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United Nations Industrial Development Organization

UNIDO/FAI Interregional Meeting on Safety in the Design and Operation of Ammonia Plants

New Delhi, India
20 - 24 January 1976

INSTRUMENTATION AND COMPUTER CONTROL FOR SAFE AMMONIA PLANTS[1]

by

M. Nobue*

* Manager of Process Design Department, Toyo Engineering Corporation, Tokyo, Japan

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SUMMARY

by

M. Nobue*

Wide range of cares have to be taken on process scheme, mechanical points, etc., in order to design a safe ammonia plant. This article gives an outline of how a safe ammonia plant can be designed focusing on the instrumentation, and further, correlation between computer control and improvement on safety of the plant.

An ammonia plant consists of several process units. Taking light hydrocarbon as feedstock for example, the plant is formed of various process units, such as preheating of feedstock by direct heating, hydrogenation utilizing Co-Mo catalyst, tubular steam reforming by external firing, adiabatic second reforming, high and low CO shift, CO_2 removal by absorption solution, methanation, synthesis gas compression, ammonia synthesis.
Therefore, the instrumentation has to be designed after due understanding of the funciton of these process units.
This article explains how the instrumentation, especially alarm and trip system for critical parts of the plant is designed from the view point of safety.

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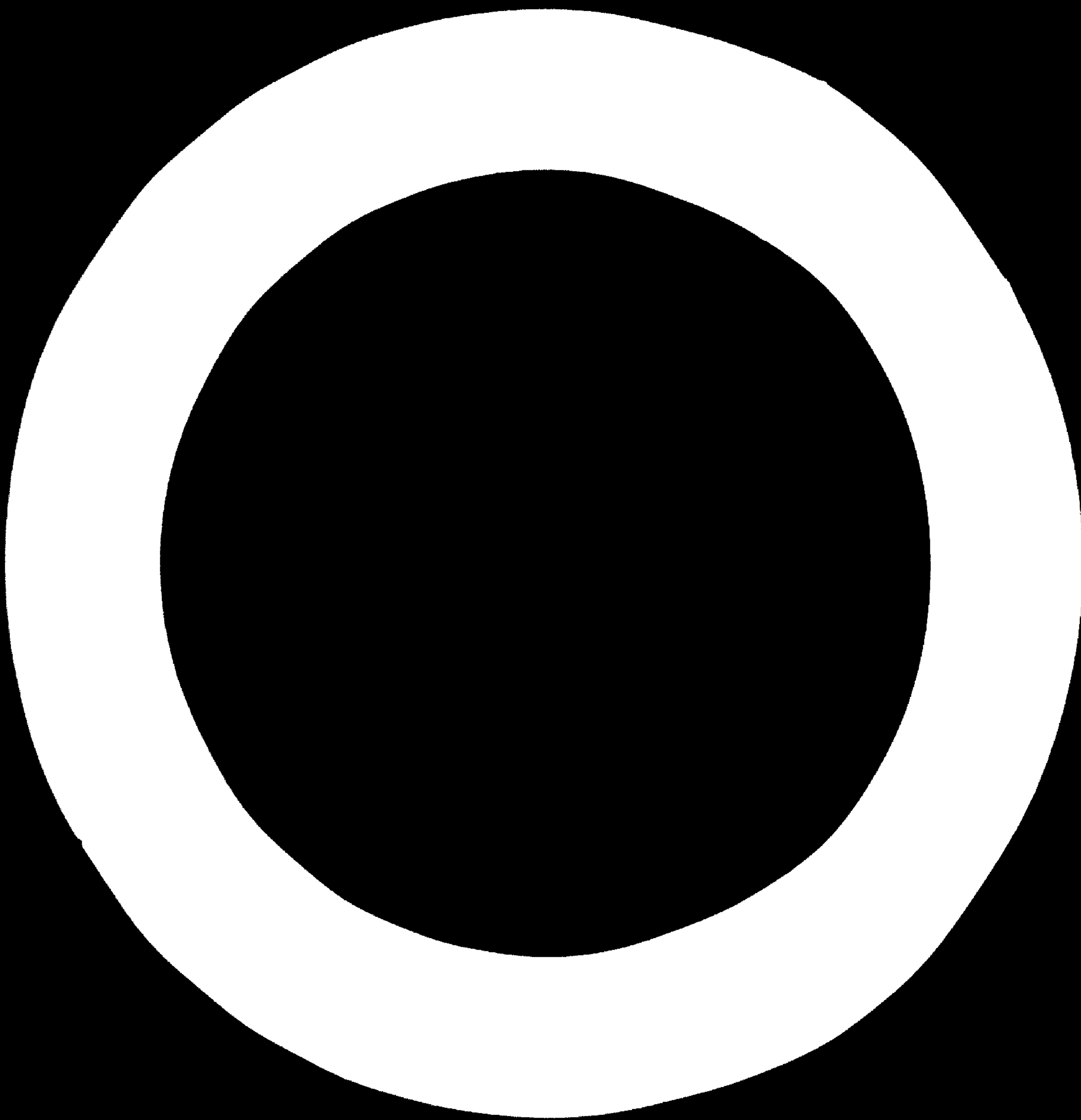


Then, it mentions about the trip system from the standpoint of the whole plant. Roughly, two kinds of approach can be considered on the trip system. One is to leave necessary measures following the trip to operators' judgements when local trips are actuated.
The other is to take the necessary measures by automatic trip aciton, covering the predicted trip conditions successively occur, in case of major local trips.

In the latter case, the trip conditions should be classified into several grades, but it goes without saying that the classification has to be done based on the policy to keep the plant being in continuous operation as much as possible.

Danger of mal-actuation of the trip system always follows us when designing the trip system, and therefore, it is necessary to improve reliability of the trip system.
This article also explains briefly about countermeasures we have taken on this problem.

Computer control system has been applied to several ammonia plants designed by us since ten years ago.
This article explains about those computer control systems from the viewpoint of the improvement of the safety of the plant, and further touches on application of computer control expected in future.

Instrumentation and Computer Application for Safe Ammonia Plant

1. Introduction

Same as other chemical plants, economy and safety are the major subjects considered when designing and constructing an ammonia plant. In order to pursue good economy, a superior process plant has to be adopted, enabling low investment cost, low materials and utilities consumptions, long stable operation with small number of operators.

On the other hand, full consideration also has to be made on the design in order to secure safety of the plant. The first step of safety design is to recognize the process function of each section of the plant. Secondly, it is required to consider mechanism of the whole plant including interrelation among various sections. Recently, in many large ammonia plants, most of power required is supplied by steam and so, it is a big problem how to design safe steam system as well as process system. Furthermore, it is necessary to pay attention to surrounding condition of the plant, like,

"Can we get stable supply of electric power? How about instrument air, or cooling water"

"Can we get steam from outside of plant in case of emergency condition?"

There are more items which have to be considered for safety design of ammonia plant, but here, I would like to give an outline about how instrumentation is designed, based on the aforesaid recognition. Further, I would like to touch on computer application from safety viewpoint.

2. Process Description (Fig. 1)

Here is shown a typical large scale plant employing steam reforming process and steam turbine driven centrifugal compressor. Feed naphtha is pressurized and heated up, and sulfur compounds in naphtha are hydrogenated on Comox catalyst, then removed by absorption in zinc oxide bed.

Desulfurized naphtha mixed with steam is then steam reformed to H_2, CO, CO_2 and CH_4 through tubular type 1st reformer. Heat required for reforming is supplied by heating from outside of tubes. In 2nd reformer, process air is added so that necessary H_2/N_2 ratio for ammonia synthesis is obtained, and CH_4 is further steam reformed on nickel catalyst. 1st and 2nd shift converter are combination of high and low temperature shift, in which CO reacts with H_2O and they are converted into H_2 and CO_2. In CO_2 removal section, most of CO_2 is removed by absorption solution, and finally the rest of CO_2 and CO react with H_2 in methanator converted into CH_4. Refined synthesis gas, H_2/N_2 ratio being adjusted to 3, is then compressed and sent to synthesis loop. Synthesis gas is circulated in synthesis loop, since one pass conversion is not high enough. Fresh synthesis gas is mixed with circulating gas, and trace of water in the gas is removed at the same time when produced ammonia is separated in refrigeration section. In order to avoid accumulation of CH_4 and argon in circulating gas, a portion of the gas is purged out and used as fuel. Synthesis gas compressor, air compressor and ammonia refrigerator are centrifugal type and driven by steam turbine. Steam generated by process heat recovery system is used for those steam turbines being supplemented from auxiliary boiler.

3. Outline of Main Instrumentation

I would like to explain about typical philosophy of main instrumentation, especially alarm and trip system, of sections important for safety of plant.

Feed System

Fig. 2 shows main instrumentation of this section. Here, special attention should be paid to abnormal temperature rise on Comox catalyst, prevention of explosion due to flame failure and protection of coil in feedstock preheater. Hydrogenation reaction of organic sulfur compounds is usually operated at 350°C ∿ 400°C. The temperature rise of this system results in hydrocracking of feed hydrocarbon, and once this reaction starts, the temperature runs away, since hydrocracking is exothermic reaction. To prevent this, high alarm for outlet temperature of feedstock preheater is provided and further, trip system is designed to cut off feedstock by extraordinary high temperature in the catalyst layer. This high alarm system is also useful for protection of the coil. Flame detector with flame failure alarm (FFA) is provided for prevention of explosion in feedstock preheater. It depends on reliabil'ty of FFA whether FFA should be connected to trip system or not.

