelling of the shot-peening process and its effects.

The Conference languages will be English and German. Both oral presentation (15 minutes plus 5 minutes discussion) and poster presentation will be provided. Those who wish to present papers should submit an abstract in typescript suitable for photocopying (one page 16 × 24 cm, beginning with the title, the author's name and location, including figures and tables) by 1st June, 1986, to the Conference Secretariat of the Deutsche Gesellschaft für Metallkunde e.V., Adenaueralee 21, D–6370 Oberursel, West Germany. Telephone: 06171/4081.

McGill seminars

The following mining and metallurgical seminars are to be held at McGill University, Canada, during the first half of 1986.

13th to 24th Jan.
Mineral project evaluation techniques and applications

This seminar is intended for those who wish to develop a broad understanding of the economic aspects associated with decision-making in the mineral industry. The seminar consists of a comprehensive and balanced mixture of lectures and team exercises that focus on project assessment techniques and their application to the analysis of mineral industry issues. Specific applications to be covered include the analysis of exploration strategies, the evaluation of mine development and operating opportunities, and the optimization of project specifications. No previous expertise in economic analysis is required from the participants, but some practical experience in the mineral industry is desirable.

Seminar Leader—Michel L. Bilodeau (McGill)

27th to 31st Jan.
Preparation of mineral feasibility studies

This seminar focuses on the documentation and level of analysis required in mineral project feasibility studies. The special considerations involved in evaluating the feasibility of mineral projects in developing countries will also be addressed. Topic areas include general data requirements, appropriate analytic techniques and computer methods, special financing arrangements, and currency exchange and revenue estimation problems. Participants will help construct a feasibility case study designed to demonstrate the preparation process and essential underlying principles.

This seminar will appeal to people in both private and public sectors, in government, and in financial institutions involved in planning and executing mineral projects. Instructing will be members of the SNC Group's feasibility study team. The SNC Group is one of Canada's leading consulting engineering firms with many years related experience in mineral project development.

Seminar leaders—Frank Wright (SNC) and J.I. Davidson (McGill)

17th to 19th Mar.
Acoustic emission/microseismic techniques in mining engineering

This three-day seminar aims to introduce practising engineers to the fundamentals and applications of systems for monitoring seismic activity associated with excavations in rock. The seminar will be conducted principally by Dr H.R. Hardy and supported by existing users of industrial monitoring systems in Canada.

The seminar will commence by reviewing fundamentals, and then consider advanced aspects of acoustic emission and microseismicity, together with equipment and systems design. Its intention is to address the application of monitoring techniques to rock engineering projects. Case-study sessions will be devoted to considering the practical problems and benefits of field applications.

Seminar Leaders—Malcolm Scoble (McGill) and H.R. Hardy (Pennsylvania State University)

24th to 27th Mar.
Blasting systems

Recent advances in cast-blasing will be included and discussed in detail in this year's seminar topics upon surface blast practice and explosives use. This technique has been gaining popularity in the United States for horizontal coal seams. The possible application to Canadian non-horizontal and coal seams will be discussed.

The underlying principles and present state-of-art practices in underground mining using large-diameter holes will again represent an important part of the seminar programme.

Competent speakers in both areas of blasting practice will be present. This will reflect proponents of computer programs, which have gained wide acceptance, and those experienced in operations.

Participants are encouraged to ask questions and to input supportive commentary during the proceedings.

Seminar Leader—R.R. MacLachlan (McGill)

5th to 9th May
Particle separation systems

A review of the principles and practice of solid–solid and solid– liquid separation technology in the minerals industry. Topics will include particle characterization (size distribution, liberation); flotation (chemistry and physics, practice, machine design including columns); gravity and magnetic separation; flocculation and selective flocculation; dewatering; process control, modelling, and instrumentation. The emphasis will be on fine particle processing.

The course is designed as an update for the practising engineer and the process development engineer and scientist.

Seminar Leaders—J. Finch and A. Laplante (McGill)

26th to 30th May
Computer applications in open-pit and mine planning

This short course, designed for engineers, technologists, and computer programmers involved in open-pit mine planning, covers important aspects of modern mine planning. The course consists of a balanced mixture of lectures, case-study discussions, and on-line demonstrations.

The fundamentals of computerized open-pit planning will be presented, and the strategies involved at each planning stage will be defined. Computer methods for open-pit design and slope stability analysis will be formally covered. Simulation and mathematical programming will be introduced. Currently available industrial software will be reviewed. On-line demonstrations will be held and comprehensive course notes will be supplied to each participant.

Seminar Leader—Yves Lizotte (McGill)

Further details are available from Lorna McFadden, Department of Mining and Metallurgical Engineering, McGill University, 3480 University Street, Montreal, Quebec, Canada H3A 2A7. Telephone: (514) 392-5426. Telex: 05-268510.