

COMPUTER APPLICATIONS AND SIMULATIONS IN FERROALLOY PRODUCTION

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INTRODUCTION

The production of ferroalloys are very expensive since they consume a lot of electrical energy and the productivity is very poor. Computers can be used at various stages of its production to reduce energy consumption, improve productivity and improve on the total logistics of furnace operation. Some of the important steps are best done by the digital computer such as material management (includes materials inventory control, material handling and tracking), furnace charge calculation, addition calculation, power input calculation and control, monitor and alarming of event and delay log. The configuration of computer needed for these operations is mainly dependent on the scale of operation. However, with the availability of wide range of mini and personal computers, the cost of installation and operation of these computers become insignificant compared to the benefits obtained from its operation. To ensure smooth operation of the computer system under the conditions exist in a furnace shop, an uninterrupted power supply (UPS) is preferred. The UPS not only protects the system from transients but also helps in maintaining the system on during power break down. Some of the applications which could be easily computerised will be detailed in subsequent sections.

MATERIALS MANAGEMENT

The main objective of this system is to produce ferroalloy at a minimum cost while maintaining consistency in quality. This is done by integrating the decision making information from raw materials procurement, furnace shop practices and product quality requirements.

At the first stage, all raw materials are characterised based on previous heat data and chemical analysis. Subsequently, the program also checks which raw materials can ensure production with least cost. To verify and optimize on a minimum cost, raw materials purchasing and utilization system, the program should report variance and identify the operating and purchasing environment which has cost deviations from the desired result of least cost of ferroalloy production.

CHARGE DESIGN MODEL

A linear program model is used for charge calculation where the following constraints also can be considered.

i) Materials availability - unit weight and total amount of material available. This constraint requires that a bounded variable linear programming approach be utilized to solve the mix-blend type application of linear programming columns.

ii) Inventory balancing

iii) Materials integrity - The composition density and yield may vary depending on the material sources and purchase.

This program determines the least cost solution that satisfies all of the chemical, physical and property constraints. The advantages of such a computerized charge model are:

1) Reduced material balance difference between predicted and actual

2) Use of greater cross-section of inventory for the charge design

3) More cost effective utilization of raw materials

ENERGY MANAGEMENT

The energy requirements of a electric furnace can be very efficiently managed through a computer control system. Besides controlling the power demand, this system can control power input and calculate the bath temperature. Fig. 1 shows the flow diagram of a typical energy management system.

The power demand control system utilizes the predictive control approach. This approach is functional whether an initiation of demand pulse is available or not. The program predicts usage by load and determines the last instant to cut the load of lowest priority.

The software can be adapted to compute demand limits in terms of kWh, kVAR, kQ etc. The program is set to handle variable demand limits. This allows for all of the presently available utility demand regulations and pricing schedules.

POWER INPUT CONTROL

The input of power to the furnace may vary depending on the raw material type and weight, position of furnace roof and auxiliary fuel usage. The computer calculation of power input and its control helps to run the process at the maximum desirable power input rate. This practice results in lower specific energy consumption, higher production rate, lower refractory wear and less electrode consumption.

HEAT AND MASS BALANCE

To optimize power requirements and selection of suitable charge mix, heat and mass balance models are employed. These models consider the heat required for each raw material to reach the reaction temperature, heats of reaction, sensible heat of

gases leaving the furnace, heat loss to the cooling water, heat loss through refractory. The electrical input energy and energy from auxiliary fuel are balanced against these heat output. These models help to calculate temperature, energy requirements, material wastage and furnace irregularities such as eruptions.

In the following example, Healy[5] presented a material and energy balance in the ferromanganese furnace operation. These balances along with the calculation of charge resistivity can throw light on the possible causes of eruption in the furnace and thus enable prescribing means of preventing eruption. A sample case study for Fe-Mn production in a 12MVA furnace is shown below.

