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CONTROL SYSTEM FOR PETROLEUM LORRY SHIPPING

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I. INTRODUCTION

In 1978, the total energy demand in Japan increased by almost 1.8 times over that of the previous ten years. In 1970, the proportion of primary energy occupied by petroleum exceeded 70%. No large change is forecast, despite the primary and secondary oil crises, and in 1978, 73.0% of all the primary energy used in Japan came from oil. This high percentage is being maintained even through atomic power has been expanded substantially.

However, the high price of crude oil can not be overlooked by either the manufacturer or the consumer and greater efforts are being made toward reducing production and circulation costs. Of course, under such social and economic conditions, the trend is toward systemization of shipping and circulation, in which automation has been comparatively late, from onsite and offsite processes which have reached complete systemization through the introduction of measuring systems and process control computers. On the other hand, the electronic control technology field, features the appearance of the 80's oriented PFU-1000 Series in the super minicomputer PANAFACOM U (PFU)-1500, the development of digital control technology centered about the microprocessor, and popularization of intelligent terminal units.

Comparatively recent examples of application of these techniques to the lorry shipping process at Fuji Electric is introduced and the outlook for the future is described. In these article, a lorry shipping control system means an automatic control system for shipping of gasoline, kerosene, light oil, heavy oil, and other petroleum products at the refinery, petroleum base, oil depot, etc. and a delivery management system to service stations and other large consumers.

II. OUTLINE OF LORRY SHIPPING

Petroleum is shipped by pipeline, ship loading and land shipping by tank car or tank lorry. Of these, shipping by tank lorry, which heavily outweighs the other methods, is described. In recent years, the pipeline system, which has gained considerable attention as an inland shipping technique, has increased as a means of shipping petroleum between the refinery and ultra-large consumers. However, the pipeline system has scarcely become popular as a shipping technique among general users. Therefore, since petroleum is maintaining its position as a primary energy source, the importance of lorry shipping will not lessen.

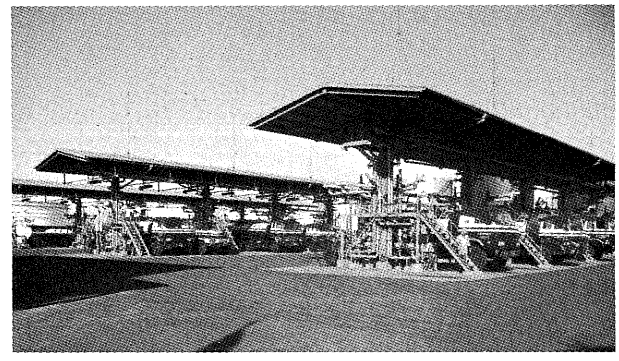

Fig. 1 Profile of lorry shipping

III. LORRY SHIPPING CONTROL SYSTEM

The general flow of a lorry shipping control system is described. At the oil depot, lorry shipping begins with the acceptance of orders (reservation) from the consumer. The accepted orders are transferred to the vehicle scheduling section, where a specific lorry number (number assigned to each lorry) and trip number (number of trips between the oil depot and consumer for each lorry) up to the scheduled shipping date are assigned and simultaneously registered in the control computer system. The system issuing the slip before shipping prepares the shipping slip at this time. On the assigned shipping date, the lorry driver receives the shipping instructions (is a series of the shipping slip), inserts the lorry card into the card reader at the pertinent bay, sets the earth unit, and sets the load amount.

When the loading arms are inserted into the individual hatches (compartments) of the lorry and the loading preparations are complete, the remote start switch on the loading arm is pressed. The computer system receives the start

signal and collates the loading set contents (kind and amount of petroleum) with the reservation contents. If the result of the check is good, the various interlocks are released, the control valve is opened, and the loading starts. When the set amount is reached, a control valve closes and the loading of one batch is completed. Opening and closing of the control valve is performed by fixed program control, considering the generation of static electricity and the prevention of water hammer. And in case of the abnormalities during loading are detected, the loading is stopped in an emergency and other interlocks are implemented for safe loading.