__1st Reforming__ (Fig. 3)

As known well, the most big problem in this section is carbon deposits on reforming catalyst due to steam shortage. Flow ratio of feed naphtha and reforming steam are controlled by flow controller respectively. Decrease of S/C ratio is warned by alarm, and when goes down further, feed naphtha is cut off by automatic trip shut down.

Secondly, pressure in furnace is kept slightly negative for safety by controlling revolution speed of the turbine for induced draft fan. Abnormal increase of the furnace pressure actuates alarm system and further increase leads to trip. This alarm is also installed at the platform of the furnace to warn operaters in the field. Alarm and trip circuit for abnormal decrease of fuel pressure is provided to prevent explosion due to the flame failure.

__2nd Reformer__ (Fig. 4)

What is important in this section is to prevent 2nd reformer from excessive air supply, which will cause abnormal temperature rise because of combustion reaction. Gas temperature at outlet of 2nd reformer is monitored with alarm. Air flow is tripped off by lack of feed naphtha. When process air is cut off, steam is automatically fed into 2nd reformer for a period of time for protection of air combustion nozzles, and air is vented at the outlet of process air heater automatically for the protection of the heater coil. 2nd reformer and its connecting parts are water jacketed for the protection of the metal, and water flow condition can be checked by the level and water temperature.

CO_2/CO Removal (Fig. 5)

The temperature rise in methanator is about 59°C and 72°C per 1% of CO_2 and CO in the gas respectively, by methanation reaction. This means that increase of CO_2, leads to dangerous temperature rise. For the monitoring of methanator temperature, thermometers with alarm are installed at several points of catalyst layer, and further, trip circuit at extraordinary high temperature will close gas inlet valve to methanator. The most important thing in CO_2 removal is to secure the flows of the solution. For this purpose, auto-start circuits of spare pumps at low flow rate are provided. In addition, trip circuit to isolate methanator is provided for abnormal low flow rate of semi-lean solution. Another important point is blow-off of process gas to CO_2 stripper through liquid line due to lack of absorber liquid level. To cope with this problem, low level alarm and trip circuit for automatic shut down of the level control valve are provided. Incidentally, capacity of safety valve (or disc) on CO_2 vapor line should be designed taking this blow-off into consideration.

Synthesis Gas Compressor and Synthesis Loop

Special attention should be paid to syn. gas compressor, because it is of centrifugal type and operated at very severe conditions.

Main instrumentations are as follows.

- Antisurging kick-back line from discharge to suction side with control device to keep minimum flow
- Liquid level especially, 1st stage suction drum has to be watched carefully to avoid liquid suction. (Usually a economizer of high pressure BFW is provided downstream of the methanator and the leakage of the exchanger, if it should occur, is dangerous. Therefore, a trip circuit of syn. gas compressor is provided by the extraordinary high level adding to the level controller with alarm.)
- Auto-start devices for each spare of lube and seal oil pumps and trip circuit to stop the compressor when oil pressure (or level) gets down. In addition, important operating variables such as gas temperature, oil temperature, vibration, shaft axial movement, rotation speed are monitored as well. Incidentally, almost same measures are taken for air compressor and refrigerant compressor.

In synthesis loop section, special case has to be taken to prevent explosion and to protect coil of start up heater. Since the heater is used only during start up and unsteady condition, the fuel is automatically cut off in case of extraordinary low flow of synthesis gas, in addition to the same consideration as feedstock preheater.

4. <u>Steam System</u>

The successive use of generated steam from process and auxiliary boiler is typically outlined on Fig-6. In almost cases, upset condition of a part of the plant results in fluctuation of steam balance. Since it is especially important to secure reforming steam, enough consideration has to be made on this point. When top turbine is stopped by trip, let down valve from high pressure line to middle pressure line opens quickly to keep middle pressure steam. Since the steam system is so complicated, quick response of operators as well as good instrumentation are indispensable to minimize bad effect when tripping. Liquid level in steam drum is kept stable, usually by three element control. To secure boiler feed water, auto-start circuit of spare boiler feed water pump and further, installation of emergency boiler feed water pump driven by diesel engine can be considered.

5. Trip System

In general, alarm gives warning before trip is actuated, and automatic trip should be considered as the last resort. Trip condition is decided from the view point of security of plant and personnel, but extent of the influence to the whole plant is different among such trip conditions. Two kinds of approach can be considered for trip system. One is to take necessary measures by automatic action for only limited part directly related to the cause of the trip, and to leave the rest to operators' judgement. This may be referred to as "local trip philosophy". The other is to secure safety of the plant by automatic action as much as possible covering the conditions predicted to occur successively. This may be called as "whole plant trip philosophy". Take process air failure, for example. In this case, actions such as air cut by emergency valve, steam injection to protect air nozzles, air vent to guard prehcater coil are the same in both philosophy. But in case of local trip philosophy, the measure after this is left to operators. On the other hand, in case of whole plant trip philosophy, attention will be paid to the condition successively occur, that is, as the result of air cut off, it will be defficult to keep syn. gas compressor running because of change of gas composition, and also, it may get impossible to secure steam to reformer due to shortage of heat recovery in process waste heat boiler. Therefore, syn. gas compressor and synthesis loop are so designed as to trip down at the same time of air cutting off. Fig. 8 shows an example of trip system based on whole plant trip philosophy. However it should be in mind that it depends on the numbers and skillness of operators, which philosophy should be applied. The following classification of trip system is usually done based on the policy to keep trip area to the minimum extent so that restart up of plant can be made quickly.

- AA - plant all shutdown
- A - process all shutdown - auxiliary boiler working
- B - process air cut-off - auxiliary boiler and 1st reformer working
- C - methanator shutdown
- D - synthesis loop shutdown - auxiliary boiler and gasification section working
- local trip

One of the big problems on trip system is needless and nuisance trip caused by mal-function of trip system. Production loss due to this problem amounts to great sum in recent large scale plant. Therefore, selection and setting of instruments should be carefully checked. To avoid mal-function, there are several methods applicable. One of them is to delay the actuation of trip signal by using timer. This measure is effective on, for instance, eliminating the influence of wind pressure in first reformer furnace, or preventing high class trip due to momentary drop of S/C ratio caused by upset condition of steam system, or preventing mal-function of thermometers due to vibration. Application of "and-circuit" is another measure to eliminate the mal-function, by which higher reliability than single circuit can be obtained, which for example is applicable to the trip circuit for flame failure. Another example is the use of external float instead of internal float type level switch to eliminate the effect of gas (liq.) flow. It goes without saying that proper work and through maintenance are inevitably required in order to get high reliability of trip system, basides the aforesaid design consideration.

6. Computer Application for Safe Ammonia Plant

Nowadays, computer application to chemical plants is not so fancy thing any more. Our company established TOPACS, who is specialized in computer control, together with Mitsui Toatsu Chemicals, Inc., and has positi ely been pushi g forward application of computer control to chemical and petrochemical fields. As for ammonia plants, we have supplied computer system to the following five plants since 10 years ago.

plant capacity	owner	country
Ammonia 500 MT/D (Urea 800 MT/D)	Mitsui Toatsu	Japan
Ammonia 1,000 MT/D (Urea 1,800 MT/D)	Mitsui Toatsu	Japan
Ammonia 1,360 MT/D		An European country
Ammonia 1,000 MT/D		Romania (Consulting service)
Ammonia 1,360 MT/D		An European country

Based on these experience, I would like to talk about the merits of computer application to ammonia plante, especially from safety standpoint.

Outline of Principles of Process Computer

Please refer to appendix A. Computer system is positioned between instrumentation system and management or operators, as is shown on Fig-9. It should be emphasized that a computer, with its speediness, huge memory and accurate processing, can give better judgements, appropriate instructions and advices without mistake, and that it can cooperate with men, can supplement men's weak points and can converse with men at all time, thus contribute not only to manpower saving, but also to safety operation of plant.

A Typical Example of Computer Applied System

Appendix B shows the example of computer applied system, which is the first one we handled. Computer receives imput signals from plant such as flow rate, analysis, temperature, pressure and level, then functions as follows and sends out the output signals.

1) Monitoring

i) basic data processing
- scanning
- averaging
- integration
- calibration
- unit conversion

ii) indirect measurement
such as S/C, H_2/feed, S/CO, H_2/N_2

iii) logging and alarming

iv) emergency data logging

v) plant management information
such as material balance (gasification, synthesis, steam system), feedstock and utilities consumptions, plant performance

2) process control

- set point control
- operating and adaptive control

Followings are the merits derived from this computer system.

1) Securing the effective operation

The effective operation equal to or surpassing the operation by highly trained operators is possible. For instance, production capacity is affected by water temperature and ambient temperature, but it is very difficult for operators to follow such changes by manipulating various operating variables. While, computer can do it easily, and production may be increased by 2 ∿ 3%.

2) Helping management people to make right decision by offering right information.

3) Giving helpful data for design development for the next plant.

4) Securing safety of the plant, including safe and fast start up/shut down.