Mass and Heat balance in a 12MVA ferro alloy furnace(Shell dia. 9.14m, depth 3.35m, electrode dia. 1.42m); basis: 1Kg of Fe-Mn

Input (298K)			Output		
	gms	%moisture	Metal: 1000gm (1700K)	Slag: 535gm (1700K)	Gas: 942.4 (400K)
1. Ore	1951	2	Mn 78.00%	MnO 38.8%	CO 56.6%
2. Coke	523	5	Fe 14.92	FeO 1.2	CO ₂ 40.5
3. Flux	121	2	Si 0.25	SiO ₂ 28.6	CH ₄ 2.9
			P 0.13	Al ₂ O ₃ 13.9	
			C 6.70	CaO 15.0	
				BaO 0.9	
Total	2595	2.6	100	100	100

Heat balance (abridged form)

Total heat required:	Gas + Charge Mix: 4.54MJ (1700K)	a) Gas-Mix reaction: 1.25MJ b) CO gas (hearth) : 1.10 c) power input (I.R): 2.19 4.54MJ
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Based on the above study, Healy[5] recommended that the sudden drop in CO₂ level should be used as an indication for raising the electrode to prevent eruption.

COMPUTER HARDWARE AND SOFTWARE

The selection of proper computer systems and peripherals is very important for the successful implementation of computerised activities in a ferroalloy plant. The computerised plant should perform the following functions very efficiently,

- i) run process control models
- ii) communicate to other computer
- iii) materials/inventory control
- iv) production tracking and scheduling

A minicomputer with multi-tasking operating system and interrupt level control could take care of most operations. With the advent of high performance micro systems such as PC 386 and 486 based micro computer with networking environment can be considered (fig. 2). The computer need not be installed next to the furnace since the hazardous environment and interference from electrical noise may affect the smooth operation of the computer system. The plant can have one central location for the main

computer unit where both analog and digital signals can be fed by telemetered multiplexing device. Terminals can be placed at various locations of the plant for the ease of operator. When the distances are greater than 100m, modems can be used to modify and boost signals. The dot matrix printers should be installed at various locations so that operators can easily produce a hard copy.

Due to the rapid stride in hardware development, the price of processor is coming down every year. However, the development of application softwares on these new platforms are considerably lagging behind. Therefore, the cost of developing application software should also be considered while selecting a system. The phenomenal growth and tremendous development in the computer industry has resulted in drastic reduction in the cost of computation. Table 1 provides a quick guideline on the possible hardware and software which could be used for modelling analysis in different applications of ferroalloy production. A brief write up on some of these software packages are given below.

ANSYS is a general purpose FEM package, mainly used for finite element static, dynamic, thermal linear and non-linear analyses. ANSYS has a wide range of library. It includes both pre and post processing and ported to all ranges of computer platforms.

ABAQUS is a general purpose finite element program designed for wide range of applications. It has a large element library and wide range of non-linear features. Also it is popular because of ease of use, efficiency and high level support.

PHOENICS is a powerful package to deal with complex 2D and 3D heat, mass and fluid transport problems including chemical reactions. It is available in wide range of computer platforms including PC/386. However, it is time consuming to learn its own FORTRAN type language and moderately expensive.

NISA is also a compact modular package for handling problems mainly in structural, heat transfer and fluid flow areas. The lowest end module is available on PC/386 platform.

F*A*C*T, the Facility for the Analysis of Chemical Thermodynamics is developed at Ecole Polytechnique, Canada. The program was initially developed on mainframe system and currently available also on PC platform in modular forms. The software has its own exhaustive thermodynamic database on inorganic compounds, molten slag solution, liquid steel with dilute solution and molten salt solution. This software can be used to generate phase diagrams and calculate equilibrium compositions.

CONCLUSION

The operations in a ferroalloy plant is highly energy intensive and therefore a carefully planned computerised system can make the plant very efficient both with respect to productivity and specific energy consumption. Some of the important areas where installation of computer would be of great help are materials management, charge design and calculation, energy management and power demand control. The computer system could also be used to run various process models both static and dynamic to determine the optimized operating parameters for different ferroalloys. It is also crucial to select a proper combination of hardware and software for successful implementation of computerised operations. Some hints are given while making these decisions.

