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APPROPRIATE AUTOMATION PROMOTION PROGRAMME

DP/IND/82/034/11-21

INDIA

Technical report: Process Automation in the Steel Industry*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Nicholas Rickard
expert in Process Automation of Iron and Steel Manufacture

Backstopping Officer: C. Gürkök, Engineering Industries Branch

United Nations Industrial Development Organization

Vienna

* This document has not been edited.

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DP/IND/82/034/11-21

Appropriate Automation Promotion Programme

Process Automation In The Steel Industry

ABSTRACT

This report describes the results of observations regarding operating practices and process automation efforts at the Bhilai and Rourkela Steel Plants of the Steel Authority of India, Limited, and lists recommendations for improvements in areas affecting product quality, energy conservation, product identification, and capital improvement planning.

The observations were conducted during February and March of 1989. Extensive interaction with operating, maintenance, and process control personnel at the department levels provided opportunity for practice and process improvement suggestions. Additionally, several lectures and seminars were held regarding techniques in the automation of steel converters, continuous casting, and computerized maintenance systems.

Detailed recommendations for process automation projects arising from these observations were discussed at both the steel plants with department and plant management. Lectures and discussions were also held with Department of Electronics personnel in New Delhi.

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I. Introduction

The objective of the mission as detailed in Job Description DP/IND/82/034/11-21 included the following tasks for the Expert:

A. Assist the centre (AAPP/DOE) in developing projects for the steel plants.

B. Deliver lectures to engineers on production planning control and maintenance systems for steel plants.

C. Visit steel plants in India and deliver lectures to plant personnel on L.D. converter, rolling mill, and finishing mill computerization.

D. Guide the project team in carrying out various development/modernization activities at steel plants and suggest the approach to carry out such activities.

The Expert was also expected to prepare a final report, setting out his findings and recommendations to the Government on further action to be taken.

The program of work was performed over a period of forty-five days in February and March of 1989 and included travel time, briefing in Vienna, visitations to Bhilai steel plant, Rourkela steel plant (both of SAIL), and activities at the Appropriate Automation Promotion Programme centre, Department of Electronics, New Delhi.

II. Recommendations

A. Bhilai Steel Plant

1. The major need for process automation efforts at the Bhilai Steel Plant lies in the Steelmaking and Continuous casting departments. The L.D. converters should be equipped with a predictive charge calculation model to improve turndown performance, yield, and data recording. The model should be installed as a static model initially (no sublance) and either operate as a completely predictive model or use an interrupted blow technique to refine operating parameters. Prior to the installation of the model existing weigh systems for hot metal, scrap, and fluxes will require upgrading. Efforts must also be taken to lower the "losson ignition" (LOI) of Lime utilized in the converters.

2. The continuous casting shop is presently an entirely manually operated facility. Process automation system should minimally be added to control the level of liquid steel in the mold and the application of secondary cooling water. Conversion of two slabcasters to digital setpoint control will be required (two are already converted) as will upgrading of the tundish stopper rodcontrol mechanisms.

3. In order to more rapidly measure the gap of pinch rolls and the alignment of the casting machines a mechanized measuring device should be designed and installed. Sketches of such a device were provided to department management and the AAPP centre.

B. ROURKELA STEEL PLANT

1. The quality of mixed gas (Blast Furnace and Coke Oven) is quite dirty at the Rourkela Steel Plant. Numerous examples of plugged dampers, fouled controls, and post combustion were observed. A gas cleaning station should be installed in the vicinity of the present gas mixer. Clean gas supplies are essential in proper setpoint control of combustion processes.

2. Additionally, a computerized system of dispatching electricity, fuel gas, and other utilities should be implemented for energy savings. There have already been discussions regarding this project with the AAPP centre in New Delhi and with the U.N.D.P.

3. With the development of the Modernization plan at Rourkela, it would be extremely advisable to develop a plant simulation model of the steel plant works including new facility additions. This model should contain production rates, operating limits, expected yields, and throughput for all manufacturing units. The model can then be utilized to examine proposed heat sizes of new steelmaking facilities, order providing practices, new facility design and production output. The use of modeling in this situation can prevent initial equipment specifications which might prove inappropriate in the long term.

C. GENERAL RECOMMENDATIONS

1. Semi-finished and finished steel products which contain improper or missing identity was observed to be a major problem at both plants visited. Identification methods should be improved (die stamping, tagging, etc.) beginning with the ingot or cast slab and progressing through rolling and finishing operations. Automated product tracking systems should also be developed to aid in eliminating mis-application of steel grades.

2. Greater effort should be made to share existing technology within the Indian Steel community. Visitations and meetings of departmental personnel involved with operations, maintenance. and process automation at other Indian steel plants will stimulate application and transfer of existing practice and process automation techniques to other facilities. A suggested model for this interaction is contained within the appendix of this report.

3. Finally, there is a need for an overall research project to develop improved means of data and voice communications within the steel plants. With the growth of process automation, more reliable data transmission techniques are needed. It is suggested that a review of existing available communication technology be performed and the information matched against the various communication needs defined within the steel plants.

III. ACTIVITIES OF EXPERT

Upon arrival in New Delhi, Mr. G.S. Varadan, Chief Project coordinator of the Appropriate Automation Promotion Programme outlined the scope of activities requested of the expert. The major activities required included:

- Develop lectures to be given to steel plant engineers on topics including L.D. converter and Continuous Caster automation, Computerized Maintenance Management Systems, and Integrated Production Management programs for steel plants. A brief abstract of the lecture subjects is included in the appendix.
- Visit the Bhilai and Rourkela steel plants and assess current process automation performance, areas for future projects, and assist operations in subjects of operating practice.
- Upon return to the New Delhi centre deliver lectures to engineers in the AAPP centre and suggest applicable process automation projects and the methods for accomplishing them.

A. Bhilai Steel Plant

A total of eleven days were spent at the Bhilai Steel Plant (see appendix for itinerary) reviewing automation, operating, and maintenance systems.

Lectures and seminars delivered on process automation included:

- Feb. 14 Lecture on Integrated Production Management Systems delivered to Integrated Control System group.
- Feb. 14 Lecture on Computerized Maintenance Management Systems delivered to Maintenance Managers and Integrated Control Systems Group
- Feb. 16 Lecture and Seminar on L.D. Converter Charge Model computerization delivered to Steelmaking management group.
- Feb. 16 Presentation on basics of Continuous Caster process automation design and hardware was presented to Steelmaking and Continuous Caster management and process control personnel.

Plant visitations were conducted in the company of operating, maintenance, and process control personnel to the following departments:

- o Blast Furnaces (no. 6 and 7)
- o Coke Plant (no. 9 battery)
- o L.D. Converter Shop
- o Continuous Casting Casting Shop and Mold Repair shop
- o Soaking Pits and Slab Yard
- o Plate Mill and Normalizing Line

In each case, following the visit, discussions were held with operating, maintenance, and process control personnel to review operating and maintenance practices as well as opportunities for process automation.

Non-departmental systems currently under development were also reviewed with the affected parties. These systems included:

- o Computerized Maintenance Management System (CMMS)
- o Traffic Management System
- o Inventory and Stores Management Systems
- o Divert Heat Reapplication Program

A closing conference was held with the Additional General Manager of Works and the Plant Division Managers. Verbal observations and recommendations were presented at this conference. A final closing meeting with the Managing Director was held to again briefly review the Experts remarks and suggestions.

ROURKELA STEEL PLANT

A Total of seven days was spent at Rourkela Steel Plant. As at Bhilai, current process automation efforts were reviewed, visits were conducted to operating departments, and several lectures were given. A discussion with the Modernization Group was also held to explore plans for new capital facilities at Rourkela.

Lectures and seminars on Process Automation included:

- o Feb.25 A presentation on Steelmaking Automation with special attention to development of predictive charge calculation models was presented to Steelmaking operations, maintenance, and process automation personnel.

- o Mar.1 A seminar was presented to the Modernization Group regarding the software and hardware requirements contained in modern L.D. converter and continuous casting facilities.