Without saying, the aforesaid various computer outputs are useful as a guide for operators for safety operation. When starting up the plant, various process conditions have to be set so that they balance each other. Many process variables can be checked simultaneously by using computer, making it possible to know the exac situation of the plant. Computers are especially competent to catch slight change of process variables, which is utilized for operation, for instance, it is very useful to know the trifle temperature rise in case of starting air feed to 2nd reformer which ordinary instrument cannot detect.
Emergency logging is another way of computer application, which is unique and effective. Computer monitors the required data simultaneously by scanning at regular intervals and memorizes them for a period of time. Under trip condition, the interval is set shorter than under normal condition. By analyzing this emergency logging data, causes and

effects of troubles, or what happened first, what followed next and so on, can be analysed. Here is an example we experienced. Fig.10 shows summary of the emergency logging data.

The symptom was as follows;

> Syn. gas compressor turbine started to vibrate suddenly, and at the same time, the compressor got into surging condition and abnormal noise came out, then the compressor was shut-down by manual trip.

After the open inspection, the turbine blades were found damaged. We analysed the emergency logging data and tried to investigate the cause. (Emergency logging is possible at 96 points in this plant, and the interval of scanning was 10 seconds under normal condition and 4 seconds under trip condition.) According to the record, the abnormal condition was found to start a little prior to manual trip. The significant phenomena around the trip time are the slow down of the rotation and increase of high pressure steam flow rate (phenomenon 1) and the sudden rise of the final stage suction pressure (phenomenon 2). Phenomenon 2 was presumably due to the temporary gas accumulation in the suction line of the final stage. Judging from these 2 phenomena, following 2 outbreaking routes could be presumable.

Route 1

> At first, the turbine brades were damaged, and the efficiency dropped, then the discharge flow of the compressor dropped, and the kick back valve opened.

Route 2

> The kick back valve opened by some reason, then the discharge gas flow of the compressor dropped, and the required power for the compressor increased suddenly, the turbine brades were damaged by the shock due to the sudden power increase.

Since phenomenon 1 outbreaked a little prior to phenomenon 2. It was concluded that route 1 was the fact. Incidentally, the operating condition of the kick back valve and instrument air were found all right as the result of inspection. The above mentioned conclusion was further confirmed by the re-inspection, by which manufacturing defect was found on the turbine.

Furthermore, the following facts were confirmed through the study of Fig. 10.

1) The block valves between compressor and synthesis loop operated properly and shut tightly. (3, 1)

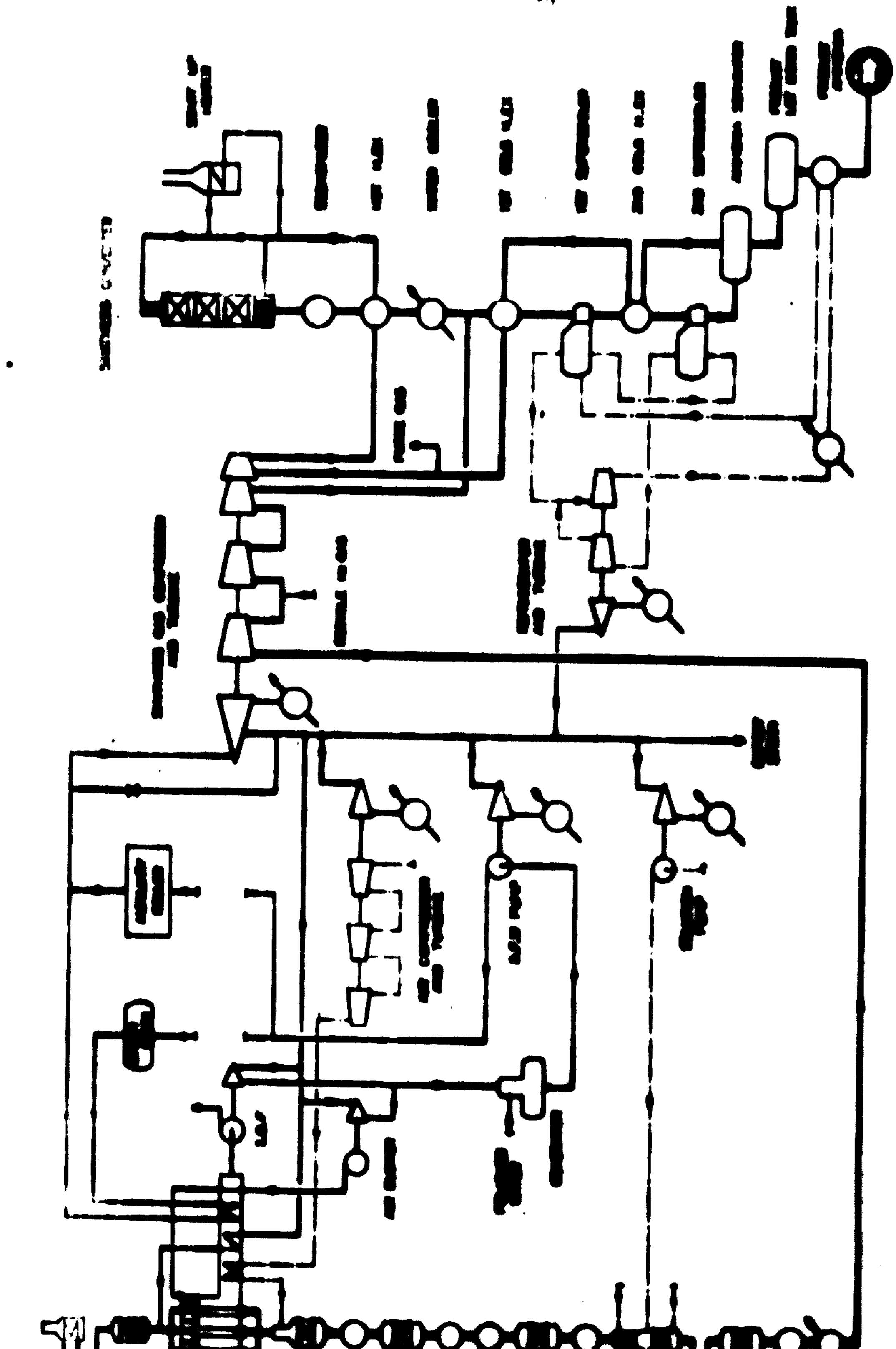
2) Controllability of combustion control of boiler system was satisfactory. (5)

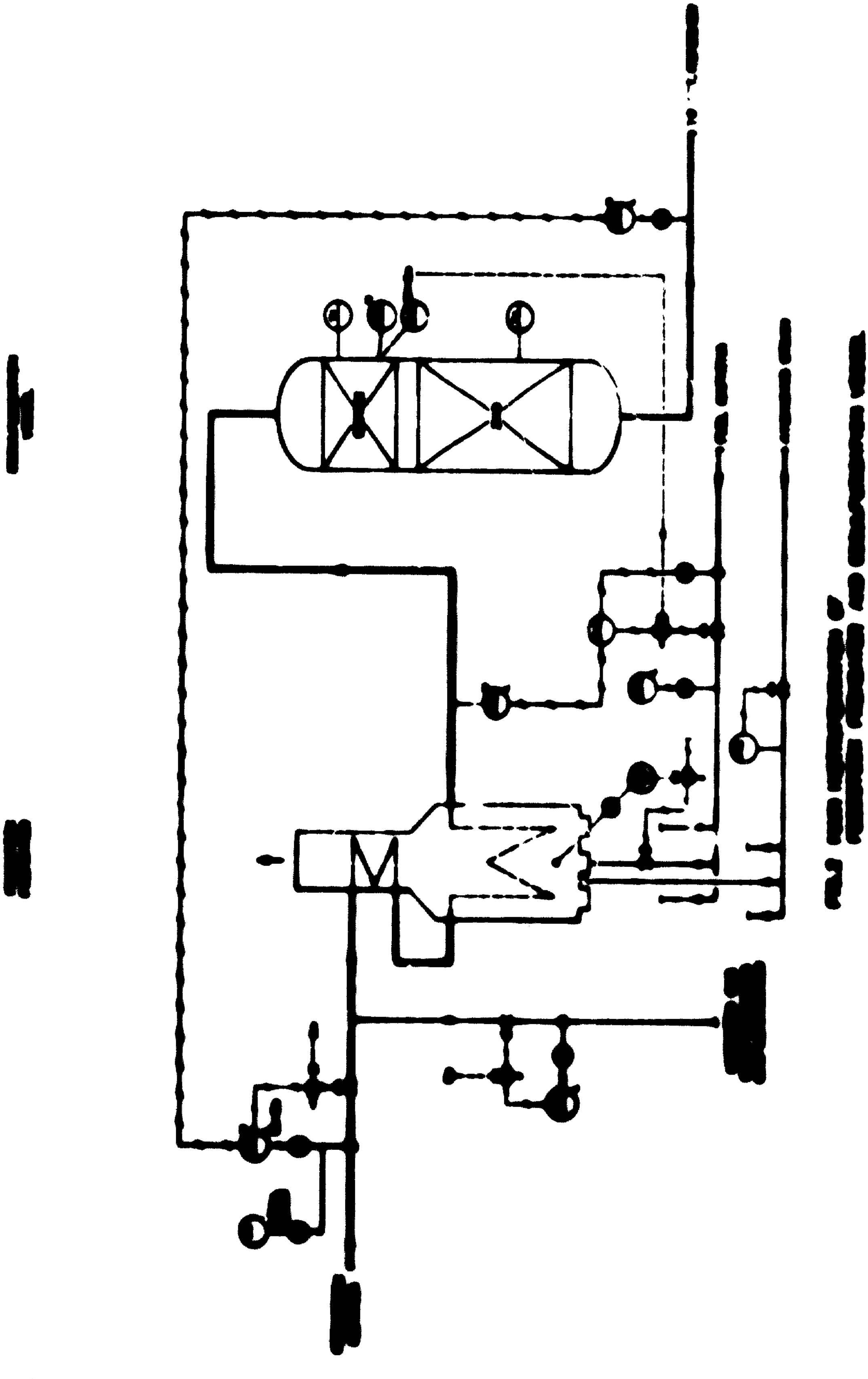
3) Seal oil system was working correctly; the setting pressure, volumes of head tanks, etc. (3, 4)