At the completion of loading of the scheduled amount, the loaded contents are printed as a shipping results. At this time, the system issuing the slip after shipping prepares the shipping slip.

At the end of each day's work, a daily report is issued automatically and a shipping result is sent to the head office (branch office). Three typical examples of realizing the functions above will be introduced. One is the distributed management system, another is the concentrated management system, and the last is the direct digital control system. These art examples of systems which actually started the operation in 1978~1979.

IV. DISTRIBUTED MANAGEMENT SYSTEM

This system consists of a "microcontroller for petroleum shipping" (FUJI MICREX LSC-μ) that performs reservation and collation and a "slip issuing terminal" (intelligent terminal) that prepares the slips. Quantitative shipping control is performed by a lorry shipping control (LSC) system.

1. System Configuration

Fig. 2 shows the configuration example of this system. The functions and specifications of the main components of this system are outlined below.

1) Petroleum shipping microcontroller

This unit stores the reservation information and performs reservation and collation, report issuing, etc. Lorry shipping microcontroller (LSC-μ), a FUJI MICREX-P subsystem, is used.

Its main specifications are:

Control form:	Microprocessor control
Storage capacity:	PROM 4K words Core 16K words
Program form:	Stored program form
Word length:	16 bits + 2 parity bits
Data format:	Binary fixed point
Process input/output points:	
Interruption input:	1
Digital inputs:	320
Digital outputs:	128
Locker:	19 inches locker x 1