Plant visitations were conducted in the company of operating, maintenance, and process automation personnel to the following departments:

- o Blast Furnaces (no.3 and no.4)
- o L.D. Converter Shop
- o Soaking Pits and Slab Mill
- o Hot Strip Mill
- o Pickling Lines
- o Cold Rolling and Finishing Units
- o Galvanizing Lines

In each case extensive discussions were held with operating, maintenance, and process automation personnel regarding operating practices and automation opportunities following the visitation.

Concluding discussions were held with the Managing Director and his staff to report verbally the Expert's comments and recommendations.

While at Rourkela, an invitation was extended and accepted to speak to the local chapter of the Computer Society Of India. The topic of the Expert's discussion was "Steps in Successful Application of Process Automation"

C. NEW DELHI (AAPP)

Following the conclusion of plant visitations, the remaining nine days were spent in the AAPP offices in New Delhi. Activities included in this time period included:

- o Mar.13 Presented lecture on process automation of Steelmaking and Continuous Casting facilities. Special emphasis was placed upon the need for integration of separate systems into an overall Steel Production Model.

- o Mar.14 Delivered seminar of Automation Potential in Hot and Cold Rolling Mills.

- o Mar.12 Reviewed presentation of Phase II plans for the Appropriate Automation Promotion Programme.

A verbal report of findings and recommendations was given to Mr. G.S. Varadan, Chief Coordinator, AAPP over a several day period. During these discussions Mr. Varadan requested the services of the author to facilitate additional projects in Indian Steel. Mr. Varadan indicated a formal request would be issued through the UNIDO office in Vienna.

IV. FOLLOW-UP ACTIVITIES

Certain items of information were requested of the Expert which could not be directly answered and which will require investigation for response. These items include:

A. Bhilai Steel Plant

1. Techniques for improving free opening of steel ladles at continuous casters.
2. Chemistries of mold powder for plate and strip product at continuous casters.
3. Details of chrome plating of continuous caster molds.
4. Samples of current L.D. converter lance designs.
5. Methods and instrumentation currently in use to determine moisture content in raw materials.
6. Experience in Zirconium Oxide refractory material in reheating furnaces.
7. Methods to control dust build-up and resultant vibration on L.D. converter primary gas fans.
8. Information on ceramic spool patching materials.
9. Lists of modern Plate Mills and Open Hearth Shops to visit.

B. Rourkela Steel Plant

1. Methods of reducing the failure rate of Ilgner motor generator couplings.
2. Methods of steam injection for heating pickling tanks.
3. Analysis of annealing base seal design and comment.
4. Supply names of manufacturers of modern sheet pilers.
5. Supply information or suppliers of graphitized carbon refractory material for Blast Furnace Bosh area. Also information on mono-block runner installations.
6. Name of suppliers of p.c. based maintenance software systems for small plants.
7. Manufacturers of high-technology inspection equipment.

The response to the above items is estimated to require approximately five man-days of effort.

V. CONCLUSIONS

At the two steel plants visited (Rourkela and Bhilai) process automation efforts underway are effective and are proceeding along well defined technical paths. Major effort has been made in Blast Furnaces, Soaking Pits, and computerized maintenance systems. The addition of on-line computers for full supervisory control utilizing a mathematical model is the next step in these areas.

Work is beginning in areas such as Coke Plant automation, Hot Rolling, and traffic management systems. Additional effort is required in areas of steelmaking, continuous casting, Cold Rolling, and energy distribution systems.

The Bhilai plant must endeavor to add process automation systems to it's existing continuous casting facility. Within ten years, at the presently announced level of capital expansion and modernization, the majority of steel in India will be continuously cast rather than ingot poured. Bhilai can serve as the training ground for practices and process automation techniques to guide the startups of VIZAG, Rourkela, and Bokaro.

In those areas where process parameters are shared by all steel plants (Coke making, Blast Furnaces, Steelmaking, and Soaking Pits/Hot Rolling) greater efforts are required to share technology and practice improvements on an inter-plant basis. Numerous examples of technology or practices needed at one plant and available knowledge at another plant were observed. A suggested model for strengthening this inter-relationship is contained in the appendix.

The modernization plan outlined for Rourkela offers great improvement potential to existing facilities. It is critical , though, that these improvements be strategically designed to properly interface with existing facilities. Items such as heat size, providing practices, production limits, and throughput are essential ingredients that must be optimized if the resulting plant is to be balanced. One technique for investigating this balance is the use of a simulation model to check production parameters prior to the decision-making point.

Visitations to foreign steel plants by operating, maintenance, and process automation personnel who will be responsible for the new facility start-up are also urged. These visits should be made prior to final equipment selection so that assessments of operational application, maintainability, and desired (appropriate) process automation can be investigated.

Visits to the various operating departments normally involved much discussion regarding operating and maintenance practices. Frequent questions were directed to the Expert on subjects in these areas and comments, where known, were provided. No attempt will be made to list all these areas of discussion in this report. Additionally, specific follow-up items were requested that the Expert could not readily supply. These are listed separately in Section IV., Follow Up Activities.

Finally, the management and work force of the two steel plants visited, as well as the AAPP personnel in New Delhi, were extremely well organized in their efforts to implement the Expert's mission. Logistics were timely and led to the maximum utilization of available time. The interest, technical competence, and desire to improve process automation performance was evident in all areas visited.

APPENDIX I

ITINERARY

Feb. 4	Travel To Vienna From Los Angeles
Feb. 5	do
Feb. 6	Meet With Unido Backstop V. Smirnov at UNIDO, Vienna
Feb. 7	Travel to New Delhi
Feb. 8	Meet with UNDP on Arrangements Meet with AAPP to discuss project assignment
Feb. 9	Preparation of Lectures to Steel Plant Personnel
Feb. 10	do
Feb. 13	Travel to Bhilai Steel Plant. Meet with Chief Supt. of Integrated Control Section, Mr. Saighal. Develop plan for Expert's activities.
Feb. 14	Deliver lecture on Design of Integrated Production Management Control Systems to INCOS group. Deliver lecture of Computerized Maintenance Management Systems to INCOS and Maintenance managers.
Feb. 15	Visit Steelmaking and Continuous Casting Shop. Held initial conference with Mr. Pai, Additional Gen. Works Manager.
Feb. 16	Continue visit to Steelmaking shop and caster. Concluding discussions with Steelmaking personnel. Presented lectures on Converter Charge Models and Continuous Caster Automation to Steelmaking personnel.
Feb. 17	Visit No. 6 and 7 Blast Furnaces. Reviewed process automation plans for no. 6 furnace. Met with Blast Furnace operations group to discuss recommendations.
Feb. 18	Discussions with Computerized Maintenance Management Group on current status of project.
Feb. 20	Discuss Traffic Management Locator System and comment on development and hardware.
Feb. 21	Visit Soaking Pits, Blooming Mill, and Plate Mill. Discuss automation progress and prospects with operations and maintenance personnel.
Feb.22	Closing presentations to Managing Director, Additional General Works Manager, and Division Managers regarding comments and suggestions.
Feb. 23	Meet with energy centre personnel and discuss need for computerized dispatching system. Travel to Rourkela
Feb. 24	Meet with Mr. Murty, Div. Gen. Mgr., Management Services and Mr. Ashis Das, Manager of Computer Services to discuss program of activities at Rourkela. Held opening conference with Mr. Tarafdar, Managing Director.
Feb. 25	Visit Steelmaking shop and Process Control Computer Group. Present lecture to operating, maintenance, and process control group on L.D. converter automation.
Feb. 27	Visit Soaking Pits and Slab Mill. Discuss operations with department personnel. Begin visit to cold rolling mill
Feb. 28	Visit Hot Strip Mill and discuss operations with department personnel. Conclude visit to cold rolling

Mar. 1 Discussions with cold rolling mill operating, maintenance, and process control personnel regarding operating practices and automation opportunities.
Discussed Modernization plans with planning group. Presented lecture and seminar on Steelmaking automation.