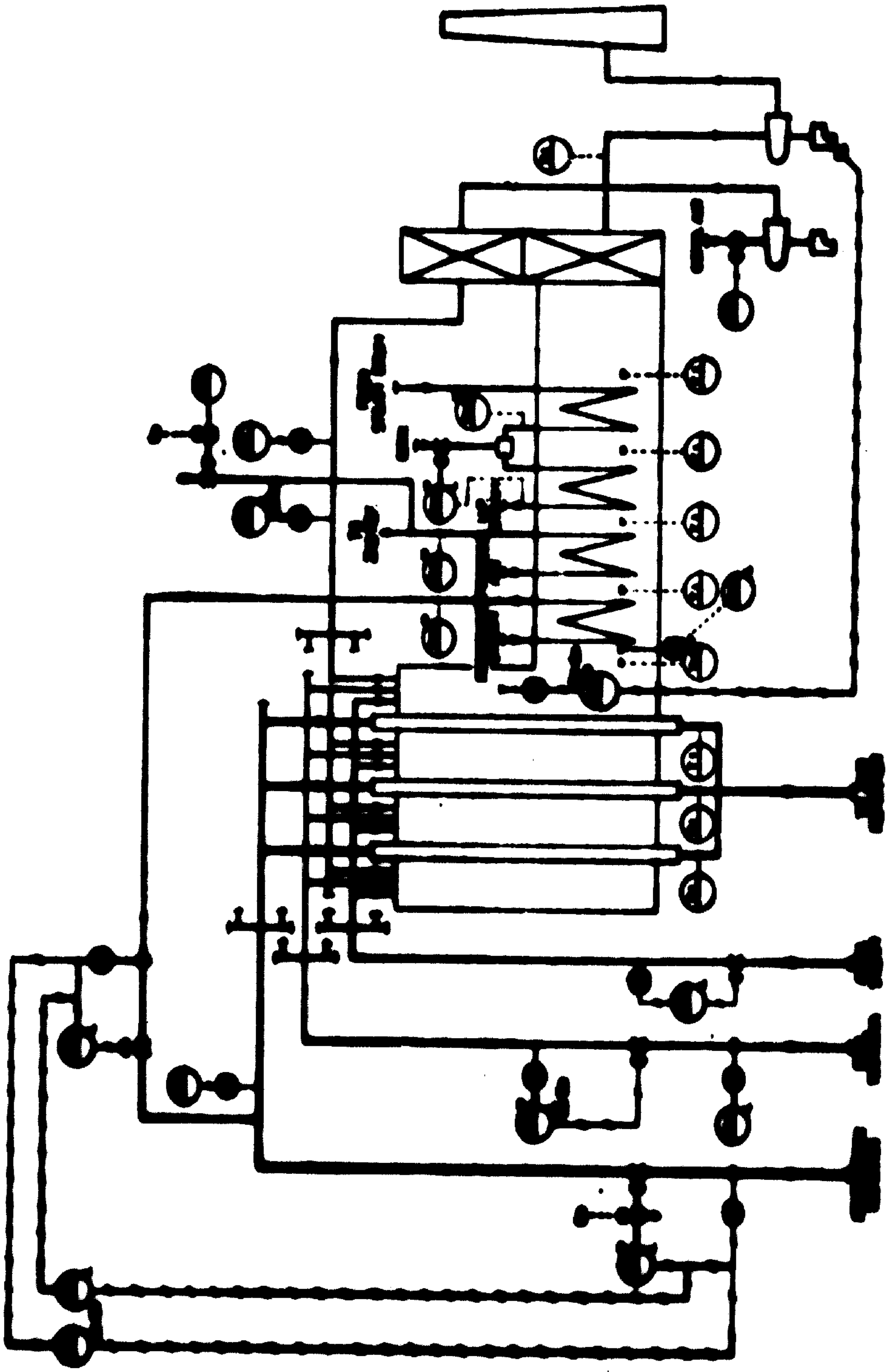
Application of Process Computer in Future

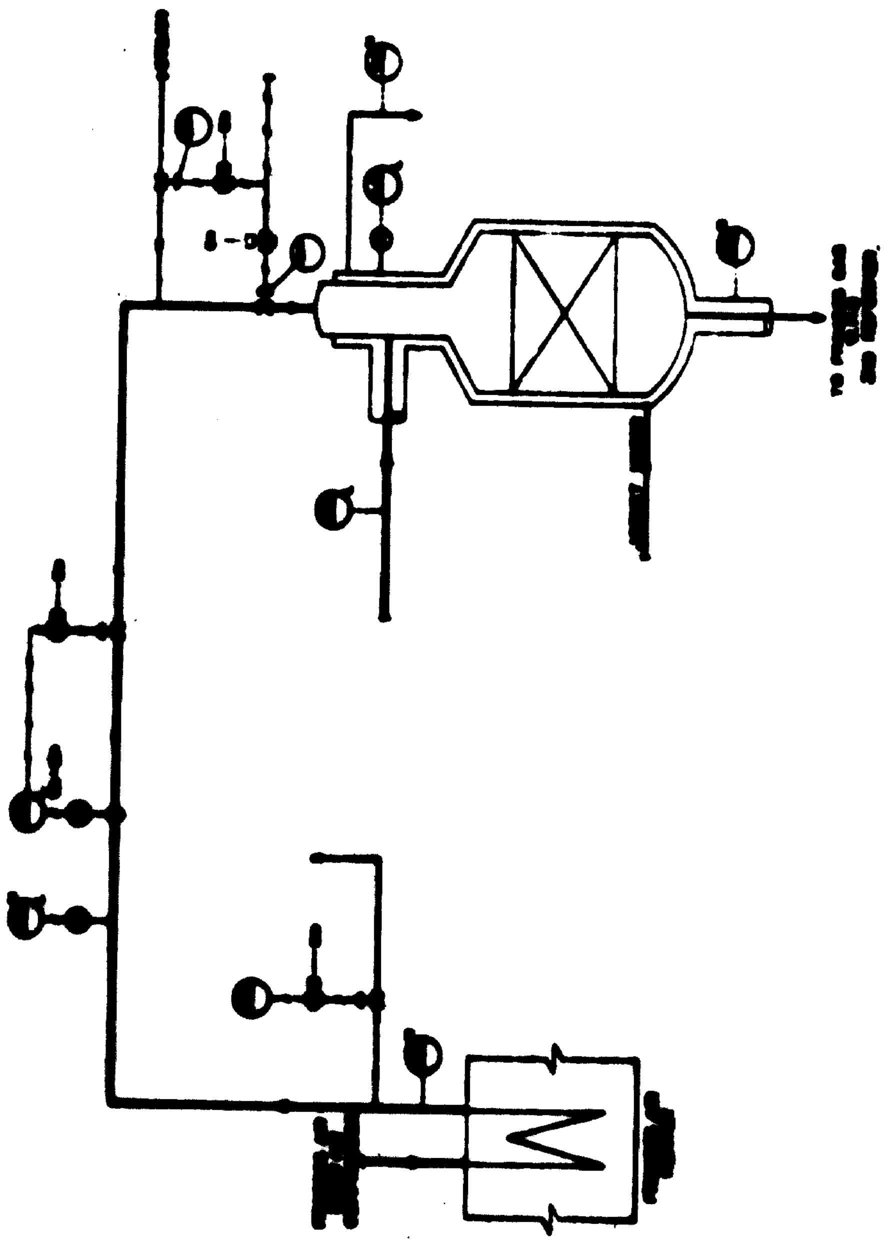
Our company are developping new area for process computer application useful for improvement of plant safety based on the experience of computer application and operation of ammonia plants. One of them is monitoring of operating condition, and operation guide for start up/shut down. One of the advantages of computers over analoque instrumentation is that computers can monitor "rate". This special feature is utilized for monitoring of increasing (decreasing) rates of temperatures and pressures, which are, in many cases, important for preservation of the equipment. CRT(Cathode Ray Tube) Display is used together with computer for this purpose. The actual condicion can easily be compared with the optimum condition by displaying the optimum curve on CRT in advance, and when operating condition deviate from the optimum condition, appropriate operation guides are given to operators.