2) Slip issuing terminal

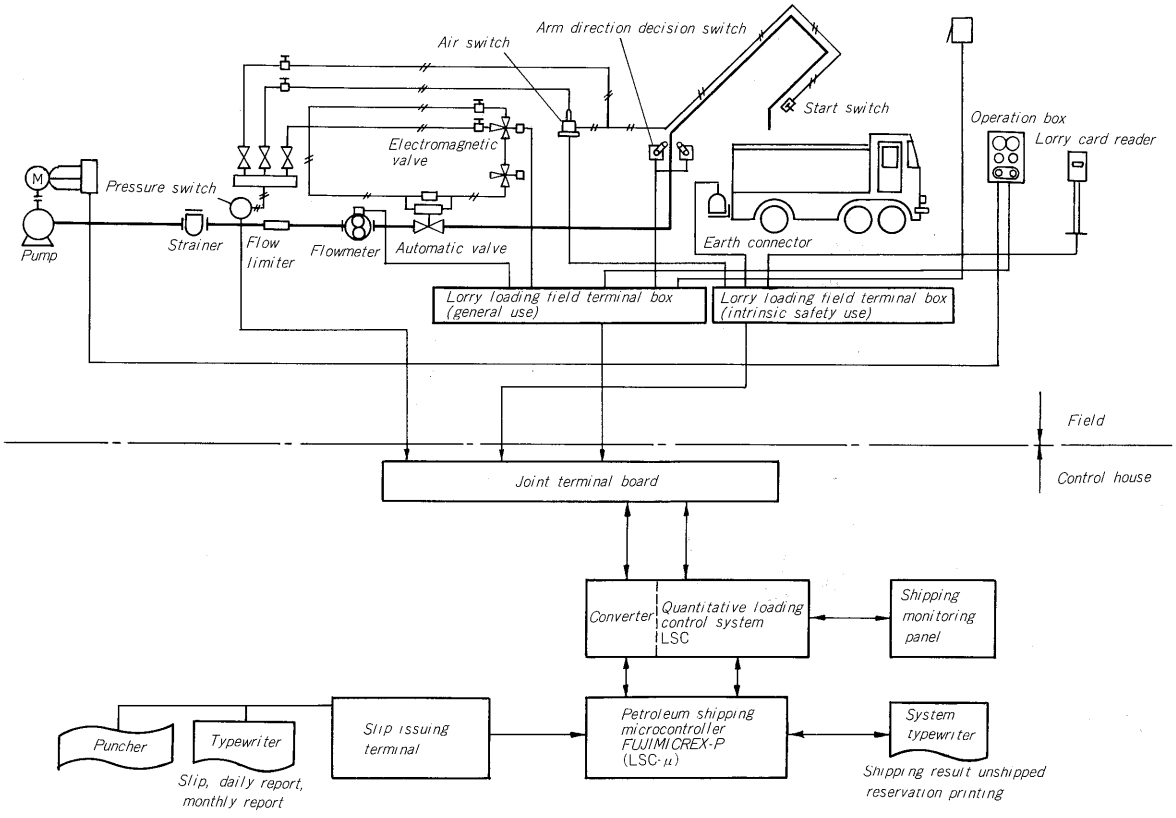

Fig. 2 System configuration

This is an intelligent terminal that sets the reservation contents (lorry number, trip number, kind of petroleum, amount, destination), issues the slips, and prints the reports for the head office, etc.

It is connected to the LSC-μ with in-line by PI/O connection. In this example, a stored program microcontroller, which is prepared by the customer, is used. The controller has an 8k words' core memory and the control ports for typewriter and tape puncher.

3) Quantitative shipping control equipment

This equipment is linked to the reservation and collation check OK signal by the LSC-μ and implements the sequence control. A LSC (Land Shipping Controller) is used. The LSC control circuit is of all solid-state circuits and modularized, including the logic circuits, input/output circuits and display lamps, and has a building block construction which permits expansion according to the number of loading arms. The LSC consists of an LSC card (point unit), CC card (island unit) and POW card (island power unit). Each unit has a front panel.

Set value, valve opening/closing, displays for overfilling and an arm signal bypass switch are installed on the front panel of the LSC card. An earth bypass switch and REMOTE/LOCAL selector switch are installed on the front panel of CC card. A power pilot lamp and power ON/OFF switch are installed on the front panel of the POW card.

Fig. 3 shows profiles of the LSC and CC cards.

The main specifications are:

Construction: 19 inches rack, Type 75 shelf, printed circuit board construction

Printed circuit board configuration:
- LSC card/arm
- CC card/island
- POW card/island

Main elements:
- C-MOS IC
- SSR (solid-state relay)
- LED (light emitting diode)

Locker: 19 inches locker/32 arms

As the circuit associated with LSC, another locker is necessary to put in the converters for the signals from the card reader.

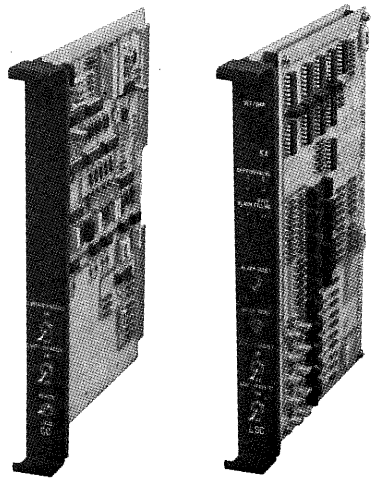

Fig. 3 Profile of LSC and CC card unit

4) Input/output typewriter

The input/output typewriter is used for maintenance of LSC-μ and for data logging. It prints the various error messages, the shipping result at the completion of one trip. And it performs reservation and unshipped schedule printing, if necessary.

Typewriter printing speed: 33 characters (max.)/sec
Paper tape reading speed: 100 characters/sec
Paper tape punching speed: 50 characters/sec

5) Shipping monitoring panel

The loading conditions at the lorry shipping field are displayed on a special wall-mounted monitoring panel driven by the LSC. The displayed items are:

(1) "loading" and "abnormal" display
(2) loading amount integration (kl/unit)
(3) "overfill", "low air pressure" and "equipment abnormal" display
(4) "pump operating" display

6) Joint terminal board

Relaying of all the process signal cables is performed at this board. Connection to the process is performed with screw terminals and connection to the LSC panel is performed with a special cable with a connector.