Mar. 2 Visit no. 3 and no. 4 Blast Furnaces. Discussions following with department personnel. Visit Energy Centre and discuss automation elements with energy group.
Met with Plant Production Control group and discussed product flow, providing practices, and product identity.

Mar. 3 Discuss Computerized Maintenance Management System and visited plant computer centre.
Held closing conference with Managing Director regarding Expert's comments and observations.

Mar. 4 Travel to Calcutta and New Delhi

Mar. 6 At AAPP office in New Delhi. Prepare notes and remarks for verbal report to Mr. Varadan, Chief Coordinator, AAPP.

Mar. 7 do

Mar. 8 do

Mar. 9 Present comments and observations regarding mission.

Mar. 10 Review project status of current AAPP activities.

Mar 13 Present lecture on Steelmaking process automation requirements.

Mar. 14 Present lecture on Rolling Mill automation basics.

Mar. 15 Travel to Vienna

Mar. 16 Meet with Backstopping Officer, C. Gürkök, UNIDO Vienna.

Mar. 17 Travel To Los Angeles, California, U.S.A.

Mar. 20 Compile information requested in Follow-up activities.

Mar. 21 do.

Mar. 22 do.

Mar. 23 do.

Mar. 24 do.

APPENDIX II
ORGANIZATIONAL MODEL OF PROPOSED TECHNOLOGY COMMITTEES

Number of Committees
1. Blast Furnace (includes Sinter Plants)
2. Coke Plants
3. Steelmaking (all processes)
4. Continuous Casting
5. Soaking Pit, Slab, and Blooming Mills
6. Hot Rolling (Plate and Hot Strip Mills)
7. Central Maintenance
8. Process Automation

Composition of Committees
Each steel plant to nominate one operations, one maintenance, and one process control specialist in the respective committee speciality. The Central Maintenance and Process automation committees will be staffed by generalists in those areas. It is critically important that those selected are involved in HANDS ON shop operation, i.e., the Operating Superintendent and the maintenance equivalent.

Frequency and Location of Meetings
Each committee should meet quarterly at a host steel plant. The hosting to be rotated among the plants.

Typical Meeting Agenda

Day 1 -	AM	Group tour of operating facility. (for example, no. 6 Blast Furnace for B.F. committee)
	PM	Group discussions of tour and items or questions raised during the tour.
Day 2 -	AM	Presentation of Technical Papers regarding current practice or process improvements. (These can be made by any member, but must be previously scheduled)
	PM	Operating Practice session. A review of current operating and maintenance problems and concerns. Questions should be collected, compiled, and distributed to individual members at least two weeks prior to the meeting to allow time for investigation and preparation of responses.

Coordination
Coordination of meeting logistics will fall primarily upon the host company. Additional steering and direction should be provided by a staff member of the Iron and Steel Ministry. The attendance of a UNIDO expert who is skilled in the individual process would be of considerable assistance.

This model is based upon the Technical Subcommittee approach utilized by the American Iron and Steel Institute and the Japanese Iron and Steel industry. It has functioned extremely well for many years and has greatly facilitated the sharing of process technology within the country's steel industry.

APPENDIX III - LECTURE SUMMARIES

Integrated Production System

A properly designed Integrated Production Management System utilizes the "building block" approach of integrating separate systems into an overall matrix. Elemental systems include:

- o Order Processing
- o Production Management
- o Maintenance Management
- o Inventory Management
- o Product Costing
- o General Accounting

A detailed description of the elements of the Production Management, Maintenance Management, and Inventory Management Subsystems was discussed.

L.D. Converter Process Automation Principles

A description of the elemental balances of thermal energy, materials, and Oxygen required in the L.D. converter process were described to lay the groundwork for a discussion of automation of the process. The methods of mathematical modeling, system architecture, software, and hardware requirements were presented. Particular attention is directed to the quality of data entered to the model in order to improve the efficiency of the predictive calculations.

Continuous Casting Process Automation

The lecture developed the elements of standard designs common to the continuous casting process and described the metallurgical processes involved. An explanation of automation of the following systems was developed:

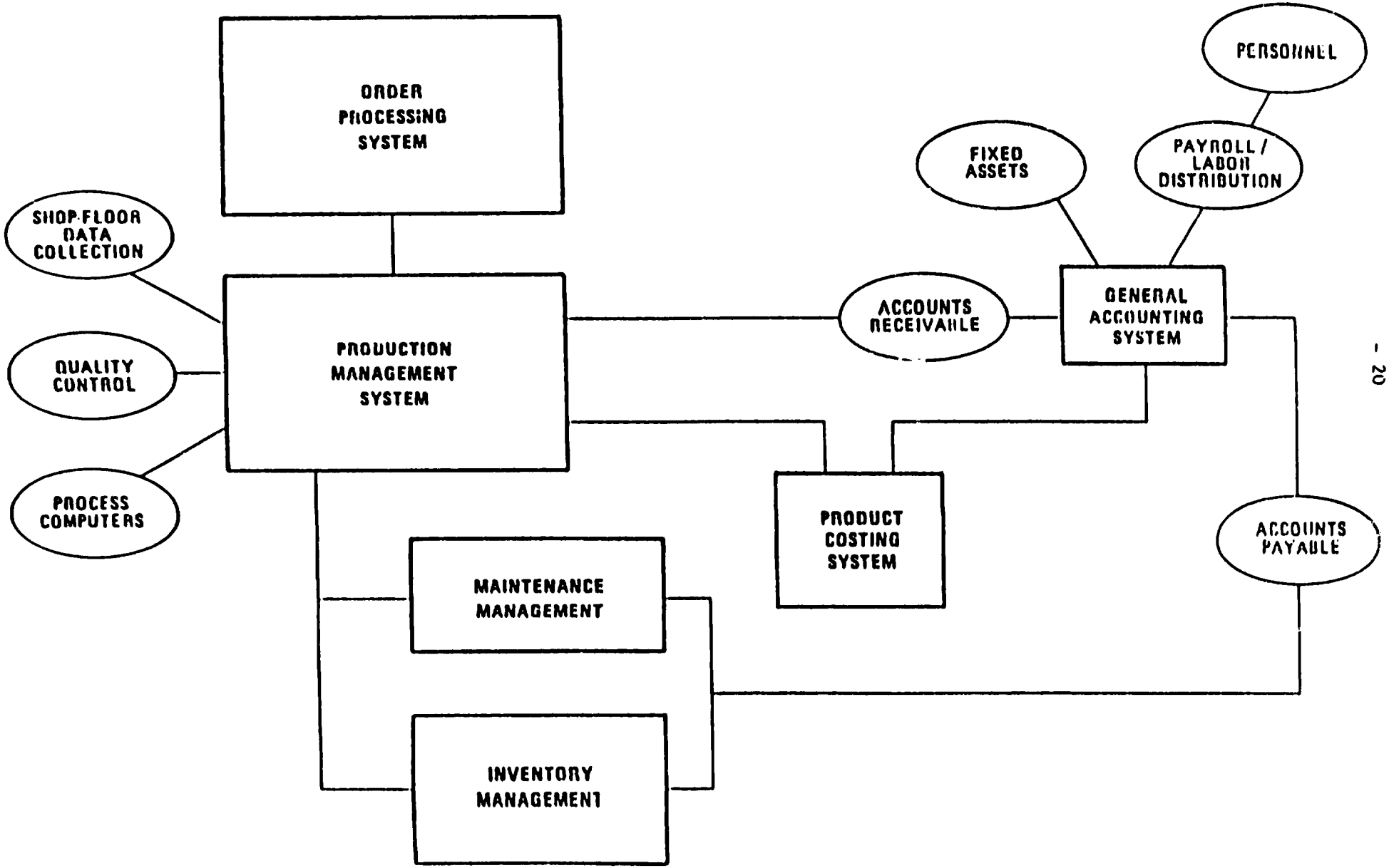
- o Control of liquid steel level in mold
- o Heat removal in Mold (primary cooling)
- o Heat removal in slab (secondary cooling)
- o Alignment of machine sections
- o Production Scheduling
- o Data Logging

Examples of automation logic and design, system architecture, mathematical modeling, and software displays were presented.