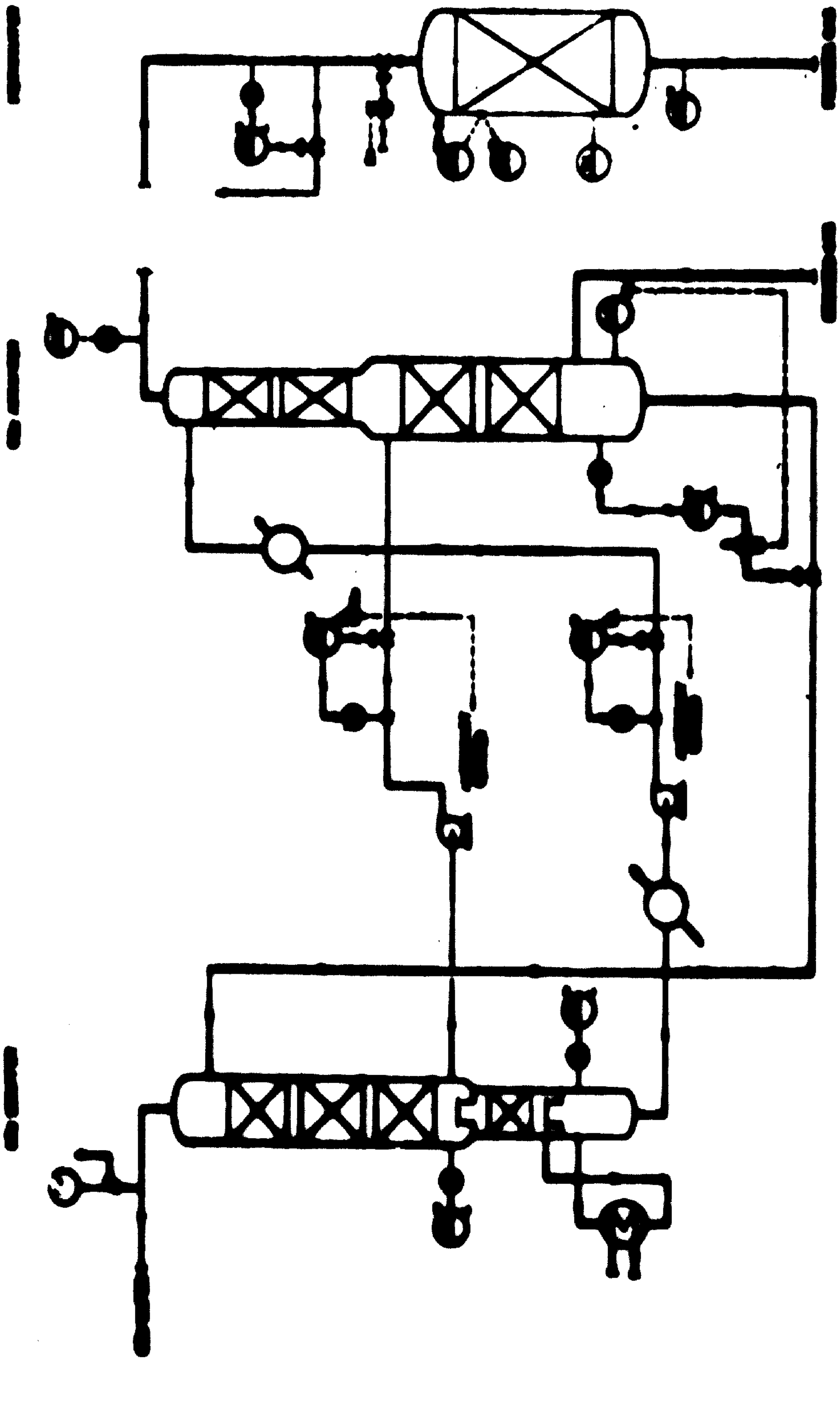
Next application is to monitor operating conditions which require considerable man power for the calculation. For instance computers can calculate and report fouling of heat exchangers, catalyst activities and the like at every moment, which are important factors for maintenance of the plant. Especially, fouling of heat exchangers, such as waste heat boilers, should not be overlooked from the safety viewpoint as well.
For other application it is also possible to design simulator model, which is useful for operators' training, based on the dynamic characteristics of the actual plant which can be obtained from computer output.
Recent developemtn of the technology for computer application system for industrial plants is remarkable. Nevertheless, panel boards in recent plants are filled up with analogue instruments, as if they are competing for the number of instruments. A system like this imposes a big burden on operators, which makes them unable to make a right judgement composedly, especially under emergency condition. Therefore, in order to solve this problem, centralized control system is being developped utilizing microprocessor which have been making progress recently, in combination with the analogue instrument.