BIBLIOGRAPHY

1. Szekely J, Evans JW and Brimacombe; "The mathematical and physical modelling of primary metal processing operations", Wiley, New York, 1987.
2. Szekely, J and Foremann, F; "Megaflop and CAD/CAM in metal processing", J. Metals, October(1986), 54-57.
3. Bale, CW and Eriksson, G; "Metallurgical Thermochemical Databases - a review", Can. Met. Quart., No. 2(1990), 105-132.
4. Szekely, J; "The mathematical modelling revolution in extractive metallurgy", Met. Trans. 19B(1988), 525-540.
5. Healy, GW; "How ferromanganese mix resistivity affects manganese gas, carbon balance and kWh per metric ton", Elec. Fur. Proc. (1991), 251-258.

Table 1. Guide to hardware and software selection

(a) Hardware Options

Computer	Megaflops	Capability
IBM-AT w/80287	.024-.07	2-D transient heat conduction problems with constant coefficients. No fluid flow problems under 2500 nodes.
IBM-AT w/MAP	.5 .12	3-D transient heat conduction with fluid flow constant coefficients. Limited only by memory and user's patience.
VAX 11/750 w/FPA	.12	Small 3-D transient heat conduction; problems under 6000 nodes.
VAX 11/785 w/FPA	.20	Moderate 3-D transient heat conduction problems; 2-D transient heat conduction with fluid flow, small 3-D fluid flow with no heat transfer; problems under 10000 nodes.
VAX 8600	.50	Medium or moderately sized 3-D transient heat conduction with fluid flow; problems under 25000 nodes.
Apollo DN660	.15	Same as (4); problems under 8000 nodes.
FPS-164 MAX	10	Small 3-D fluid flow with heat transfer and with variable coefficients; virtually unlimited problems.
FPS-264	30	Fairly large 3-D fluid flow with heat transfer and with variable coefficients; virtually unlimited problems.
CYBER 205	20	Moderately sized 3-D fluid flow and heat transfer with variable coefficients; virtually unlimited problems
CRAY X-MP CRAY YMP-23 CM-5	40 3000 131000	Large 3-D fluid flow with heat transfer and variable coefficients; virtually unlimited problems.

(b) Available Hardware and Price ranges

Class of Computer	Price Range
I. IBM-PC (386 or 486)	\$5 to 10 K
II. Workstation class: MicroVAX II DEC 8250, 8350 Sun 3.4	\$20 to 100 K
III Minicomputers: MicroVAX III DEC 8500, 86800 MASSCOMP 5000 Intel ipSC/2 Sugarcube	\$30 to 200 K
IV Mini-supercomputers: DEC VAX 8700, 8800 Convex Intel iPSC/2-VX/d3	\$300 to 800 K
V. Mainframe class: IBM 1808, 3090 Cyber 875 FPS Array Processors Intel iPSC/2-VX/d4	\$500 to 2000 K
VI. Supercomputers: Cray-1 and X-MP, YMP Cyber 200 Fujitsu VP400 Intel iPSC/2-VX/d5	Several millions of dollars
VII. Massively parallel processors: Intel IPSC/2.VX/d6 Thinking machine CM-5	Several millions of dollars

(c) Partial List of Available Software

Name	Application	Notes
ANSYS	structural,thermal,electrical,magnetic	finite element
ABAQUS	structuralthermal,nonlinear analyses	finite element
NASTRAN	structural	finite element
FIDAP	fluid dynamics	finite element
PHOENICS	fluid dynamics,heat transfer,chemical reaction	finite volume
FLOW 3-D	fluid dynamics	finite difference
FLUENT	fluid dynamics, heat transfer	finite difference
NEKTON	fluid dynamics,heat transfer	finite element (spectral)
NISA	fluid dynamics, heat transfer	finite difference
IMSL	math/satistical library	
LINPACK	math library	
MINPACK	minimization/optimization library	
EISPACK	eigenvalue library	
ASPEN	flowsheet simulation	sequential,modular
FLOWTRAN	flowsheet simulation	
SOLGASMIX	chemical equilibrium	
ECES	aqueous chemistry	
F*A*C*T	phase diagrams, chemical equilibrium	
ROMULUS	solids modeling	
PATRAN	solids modeling, finite element pre and post processing	
SLAM II	event simulation	
MAGNUM	magnetics	finite element
THERMOCALC	chemical equilibrium, phase diagram	