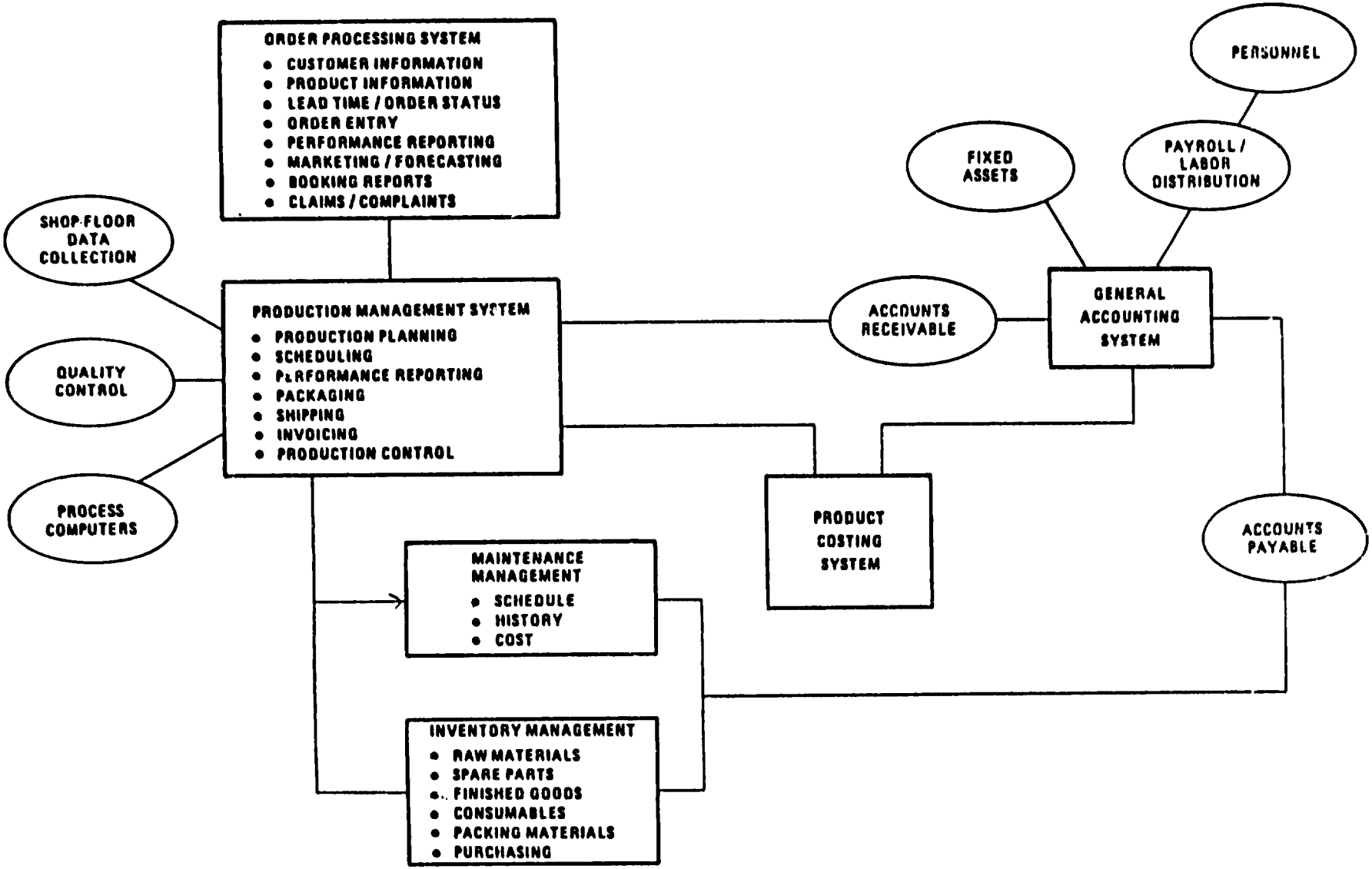
Integrated Production Systems

Overhead displays

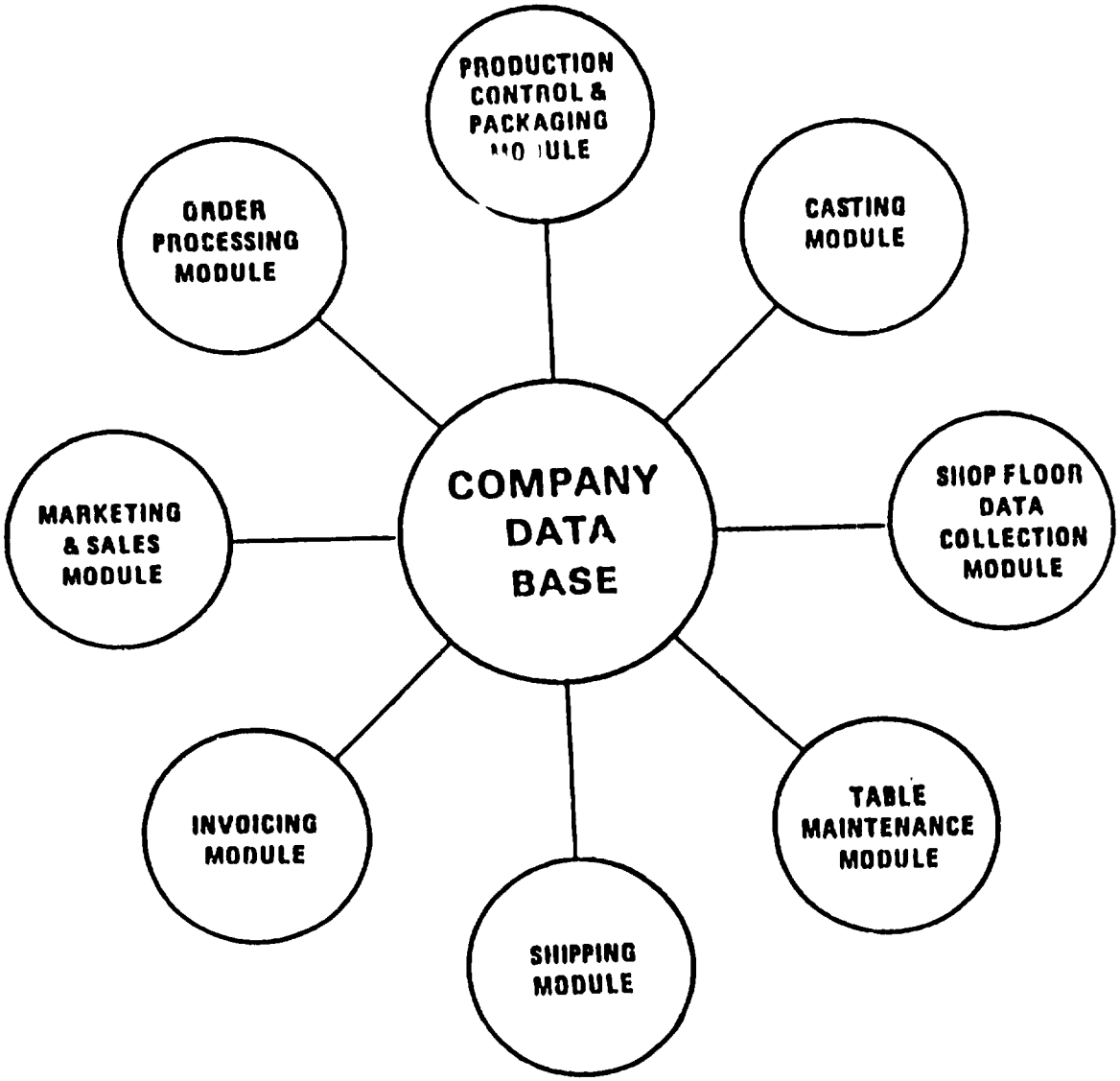
INTEGRATED PRODUCTION SYSTEM



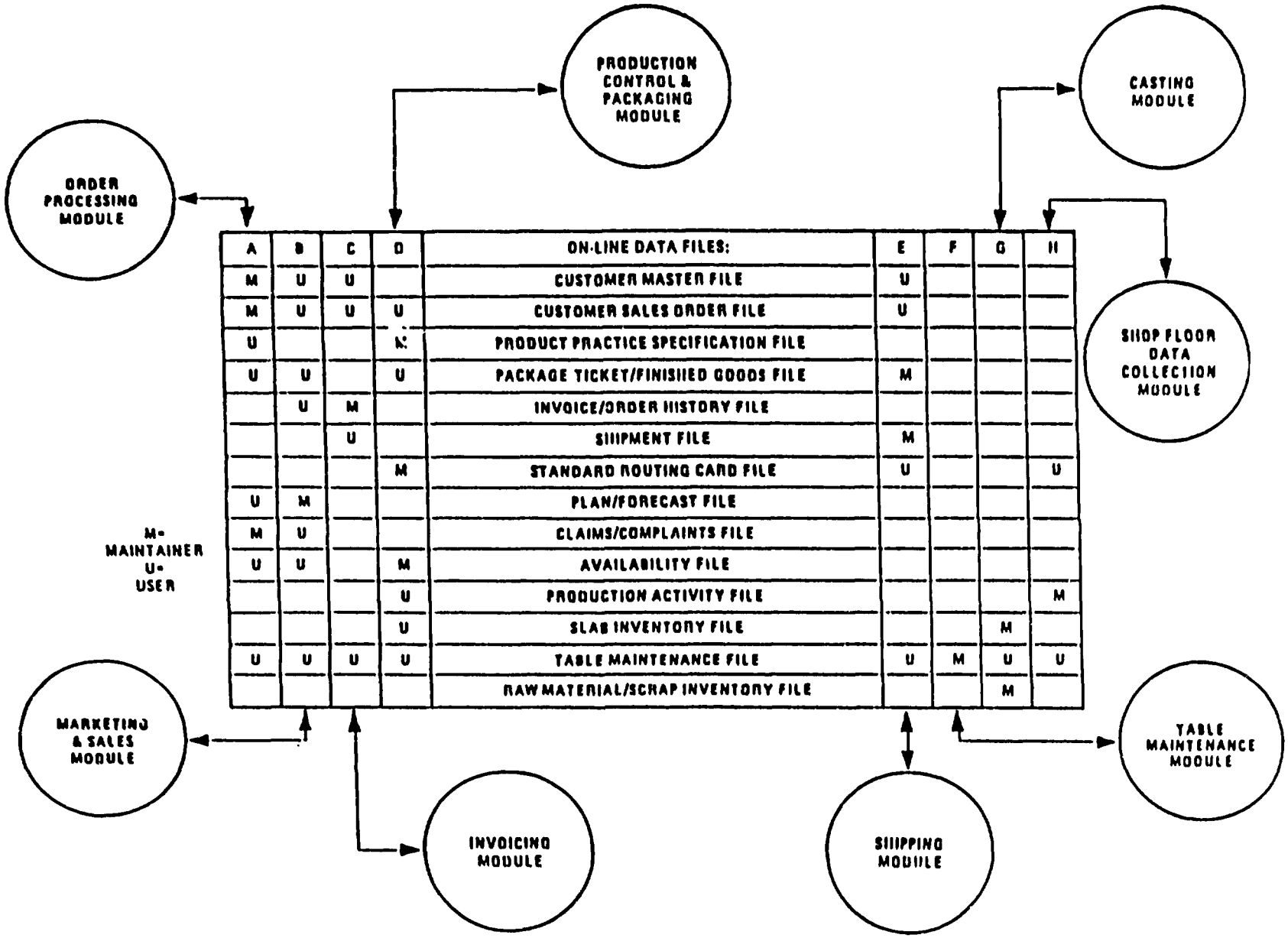
INTEGRATED PRODUCTION SYSTEM



PRODUCTION MANAGEMENT SYSTEM

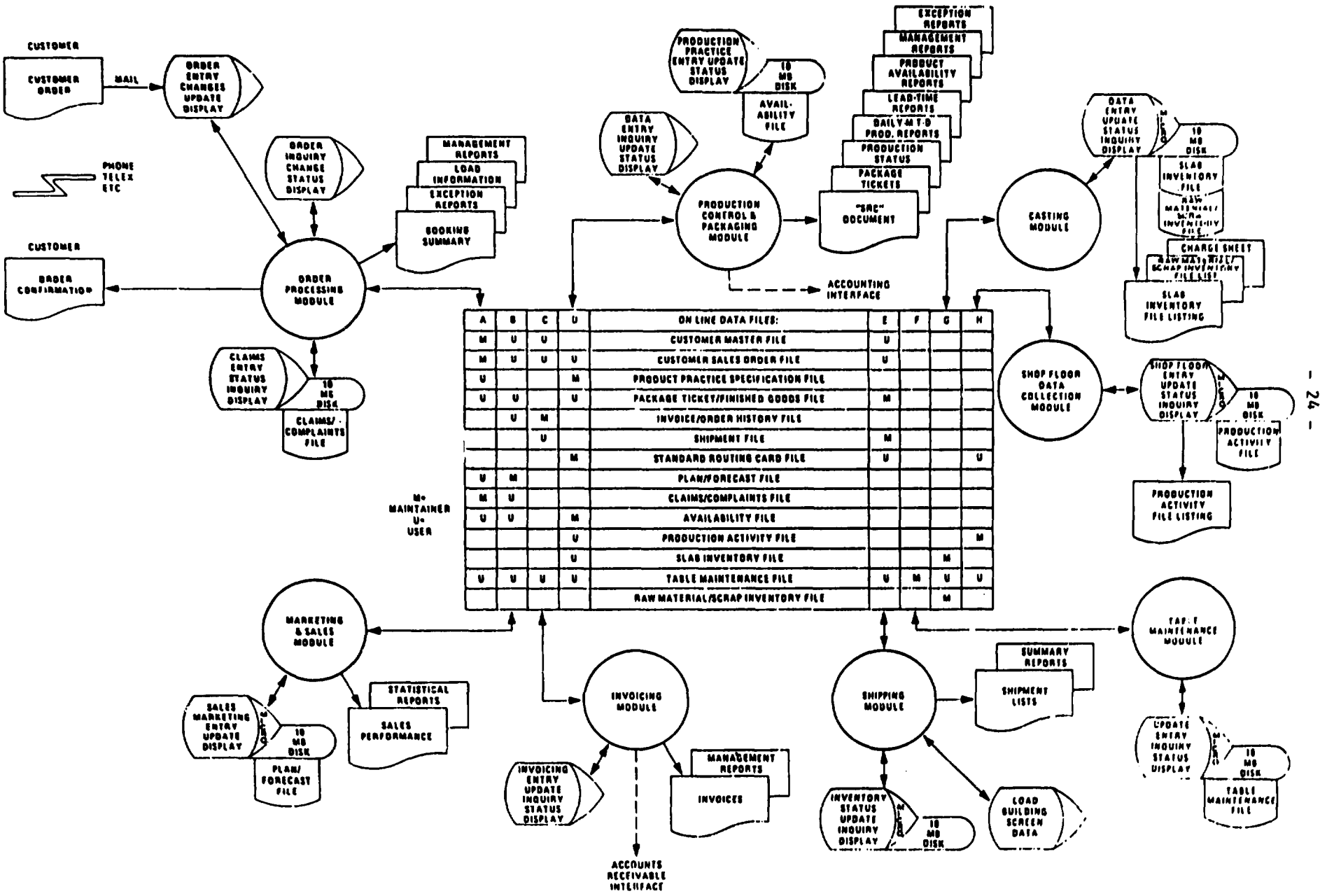


PRODUCTION MANAGEMENT SYSTEM ARCHITECTURE



A	B	C	D	ON-LINE DATA FILES:	E	F	G	H
M	U	U		CUSTOMER MASTER FILE	U			
M	U	U	U	CUSTOMER SALES ORDER FILE	U			
U			M	PRODUCT PRACTICE SPECIFICATION FILE				
U	U		U	PACKAGE TICKET/FINISHED GOODS FILE	M			
	U	M		INVOICE/ORDER HISTORY FILE				
		U		SHIPMENT FILE	M			
			M	STANDARD ROUTING CARD FILE	U			U
U	M			PLAN/FORECAST FILE				
M	U			CLAIMS/COMPLAINTS FILE				
U	U		M	AVAILABILITY FILE				
			U	PRODUCTION ACTIVITY FILE				M
			U	SLAB INVENTORY FILE			M	
U	U	U	U	TABLE MAINTENANCE FILE	U	M	U	U
				RAW MATERIAL/SCRAP INVENTORY FILE			M	