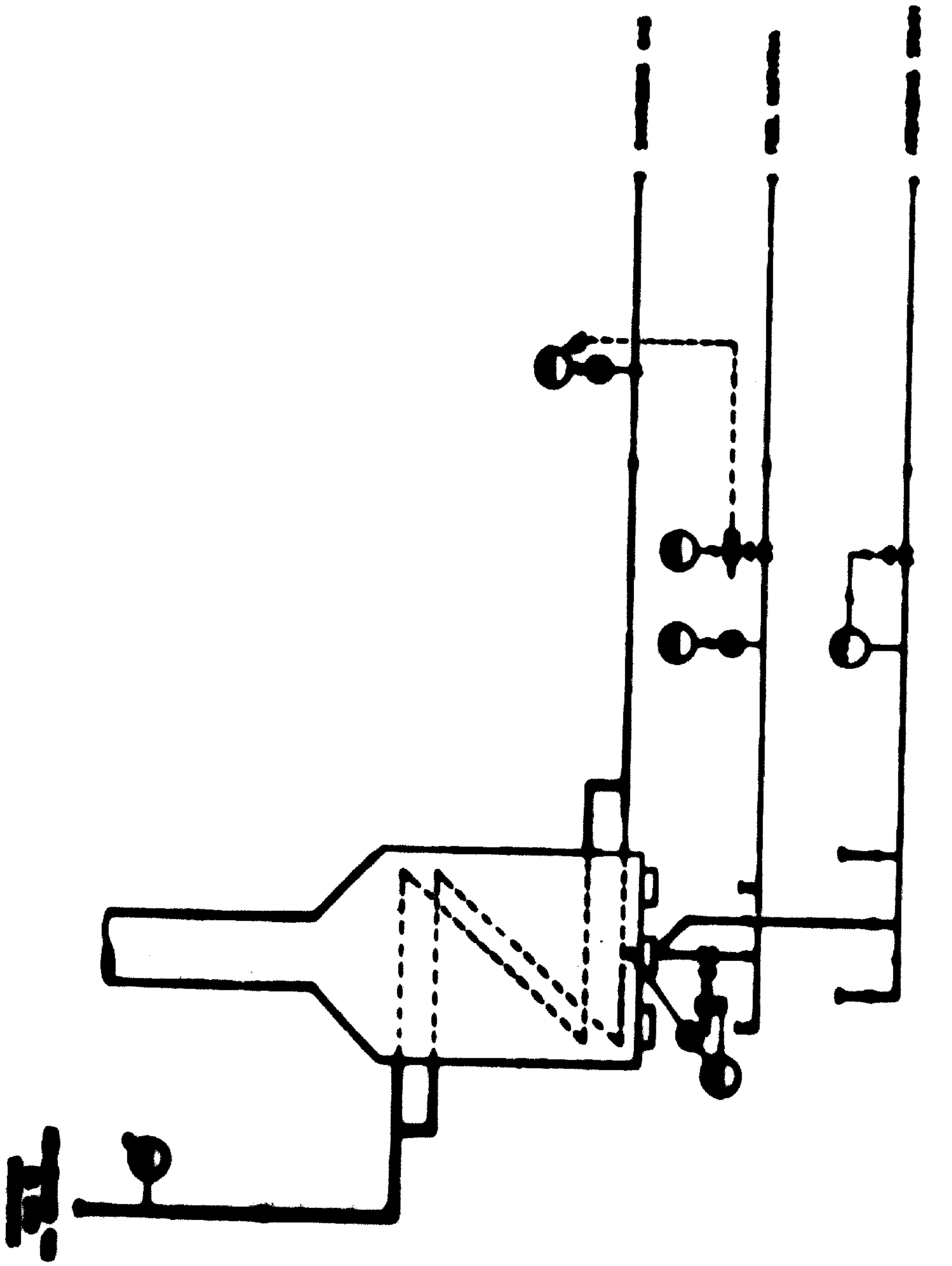


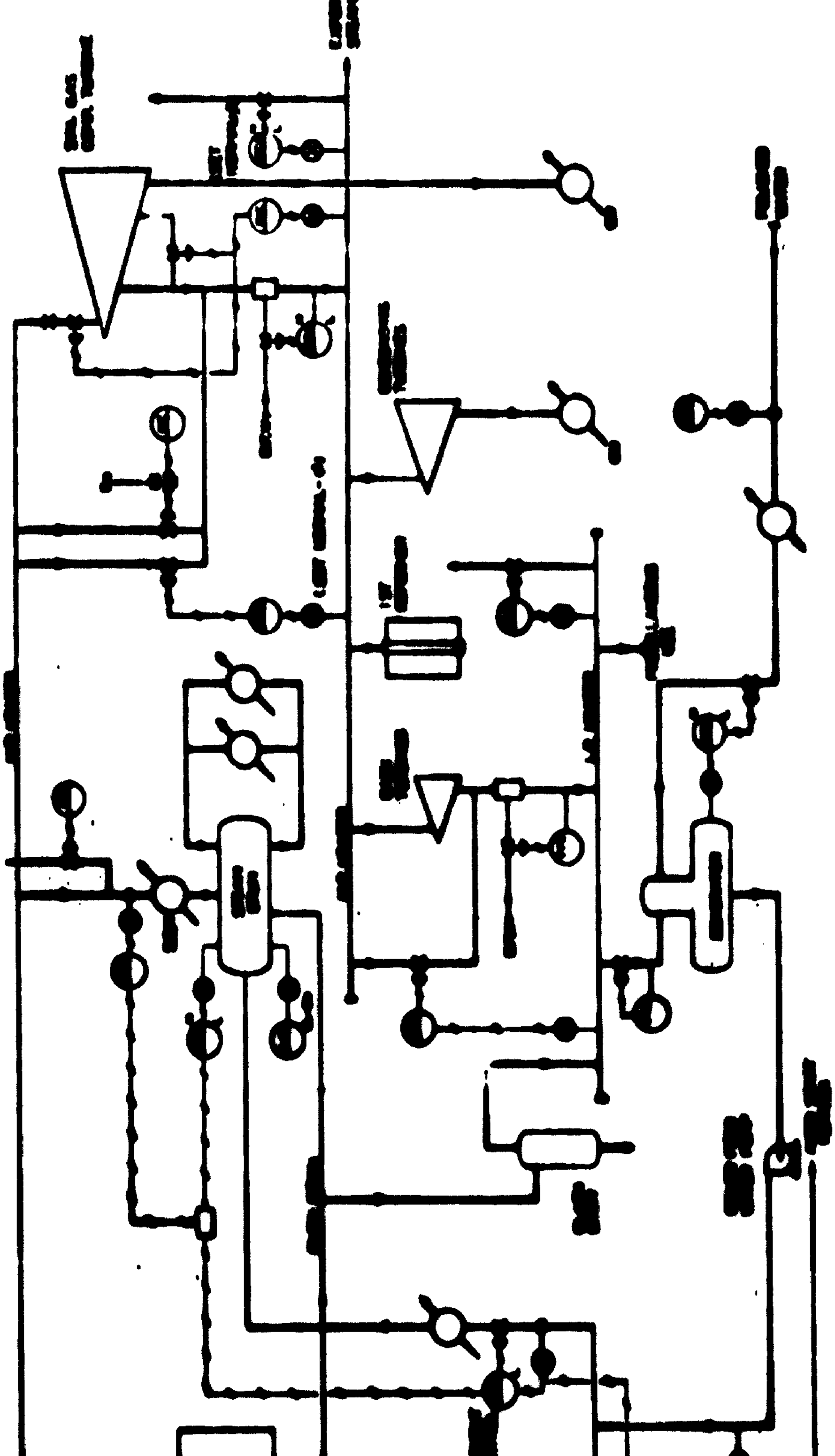












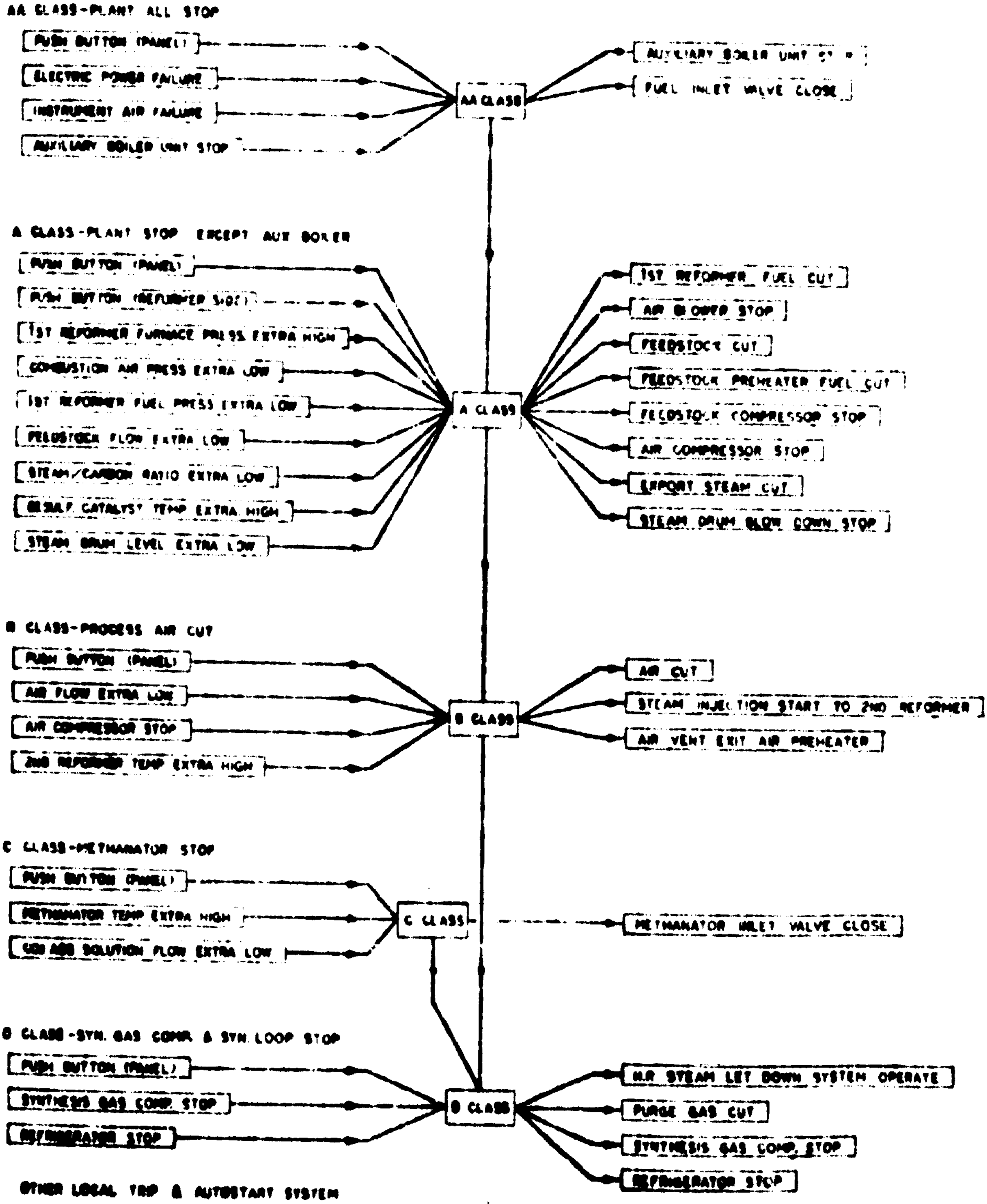


FIG.8 TYPICAL TRIP SYSTEM OF AMMONIA PLANT

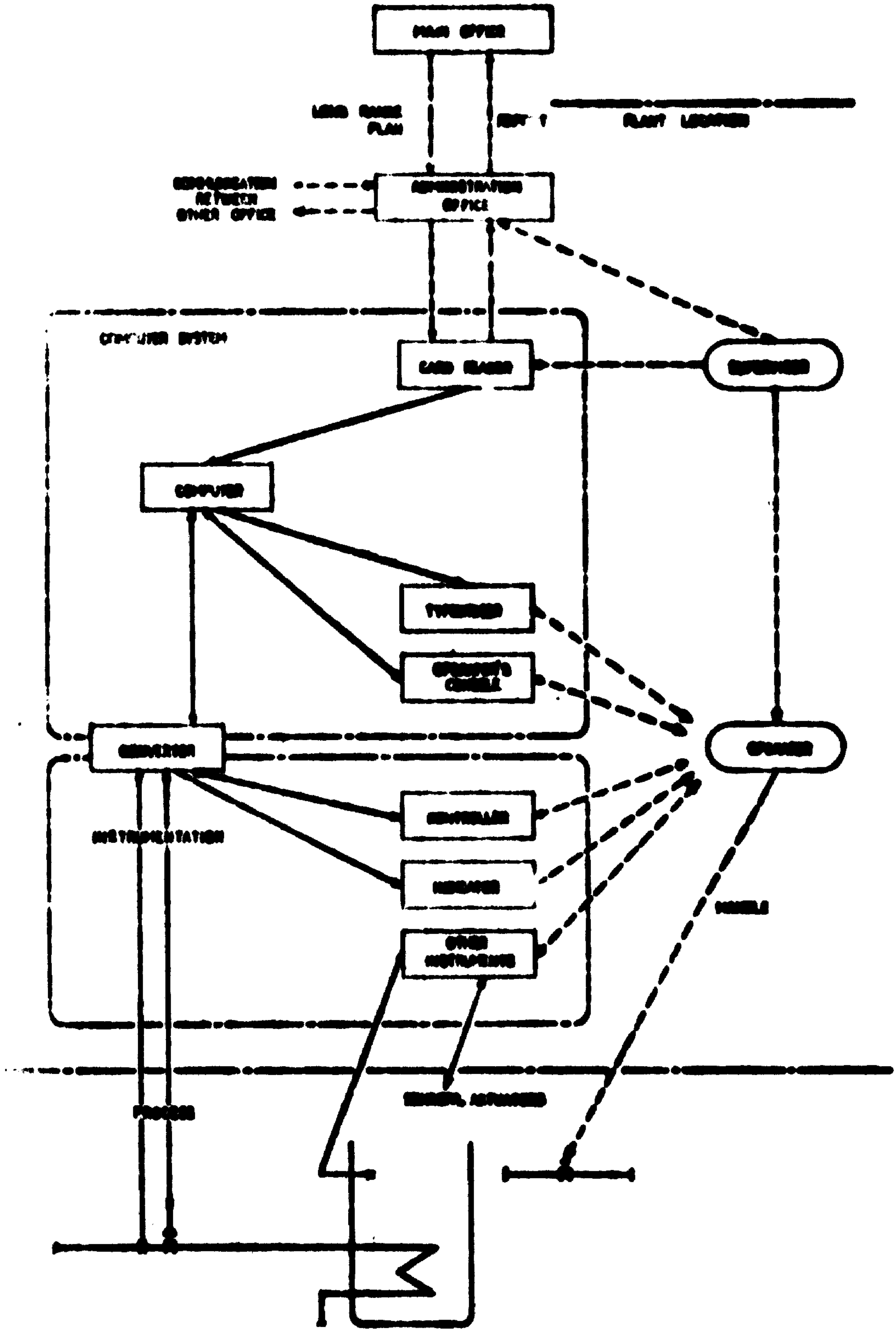


FIG. 9 A SCHEMATIC ILLUSTRATION OF INFORMATION FLOW

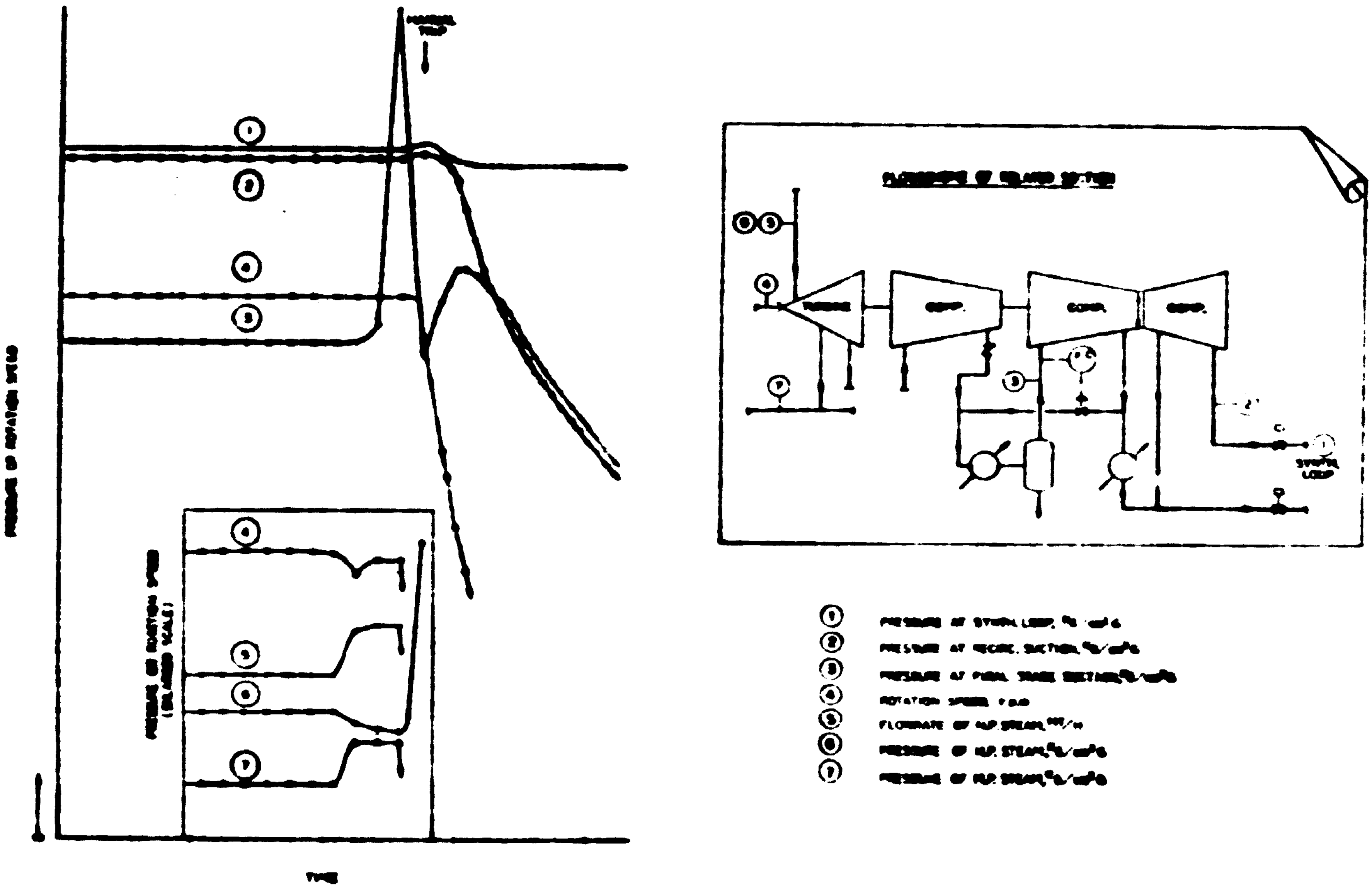


FIG.10 EMERGENCY LOGGING AT SYN.GAS COMPRESSOR TRIP

APPENDIX A OUTLINE OF PRINCIPLES OF PROCESS COMPUTER

1. BUILDING A COMPUTER APPLIED SYSTEM

1.1 Project Team

It will be convenient to organize a project team for implementation of a computer applied system. The team member will consist of;

- process engineer
- instrument (and/or mechanical) engineer
- computer specialist

1.2 System Engineering and Design

Computer specialists and instrument engineers should analyze the requirements in the available equipment. Decisions on each individual piece of equipment should be made considering price, performance characteristics, accuracy and reliability.

2. CONCEPT OF HARDWARE AND RELATED TERMS

2.1 Hardware

The hardware components of the system include the main-frame computer, sensing devices, actuating devices and the input/output devices needed to tie the system together and to communicate with the operator.

(1) Central processing unit (C.P.U.)

The central processing unit is the mainframe of the whole hardware system.

(2) Peripherals

Peripherals are such units or devices as bulk memory unit, card reader, card punch unit, line printer, typewriter operators' console etc.

(3) Process input/output devices

There are two input/output loops for C.P.U.:

Among the measurement devices, C.P.U. and control devices (analog controllers); and among the periferals and C.P.U. Here, we discuss about process input/output devices consisting of the former loop.

1) Signal condition

Analog sensor signals cover a wide range of patterns, strength and levels, which must be converted to a common signal level by this element.

2) Multiplexer

A multiplexer is a switching device which selects inputs to (or outputs from) the computer.

3) Amplifier

Low amplitude signals must be amplified to allow accurate transmission over long distances.

4) ADC or DAC

Analog-to-digital converter (or Digital-to-analog converter) converts analog signals to digital values (or vice versa).

5) Status register