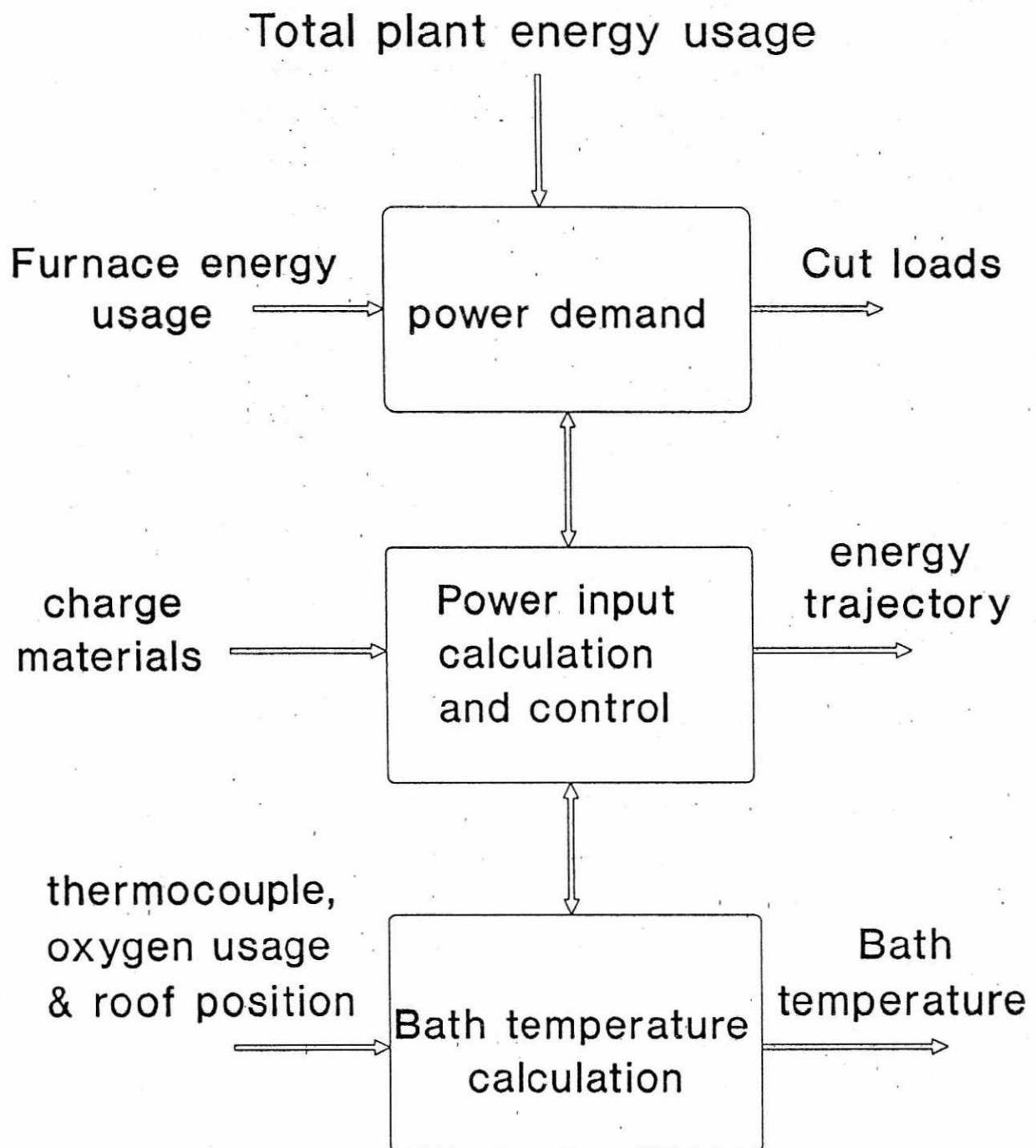


Fig. 1 Energy management flow diagram

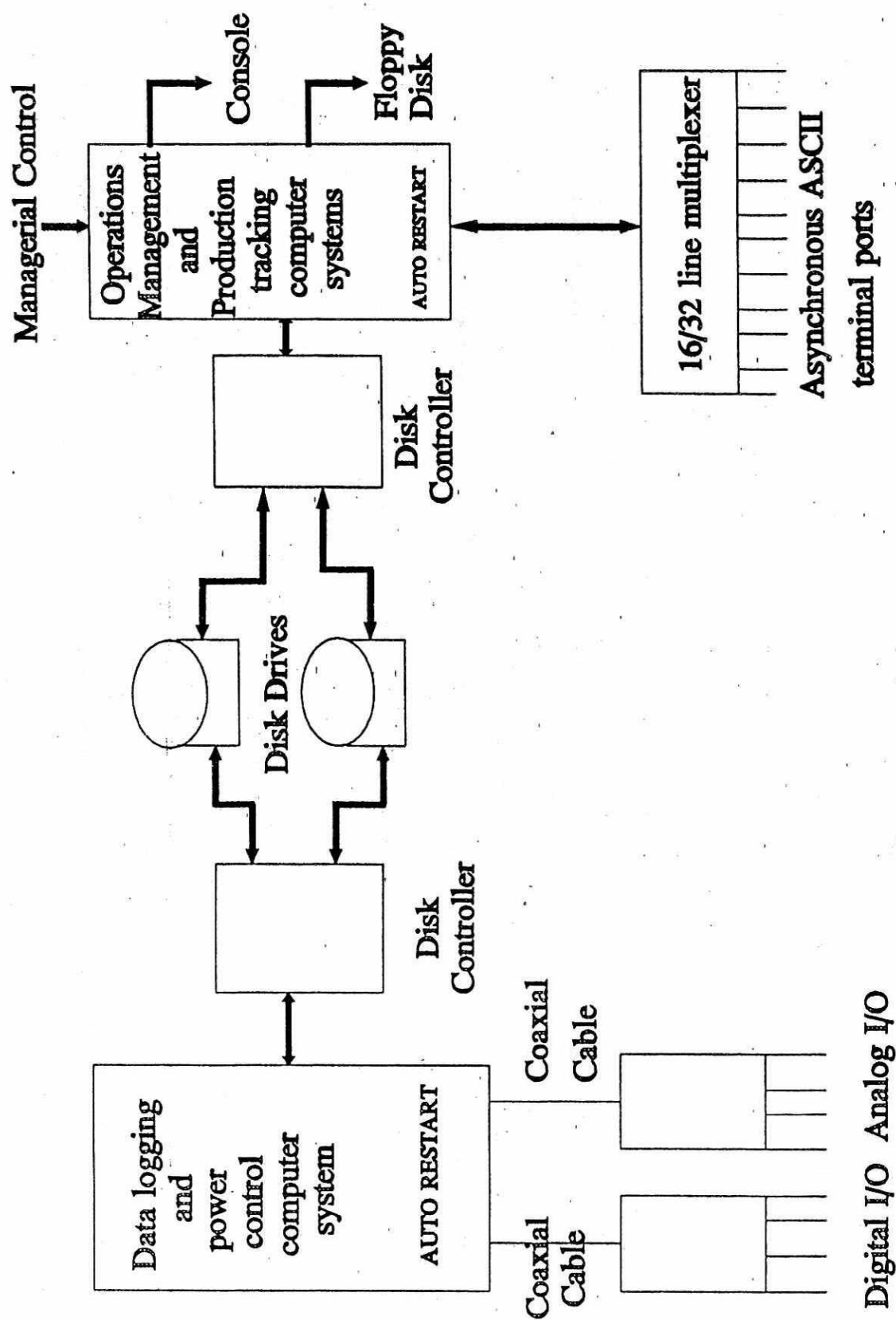