Joint terminals, connectors and receptacles, intrinsic safety explosion proof barrier terminals, etc. are installed on this board. (Self-standing, one-side maintenance, panel)

7) Field installed control equipments

To constitute the lorry shipping system the field installed control equipments are as follows:

(1) Flow transmitter (transmitting system by double cam)
(2) Control valve (2-stage operation ball valve with electromagnetic valves)
(3) Card reader (data 8 bits + parity bit + insertion verification bit)
(4) Earth chuck
(5) Loading arm location switch
(6) Loading amount setter (switching of 1, 2 and 4 kl)
(7) Remote start switch
(8) Emergency stop switch
(9) Alarm lamps and buzzer

2. System Features

The biggest feature of this system is that the intelligence is distributed to the shipping microcontroller (LSC-μ) and slip issuing and the danger is distributed by distributing the functions. Trouble at one must not affect the others so that the control system is not entirely shutdown.

It is needless to say that the quantitative shipping controller (LSC), which is built of genuine hardware logic circuits, performs its quantitative shipping function without being affected by the trouble of two processing equipments.

This configuration is said to be suitable even for minor-scale depots because of the compact hardware and panels.

V. CONCENTRATED MANAGEMENT SYSTEM

This system performs concentrated management by means of a process computer. It has two functions. One is collating with the reservation. And another is issuing the shipping slip. Those are described in section IV. The LSC, previously described, is suitable as the shipping control equipment, but the existing field type relay sequence unit was used in this example.

1. Computer System Configuration

Fig. 4 shows a system configuration example of this system and *Fig. 5* shows its profile. The functions and specifications of the component units are outlined below.

1) Central processing unit

The central processing unit (CPU) and auxiliary storage unit (DISK) play a main part in this control system. This system performs the batch processing from loading calculation to tank stock management in addition to reservation, vehicle scheduling, collating with reservation issuing the slip, printing the report and inquiry utility. In this system, as the CPU, the medium size PFU-1300 model of the newest process computer PFU-1000 series is used. Its main specifications are:

Control form: Micro-program control (ROM)
Calculation system: Fixed point, floating point
Main memory storage capacity: 64K bytes
Main memory cycle time: 0.75 μs/2 bytes
Auxiliary memory storage capacity: 2.4M bytes (fixed head)
Mean access time: 12.5 ms

2) System typewriter

The system typewriter is used for the system maintenance.

Printing speed: 40 characters/sec.
Paper tape reading speed: 40 characters/sec.
Paper tape punching speed: 30 characters/sec.

3) Paper tape reader/puncher

The shipping report is punched by the paper tape puncher for data transmission (MODEM) to the branch office.

Reading speed: 300 characters/sec.
Punching speed: 50 characters/sec.

4) Line printer

The line printer prepares 11 kinds of reports.
Printing speed: 120 lines/min.

5) Typewriter

Two typewriters issue 4 kinds of slips.
Printing speed: 165 characters/sec.

6) CRT display and keyboard

In this system, the CRT display and keyboard gives the reservation, vehicle scheduling setting, manual slip issuing, inquiry, report preparation command, tank stock calculation command and various utility commands in conversation format to guide the operator by CPU as a man-machine interface. (Two are used.)