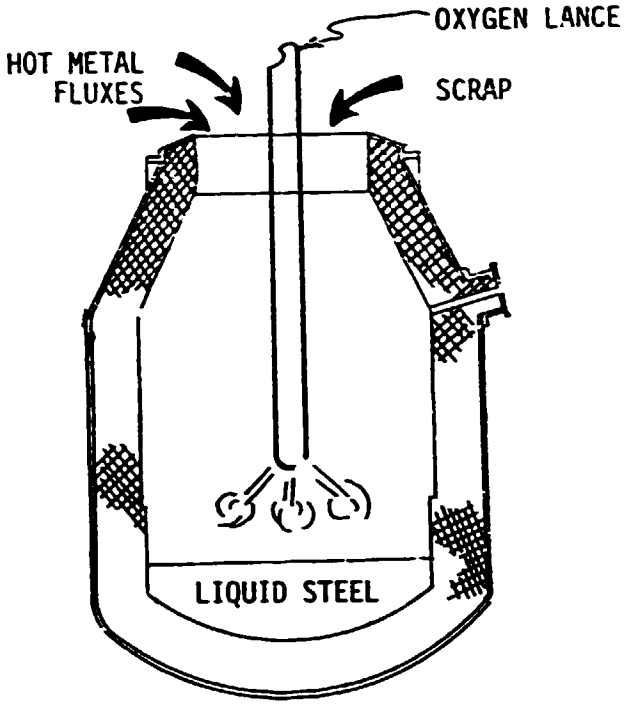
PRODUCTION MANAGEMENT SYSTEM ARCHITECTURE



A	B	C	D	ON LINE DATA FILES:	E	F	G	H
M	U	U		CUSTOMER MASTER FILE	U			
M	U	U	U	CUSTOMER SALES ORDER FILE	U			
U			M	PRODUCT PRACTICE SPECIFICATION FILE				
U	U		U	PACKAGE TICKET/FINISHED GOODS FILE	M			
	U	M		INVOICE/ORDER HISTORY FILE				
		U		SHIPMENT FILE	M			
			M	STANDARD ROUTING CARD FILE	U			U
U	M			PLAN/FORECAST FILE				
M	U			CLAIMS/COMPLAINTS FILE				
U	U		M	AVAILABILITY FILE				
			U	PRODUCTION ACTIVITY FILE				M
			U	SLAB INVENTORY FILE			M	
U	U	U	U	TABLE MAINTENANCE FILE	U	M	U	U
				RAW MATERIAL/SCRAP INVENTORY FILE			M	

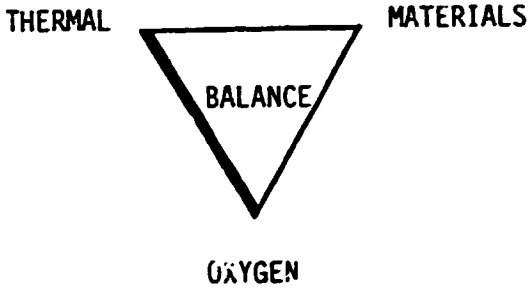
L. D. Converter Charge Calculation Model

Overhead displays



3-1 OXYGEN FURNACE

To refine hot metal into steel in the basic oxygen steelmaking process, hot metal, scrap, and fluxes are charged into an oxygen furnace and oxygen blown onto the surface for approximately 15 minutes. Oxygen is blown through a lance at 26000 standard cubic feet per minute (SCFM) at a velocity of MACH 2.3.



3-2 BALANCES REQUIRED IN AN OXYGEN FURNACE

Refining hot metal into steel demands three balances to obtain the desired heat weight, carbon, and temperature at the end of the oxygen blowing period.

OXYGEN - The correct amount of oxygen is required to obtain the proper carbon.

THERMAL - The reaction of oxygen, fluxes, and hot metal generates heat. The proper amount of scrap must be added to obtain the proper temperature at the end of the oxygen blow.

MATERIALS - The correct amount of scrap and hot metal must be used to obtain the desired heat weight, normally 230 tons.

None of the three areas of balance is independent of the others and a change in any of the areas will affect the others.

The following is a summary of the three balances required in an oxygen furnace.

1. THERMAL BALANCE

Sensible Heat Input + Exothermic Heat = Sensible Heat Output + Heat Losses

a) Sensible Heat Input
- Hot Metal
- Scrap
- Fluxes

b) Exothermic Heat
- Oxidation of C, Mn, P, Si
- Oxidation of Fe
- Vessel CO_2 reaction

c) Sensible Heat Output
- Steel
- Slag

d) Heat Losses
- Heat loss per blowing minute
- Fume loss
- Reduction of carbonates in fluxes
- Reduction of charge oxides
- Reduction of ore or pellets
- Vaporization of moisture in fluxes

2. MATERIALS BALANCE

Iron Balance:

Wt. Iron In = Wt. Iron Out + Losses

a) Wt. Iron in
- Hot Metal
- Scrap
- Pit Scrap
- Cold Iron
- Charge Alloys
- Pellets

b) Wt. Iron Out
- Steel

c) Losses
- Slag Losses (FeO)
- Fume losses

3. OXYGEN BALANCE

Oxygen In = Oxygen Out

a) Oxygen In
- Lance O_2
- O_2 in pellets
- O_2 in raw dolomite
- O_2 in charge alloys

b) Oxygen Out
- O_2 to oxidize Mn, Si, P
- O_2 to oxidize C to CO & CO_2
- O_2 to oxidize Fe
- O_2 dissolved in steel

BOP CHARGE CALCULATION

Kaiser has chosen to use a charge calculation computer model to handle the complicated mathematical functions required to determine the proper amounts of hot metal, scrap, fluxes and oxygen to obtain end point specifications. The model will comprehend the material, thermal and oxygen balance.