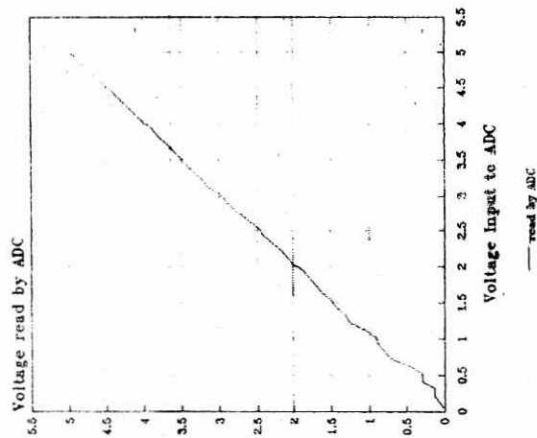
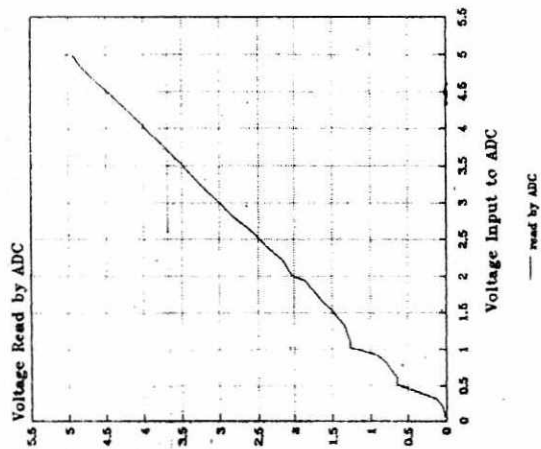