Display characters: 1,920
Display area: 16 inches

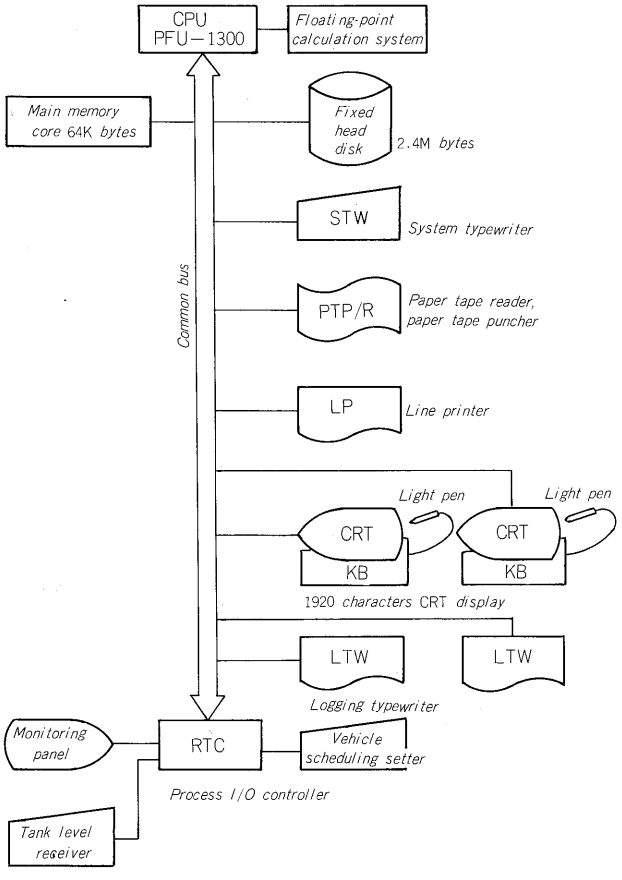

Fig. 4 Block diagram of RTC system

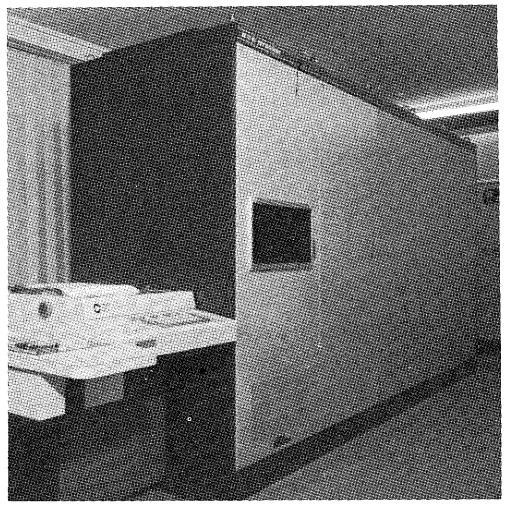

Fig. 5 Profile of RTC system

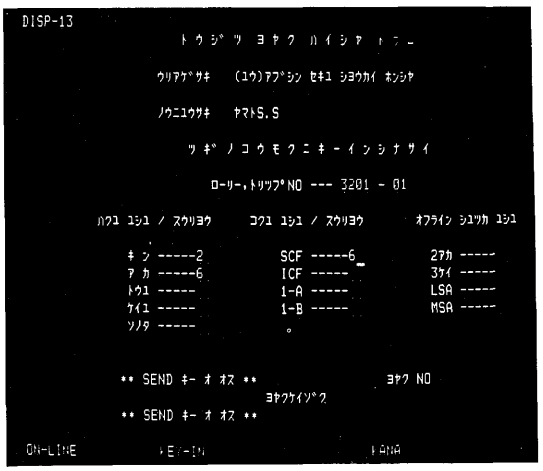

Fig. 6 Example of CRT display

Display color: Three colors (green, red, white)
Character generation system:
7 x 9 dots
Light pen: YES

Fig. 6 shows an example of the CRT display.

7) Vehicle scheduling setter

A special vehicle scheduling setter installed in the office is used separately from the CRT display and keyboard (KB) installed in the computer room.

8) Shipping monitoring panel

This panel displays the loading conditions at the lorry loading site. In this example, the panel provided by the customer was used.

9) Process input/output controller (RTC)

This is an interface unit for smooth exchange of input/output signals between the central processing unit (CPU) and process (shipping site). The number of inputs/outputs is:

Interruption: 144 points
Digital input: 304 points
Digital output: 128 points
Pulse input: 8 points
(12 bits counter)

10) Joint terminal board

This board is used only as a signal relay function.

2. Software System Configuration

Fig. 7 shows the software configuration of this example.