The purpose of status register is to facilitate the processing of incoming digital or pulse signals (from switches or on/off devices) by the C.P.U. Such signals are used alarm conditions, operative motors or other process status.

6) Operator's console

The design of operators' console varies by the characteristics of the process, control and supervisory requirement and personal preferences of the user.
Manual input devices, such as keyboards or dials, or visual display, are usually provided at the console to permit the operator and production engineer to call up or to get special information for typewriter, display or C.P.U.

2.2 Software

Software is a bunch of programs, and the whole computer function is performed through executing them.

(1) Operating system

The operating system, or executive, is responsible for scheduling various other portions of the software system, maintaining communications between the various programs in use, and handling real-time input and output.

(2) Process monitoring system

Main purpose of process monitoring system are to supply information for the operators to keep the plant at good condition. This function is usually called as data acquisition.

Various kinds of plant data are scanned and processed to their suitable forms.

Some of its functions are;

1) Basic data processing
(scanning, smoothing, averaging, integration, conversion, calibration etc.)

2) Limit checking and alarming

3) High speed data gathering at an emergency

4) Indirect measurement

5) Reporting

6) Communication between operators and computer

7) Material and/or heat balance of some parts of the process

(3) Process control system

The process control system accepts processed plant information from the process monitoring system and analyzes the plant status and then decides the better operation condition.

(4) Management information system

The program is responsible to supply plant-wide decision making information.
This software is used to generate operating information for management control, and production or inventory control etc.. Such informations are communicatable directly to the administrative office of the plant complex.

(5) Background jobs

The background jobs, processed at lowest priority level, are of independent programs of on-line software. Long term product scheduling program will typical example.