Fig 2. A model computer system for Ferro alloy production

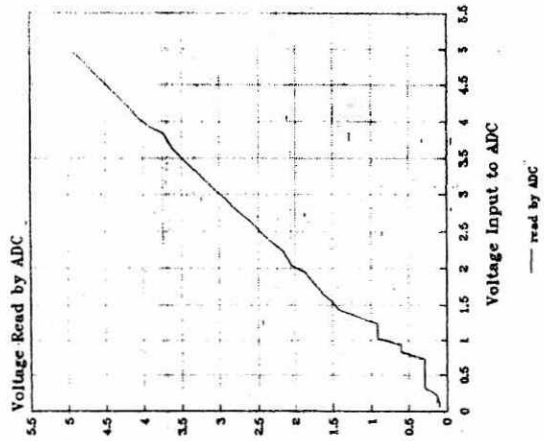
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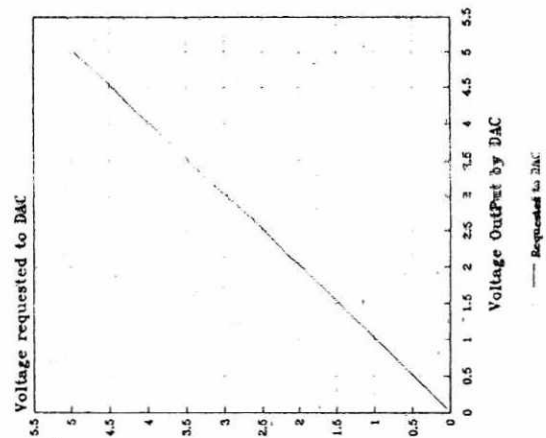
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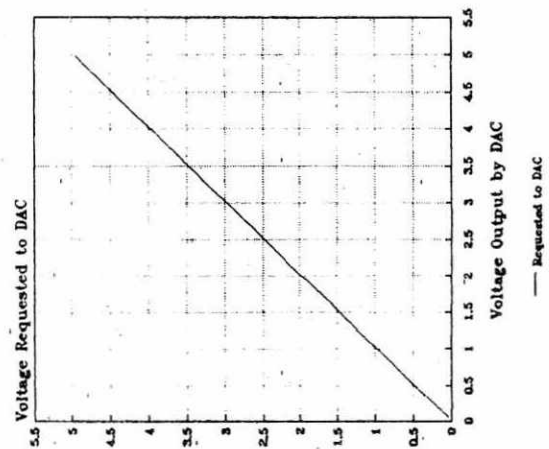
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Curves for IC 084 pos 123



Curves for IC 084 pos 312



Curves for IC 084 pos 231