3. System Features

The features of this system, which uses a high processing speed CPU, large capacity and high-speed access disk, and conversational type man-machine interface, is that one dimension data management and concentration of management data are possible and an effective management system that integrates process control and data processing can be built. In other words, the range of control and management in lorry shipping can be extended and total concentrated

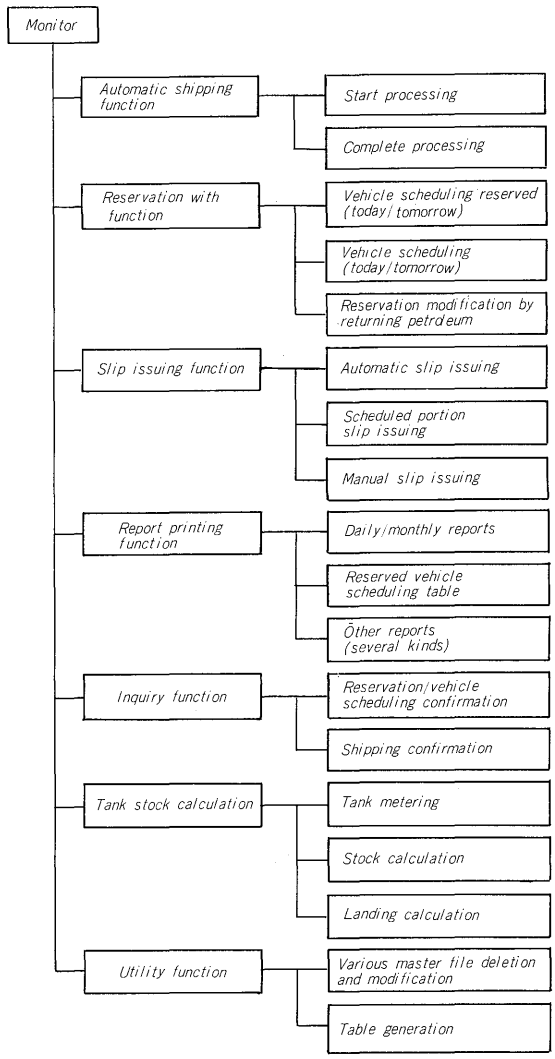

Fig. 7 Application software system

management as a petroleum depot up to utility functions that permit tank yard management, landing calculation, operation record calculation and management and maintenance of various master files and tables is possible.

This system is said to be applicable to medium scale and larger depot and refinery shipping facilities, because a wide range of management contents from the standpoint of quality and quantity is possible.

VI. DIRECT DIGITAL CONTROL SYSTEM

This system directly controls the shipping process by means of a DDC (Direct Digital Control) computer. That is, the computer reads the signals from the flow transmitters directly without the intervention of a hardware logic shipping control device such as the two systems previously described.

1. System Configuration

Fig. 8 shows a configuration example of this system.