APPENDIX B A TYPICAL EXAMPLE OF COMPUTER APPLIED SYSTEM

1. PROGRESS

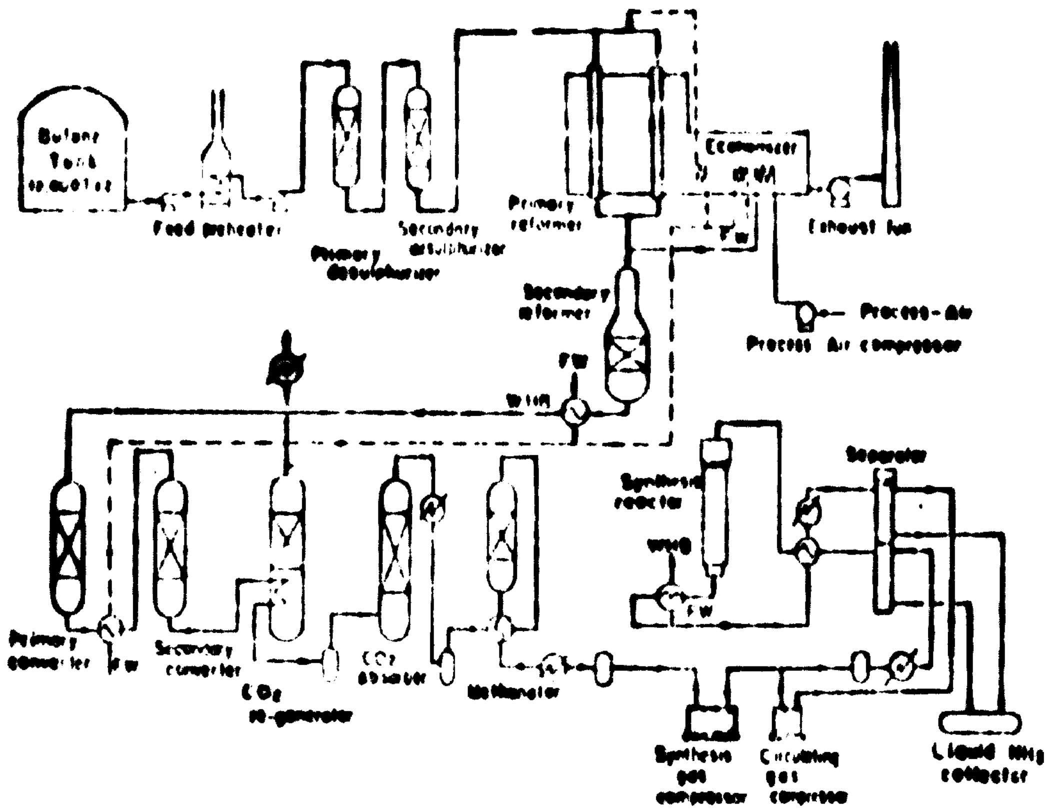
Mitsui Toatsu Chemicals has established his 500 MT/D ammonia plant at Sakai, Osaka, Japan in 1966. This is the first ammonia plant in Japan which is operated under computer control. Successively, Mitsui Toatsu Chemicals established his 1,000 MT/D newest ammonia plant at Sakai in 1969. Also this plant has been under computer control.

These control systems have been developed by co-operation of TEC and Mitsui Toatsu, (now, main members engaged have been belonged to TOPACS) and have shown satisfactorily good results.
This control system is designed to cover both ammonia plant and urea plant with one control computer.

The system had been developed keeping pace carefully with the plant construction schedules using a large general purpose digital computer, as well as IBM 1800 DACS.

The control models have been developed through those plants live data gathered by the control computer itself. Continuous plant operation is being carried on by means of the complete closed-loop control.

2. PROCESS FLOW



500 $^{MT}/_{D}$ ammonia process flow

3. CONTROL COMPUTER AND ITS PERIPHERAL

3.1 Processor Controller (TBM 1800 Dacs Model II)

core memory	32 kilo-words (16 bits/word)
cycle time	2 μs
interrupt	12 levels

3.2 External Memory (IBM 2310 Disk Storage)

memory capacity	512 kilo-words x 2 sets
access time	300 ∿ 700 ms

3.3 Card Read/Punch (IMB 1442 Card Read Punch)

read speed	300 cards/min.
punch speed	60 cards/min.

3.4 Typewriter (IBM 1816 and 1053 typewriter)

typewriter with key-board	14.8 ch./min. x 1 set
typewriter	14.8 ch./min. x 2 sets

3.5 Process Operator's console (POC)* 1 set

* Process operator's console (POC) is an important communication device between process operator and control computer, which has the following functions.

(1) Print functions

- instantaneous value of analog input
- averaged value of analog input
- integrated value of analog and pulse input
- indirectly measured value
- value of hand input
- block print
- multi-points print
- constant for instrument
- closed-data print

(2) Trend-print functions

- trend-print for one specified variable
- trend-print for a specified block-data
- cancel of trend-print

(3) Print functions for upper and lower limit values

(4) Limit value change

(5) Stop or revival

- comparation
- closed-loop control
- trend test
- emergency data log

(6) Alternating some constants

(7) Status print

- comparation
- closed-loop control
- emergency signals
- registered block-data
- digital input and output

(8) Others

- research data
- multi-points trend-print
- data dump of emergency stop

4. PROCESS INPUT/OUTPUT

4.1 Analog input

temperature	74 points
flow rate	31
pressure	23
liquid level	6
analyser	8
electric power measuring	1
set-point station	some
others	some

4.2 Digital input

	interrupt	electric contact
signals for summations	4	
POC (push button)	5	
POC (switch)		46
process accident and emergency	25	3
others	4	16

4.3 Digital output

	pulse	electric contact
instrument panel		5
POC		4
buzzer		1
process emergency		4
set-point station	some	some
others		some

5. FUNCTIONAL CHARACTERISTICS OF THE SYSTEM

5.1 Process Monitoring Programs

(1) Basic data processing

- Scanning

- Numerical filtering (averaging)

Numerical filtering is frequently desired in order to obtain a single representative value of signal. Many different schemes exists for producing averaged data, including straight-foward one of taking the simple average of readings.
The exponential smoothing method is adopted to smooth time-varying data.

$$\bar{X}ji = \alpha j(\bar{X}ji-1 - Xji) + Xji$$

where

$\bar{X}ji$: new averaged value at point j

Xji : new instantaneous value

$\bar{X}ji-1$: old averaged value

αj : fixed coefficient at point j

$$0 \leq \alpha j \leq 1$$

- Integration

Integration of flow signals is required for material balance calculation and several reports.
For example, ammonia production rate per hour, butane feed rate per hour, and utilities consumptions per day are those which integration is necessary.

Calibration

It is not rare cases that require calibrating operation for some instruments. For example, flowmeter is often used under somewhat different condition from its designed condition. In such case, the values from the sensor do not show real values otherwise calibration is done referring the real condition. The calibration is performed with real temperature, pressure and, in some case, composition.

Unit conversion programs

In digital control computer, process data are treated in basis as digital values corresponding voltage signals. Operator needs to know not voltage but its equivalent value in industrial unit. Mathematical models also require such converted data.

(2) Indirect measurement

The necessity of indirect measurement is mentioned before, and some examples of indirectly measured variables in this control system are shown below.

Reformer

- Steam-carbon ratio (mol/mol)
- Steam-hydrogen ratio (mol/mol)
- Hydrogen-butane ratio (mol/mol)

Shift converter

- Steam-carbon monoxide ratio (mol/mol)

CO_2 absorber

- gas-absorbent ratio (Nm^3/ton)

Compressor

- hydrogen-nitrogen ratio (mol/mol)

Synthesis reactor

- inlet gas hydrogen-nitrogen ratio (mol/mol)
- purge gas rate (ton/hr)

Quantities of steam generated in the waste-heat boilers and heat duty of several heat exchanger are also measured indirectly.
Those variables are determined from heat and mass balance calculation using chemical equiliberium equations, reaction rate equations, and physical equilibrium equations.
Such indirect measuring is also excuted at constant period.

(3) Logging and alarming

Operators can refer the plant behavior through the logging function of the control system. The logging operations can be divided into two groups, the periodical logging and arbitrary responding. The later operation is done by operator's request via POC.

The process variables are scanned and checked against their validities. If any variables violate their high or low limits, the interruption occurs and alarming functions are executed automatically.
Another type of check is required for some process variables, whether the rate of change is too fast or not.

(4) Emergency data logging

All the modern plants are designed safe and secure in instrumentation as well as process itself even if in an emergency. In an emergency, however, many process variables change in a moment automatically or by the result of the actions of operators. It is not always clear that what is the true cause process equipment, instrument or operation etc.

The computer system gathers and presents these data (values of relevant variables) before (for five minutes; in every thirty second) and after (for fifteen minutes; in every two second) emergency condition. These data are very useful for improvement of the process itself, instrumentation and operation in next.

(5) Plant management information

This control system is also very helpful for the managers of the plant. The plant productivity and overall plant performance are reported periodically as the typed management-report.

These reports are produced automatically by hour, by shift, by day, by week and by month. The production quantities, the raw material consumption and utility consumptions are included in these reports.

5.2 Mathematical Models of the 500 MT/D Plant

The mathematical models developed for this 500 MT/D ammonia plant cover whole process and these programs can be devided into following two main classes.

1) Gas preparation section

2) Ammonia synthesis section

Throughput maximizing is our major object. First, the operating condition of the ammonia synthesis section is searched as to succeed maximum throughput of ammonia production. Then the operating condition of the gas reforming section is specified as to confirm the synthesis operating decisions.

The models are programmed to act for each specified environments condition. So, the adaptational operation of computer is required before optimization, depending on the plant condition.

The models is slowly and continuously modified to produce increasingly better optimization. Equations are provided that automatically adjust its parameters if the model does not exactly represent the actual process performance. This modification is done by the adaptation program.

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