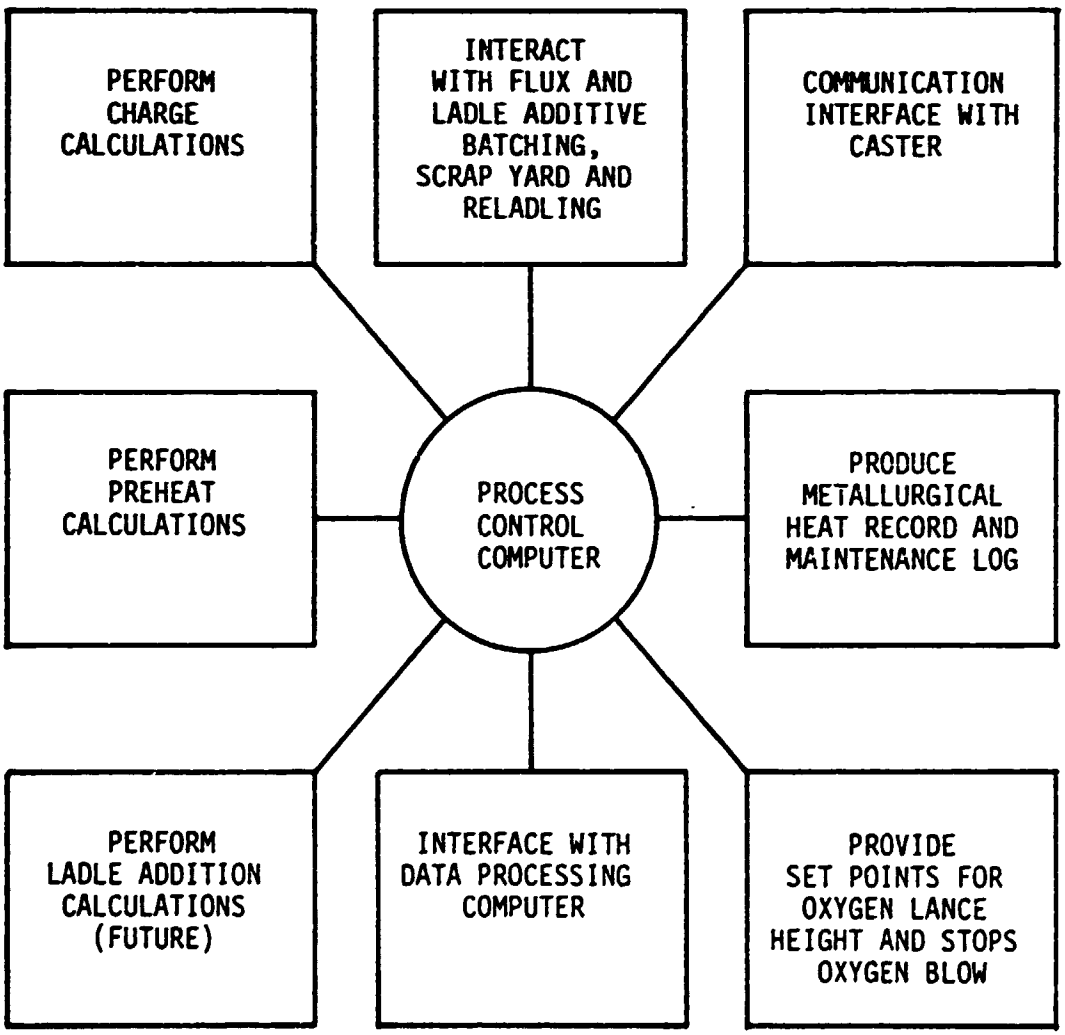
To obtain these proper amounts, four separate charge calculations will be made during the course of making a heat. They are:

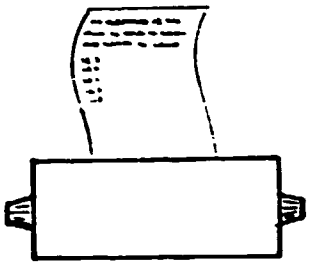
1. Preliminary scrap and hot metal calculation.
2. Trim scrap and hot metal calculation
3. Flux calculation.
4. Oxygen calculation.

Each calculation step uses the most current information available to calculate the next furnace additive. The following displays are pictorial representations of the four calculations.

2.1 BOP PROCESS CONTROL COMPUTER

SCOPE OF FUNCTIONS



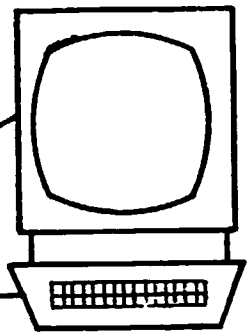


COMMUNICATES TO OTHER COMPUTERS:

. CHEM LAB
. CASTER
. IBM
. SUPPORT

PRINTS OUT METALLURGICAL LOG RECORDS

DISPLAYS INFORMATION TO OPERATOR CRT DISPLAY



PERFORMS CHARGE CALCULATIONS

PROCESS CONTROL COMPUTER

KEYBOARD

TDC

DLC

WEIGH SYSTEM

READS IN FROM TDC:

. OXYGEN FLOW
. FUEL OIL FLOW
. EPA, PEC DATA
. MAINTENANCE DATA

INPUTS FROM DLC:

. OPERATOR CONTROLS
. MODES OF OPERATION
. ACTUAL LANCE HEIGHTS
. ALARMS

OUTPUTS TO DLC:

. LANCE HEIGHT SETPOINTS
. OXYGEN BLOW CONTROLS
. COMPUTER MODE PERMISSIVES, ETC.

OUTPUTS TO WEIGH SYSTEM:

. ORDERS UP BATCHING OF MATERIALS
. ORDERS SCRAP AND HOT METAL

INPUTS FROM WEIGH SYSTEM:

. ACTUAL WEIGHTS
. STATUS OF EACH AREA

Continuous Caster Automation

Overhead displays

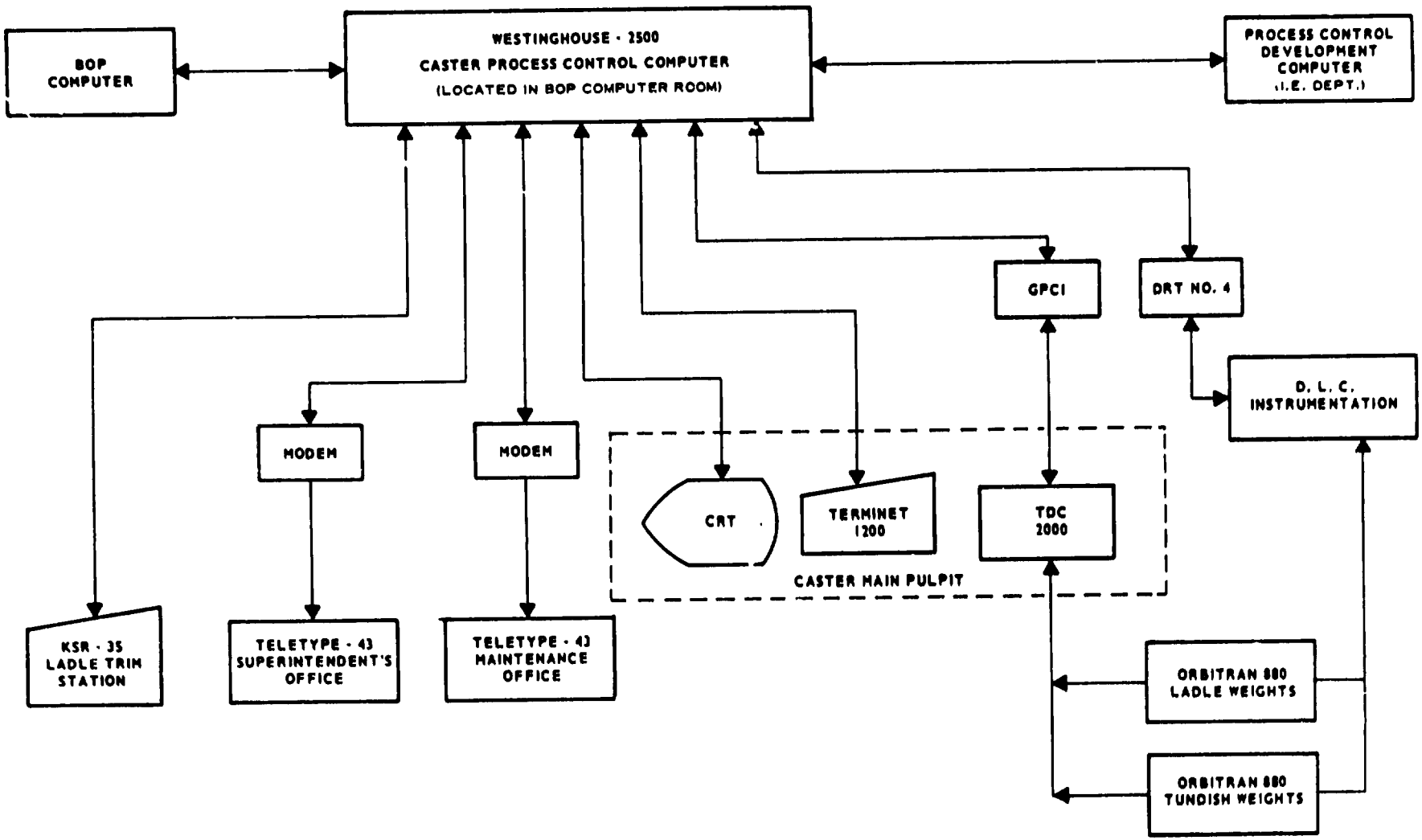


FIGURE 10 - 01

SCHEMATIC OF CASTER PROCESS CONTROL SYSTEM

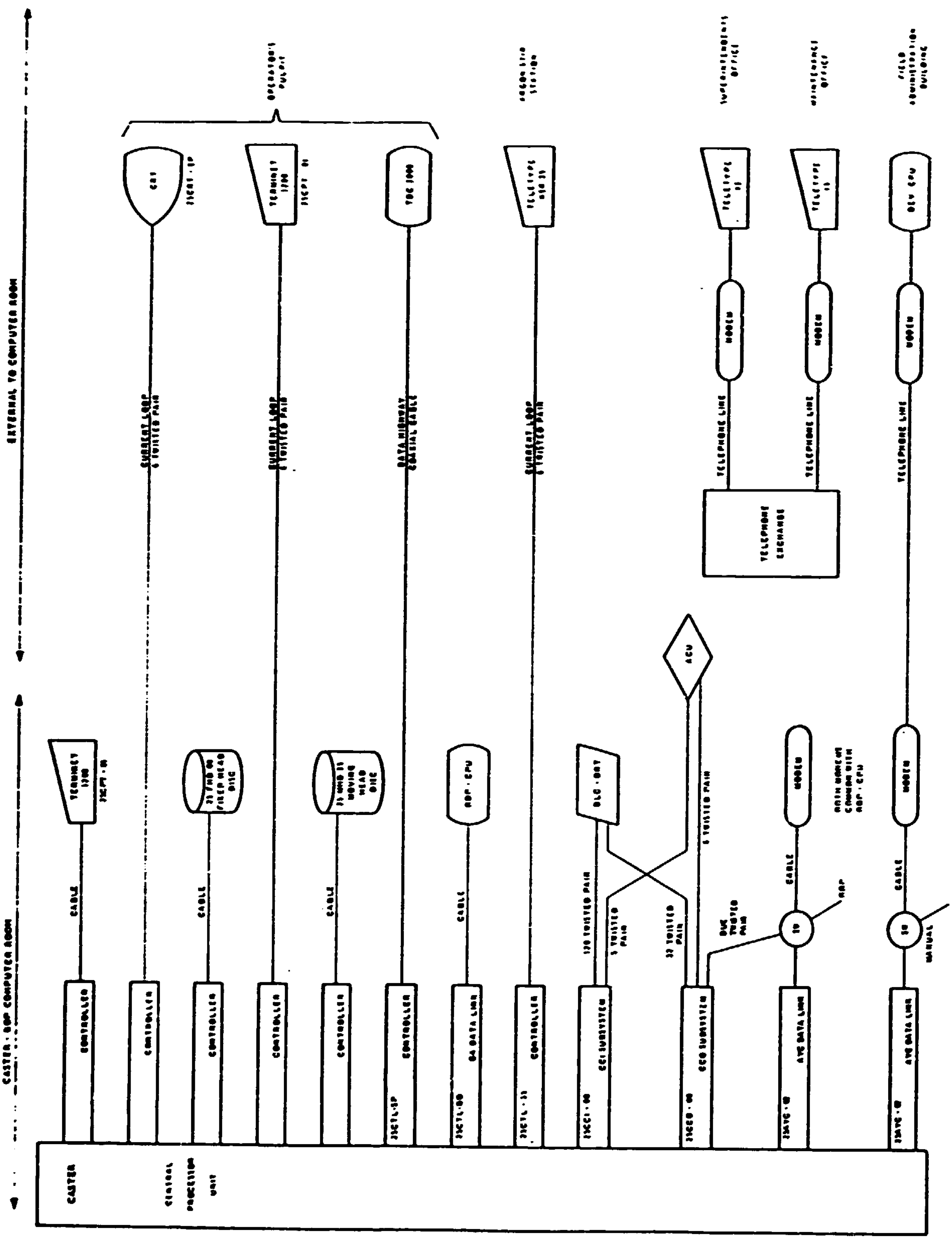


FIGURE 10 - 02

PROCESS CONTROL COMPUTER-SYSTEM HARDWARE

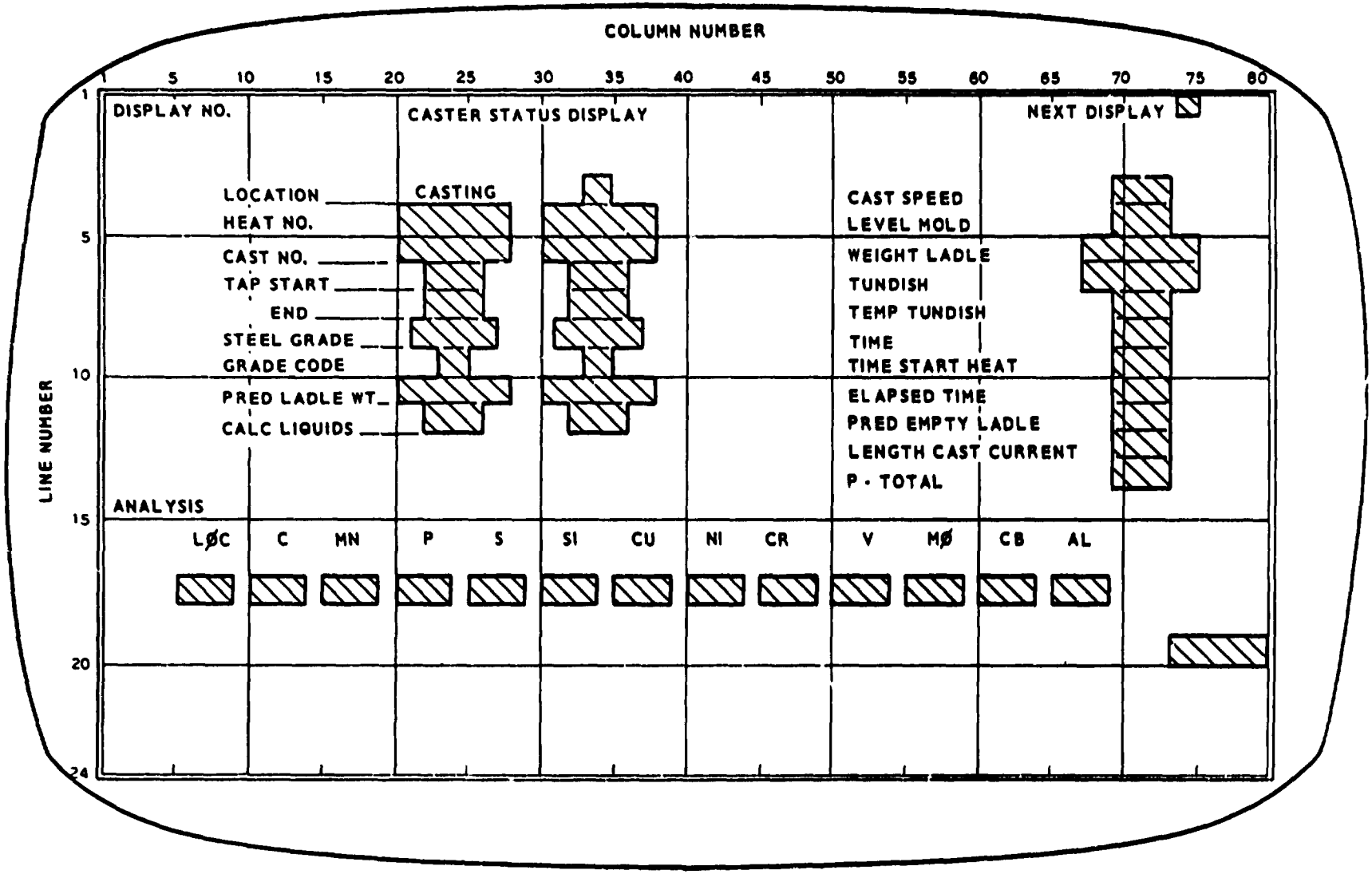


FIGURE 10 - 03

PROCESS CONTROL SAMPLE CRT DISPLAY