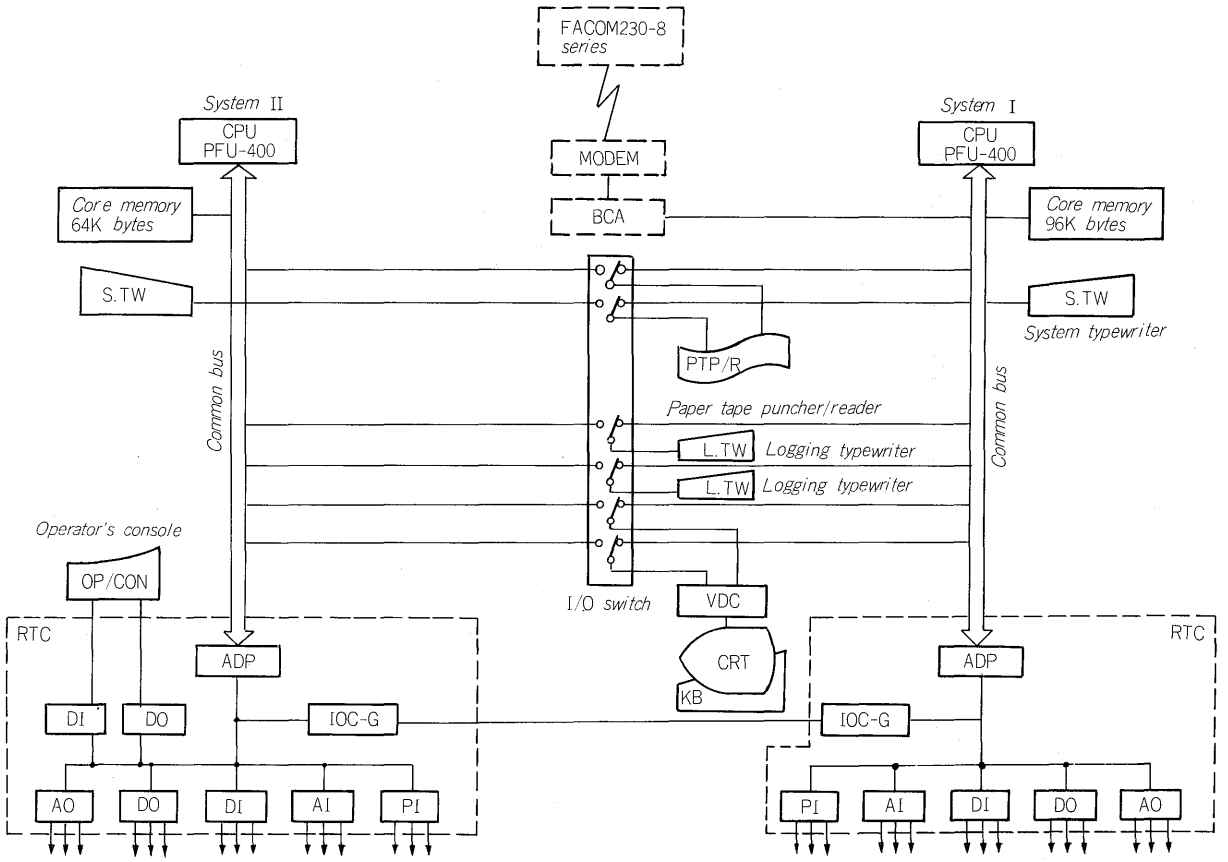

Fig. 8 Block diagram of RTC system

The functions and specifications of the component units are outlined below.

1) Central processing unit (CPU) and main memory

PI control of instantaneous flow, program control, blending control, quantitative control, pump control and report printing are performed by the parallel operation of the two CPUs that play the main part of this system. This system uses two PFU-400 as the CPU. Storage unit consists of only a main memory unit (magnetic core) to realize a highly reliable DDC system.

Its main specifications are:

Control form: Micro-program control
Arithmetic form: Binary fixed point
Main memory storage capacity:
96k bytes (System I CPU)
64k bytes (System II CPU)
Cycle time: 750 ns

2) System typewriter

Each system typewriter is used by System I and System II for printing of DDC system messages and system maintenance.

3) Paper tape reader/puncher

The paper tape reader/puncher is used for system maintenance. One common reader/puncher is used by System I and System II.

4) Logging typewriter

This typewriter prints the shipping record table and daily shipping reports. Two typewriters are used in common by System I and System II (Slips are issued by a special higher level machine.)

5) CRT display and keyboard

The rack (island) operating conditions, pump operating conditions, etc. can be called to the CRT display screen as necessary. The receiving flow and shipping record by arm are displayed and the PI constants, gradient constants, blending ratio, etc. in flow control are also set. One CRT display and keyboard is used in common by both System I and System II.

Display screen: 20 inches
Display characters: 640
Fluorescent body: Color
Character generation system:
5 x 7 dots

6) Operator's console

The rack and pump operating conditions can be displayed and the gradient control data can be set. It serves the backup of a CRT display and keyboard (KB) and is used in common by System I and System II. It is a desk top type consisting of ten-keys and a numeric display unit.

7) Input/output switching unit

This unit switches the I/O bus of the I/O devices (logging typewriter, paper tape device, CRT display) which are common to System I and System II. These I/O devices are normally connected to System I and are switched to Sys-

Table 1 Numbers of input/output signals

Input/output \ System	System I	System II
Interruption	16	16
Digital input	288	320
Digital output	160	224
Pulse input	32	32
Analog input	32	16
Analog output	32	32
Series type communication device	1set	1 set

tem II when the CPU of System I is shut down.

8) Process input/output controller (RTC)

This is the interface unit between the central processing unit (CPU) and process (shipping site) of this DDC system.

Table 1 shows the number of input/output points (number of installed devices).

Serial type communication devices are used in data transfer between the System I and System II CPUs.

9) Field installed equipments

The field installed equipments comprising this DDC system are outlined below.

(1) Flow transmitter (0.5 *l*/pulse)
(2) Resistance thermometer bulb (temperature compensation)
(3) Continuous type control valve (equal percent, single port, P-port)
(4) Electro-pneumatic converter (4~20 mA DC/0.2 ~ 1 kg/cm^2)
(5) Card reader
(6) Earth chuck
(7) Location switch
(8) Operation box
(9) Remote start switch
(10) Orifice, differential pressure transmitter (receiving flow line)

2. System Functions

1) Job sharing in two systems

The System I CPU takes care of the odd numbered bays and the System II CPU takes care of the even numbered bays. Therefore, both System I and System II can access the point of swing loading arm. This system is said to be a system that harmonizes duplexing (two way access) and load sharing.

2) Flow control

Flow control realizes a gradient setting curve unique to each control point by 10 parameters that permit individual setting for each control point (adjusting valve).

The equation used in PI control is:

$$U_n = \frac{100}{K_P} e_n' + \frac{\Delta T}{K_I} \sum_{i}^{n-1} e_i'$$

U : Output value
K_p : Proportional band
e : Error
K_I : Integrating time
ΔT : Control period (1 sec.)

The control period is 1 second, but is made 1/8 second before control valve cutoff.

3. System Features

The feature of this flow meter with high-speed voltage pulse transmitter (0.5 *l*/pulse), continuous control valve and DDC unit system compared to the example of the previously described two system combining a flowmeter with two-stage cam transmitter (1 kl/pulse) and two-stage switching ball valve with magnetic valve is that the flow gradient pattern can be freely changed from the CRT keyboard. The prevention of water hammer by changing the gradient pattern is effective for direct shipping (shipping directly by means of pumps in a refinery several hundred meter away) when the pipes are long.

VII. FUTURE PROSPECTS

Because of the unique features of the three system examples introduced above, the one won't probably give place to another completely in the future. Therefore, Fuji Electric wants to take-up the general trend from obtaining orders and actual transaction.

The first trend is the increase in the needs for petroleum shipping microcontrollers (computer) and intelligent terminals having communication functions as one data stations in an online network system. An essential condition demanded of an interface is that connection with different system models should be a general interface (MODEM, etc.). These will probably be an extremely effective means of opening the road to realtime processing (remote entry, remote inquiry, etc.) of the voluminous data generated locally. The second trend is the needs for a super minicomputer that permits automation (VSS: Vehicle Scheduling System) of lorry scheduling performed manually (vehicle scheduling plan expect) at present. When the VSS computer installed at the branch offices and other ordering centers performing the above communication function, a national wide online network system in lorry shipping will be established in the true meaning.

The third trend is the noticeable movement toward the adoption of a medium - floppy disk - that provides high density storage and high speed access of data as a medium of scheduling data. The trend toward the adoption of floppy disk instead of paper tape matches the demand of the age for resources saving and should increase steadily.

The three trends in the lorry shipping process described above, depending on the development of hardware and electronic components, especially including LSI, by meeting social and economical demands, and adding various variations, can be expected to develop continuously one another.