Instrumentation and Control System for a Petroleum Stockpiling Base

Ryosei Segi

1. Introduction

Petroleum has a wide range of applications and is an essential energy resource for supporting the economy. As Japan, however, is not blessed with oil resources and must depend on imports to meet 99.7% of its demand, it has been stockpiling petroleum since 1972 in order to ensure a stable oil supply. Japan has been stockpiling petroleum in two ways; private stockpiling under the Oil Reserve Law and state stockpiling by the Petroleum Corporation. The target storage by the former is 70 days of use, while that by the latter is a total of 50 million kl.

Recently, Fuji Electric has shipped via Chiyoda Corp. the Instrumentation and Control System for the Kikuma Reserve Base, which is one of the state petroleum stockpiling bases which uses the underground oil storage method. This system is now in the final testing stage aiming for a first injection in March 1994.

This article outlines the petroleum stockpile facilities, and describes the features and functions of the control system.

2. Facility Outlines

The underground oil storage method calls for the making of a cave to store oil in a rock bed lower than the stable water table and to keep the water pressure around

Fig. 1 Principle of underground oil storage method

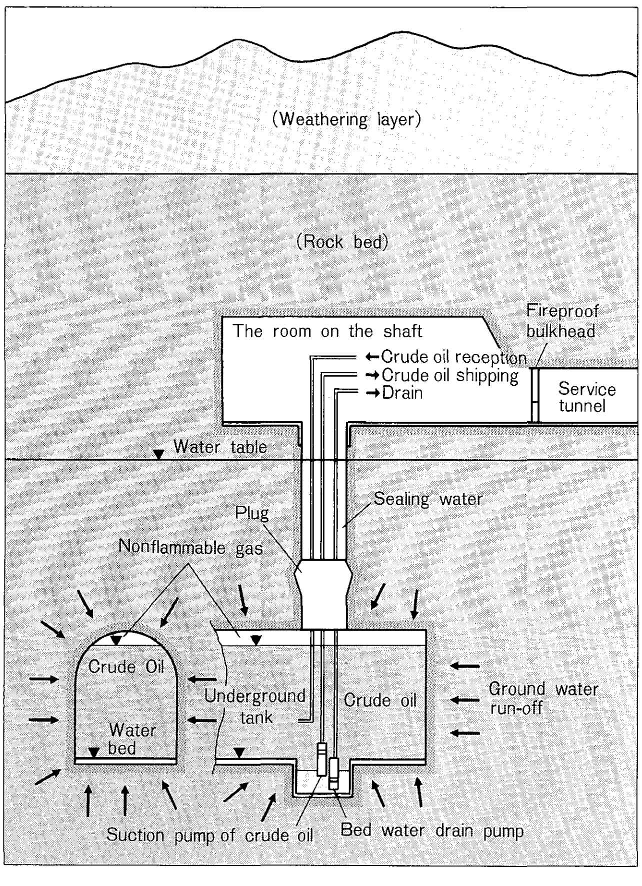


Table 1 Outline of the Kikuma reserve base

Item	Description
Storage capacity	1.50 million kl
Underground oil storage tank	Water-sealed, atmospheric-storage gallery with a fix waterbed Width: 20.5m, Height: 30m No. 1 unit: 594,000 kl No. 2 unit: 745,000 kl No. 3 unit: 25,000 kl (old type plant)
Ground shift tank	Cylindrical steel floating roof tank 34,000 kl x 4 units
Facilities in the reserve base	Oil manipulation, service, electrical instrumentation, pollution prevention, disaster prevention, and control facilities
Base-related harbor facilities	Using the existing facilities of the Taiyo Sekiyu Corp. Kikuma Refinery 130,000 Dwt-class, buoy-type, multi-point mooring and 88,000 Dwt-class, solid mooring, one for each

Fig. 2 Conceptual diagram of the Kikuma reserve base

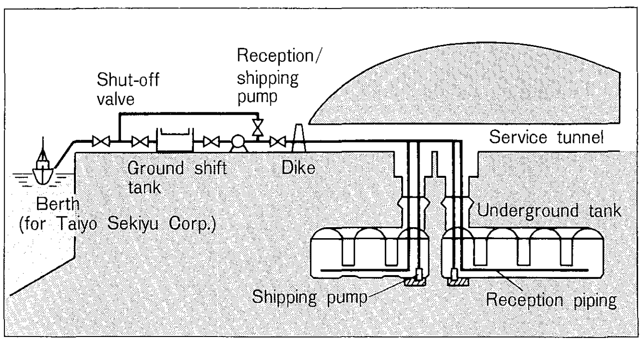
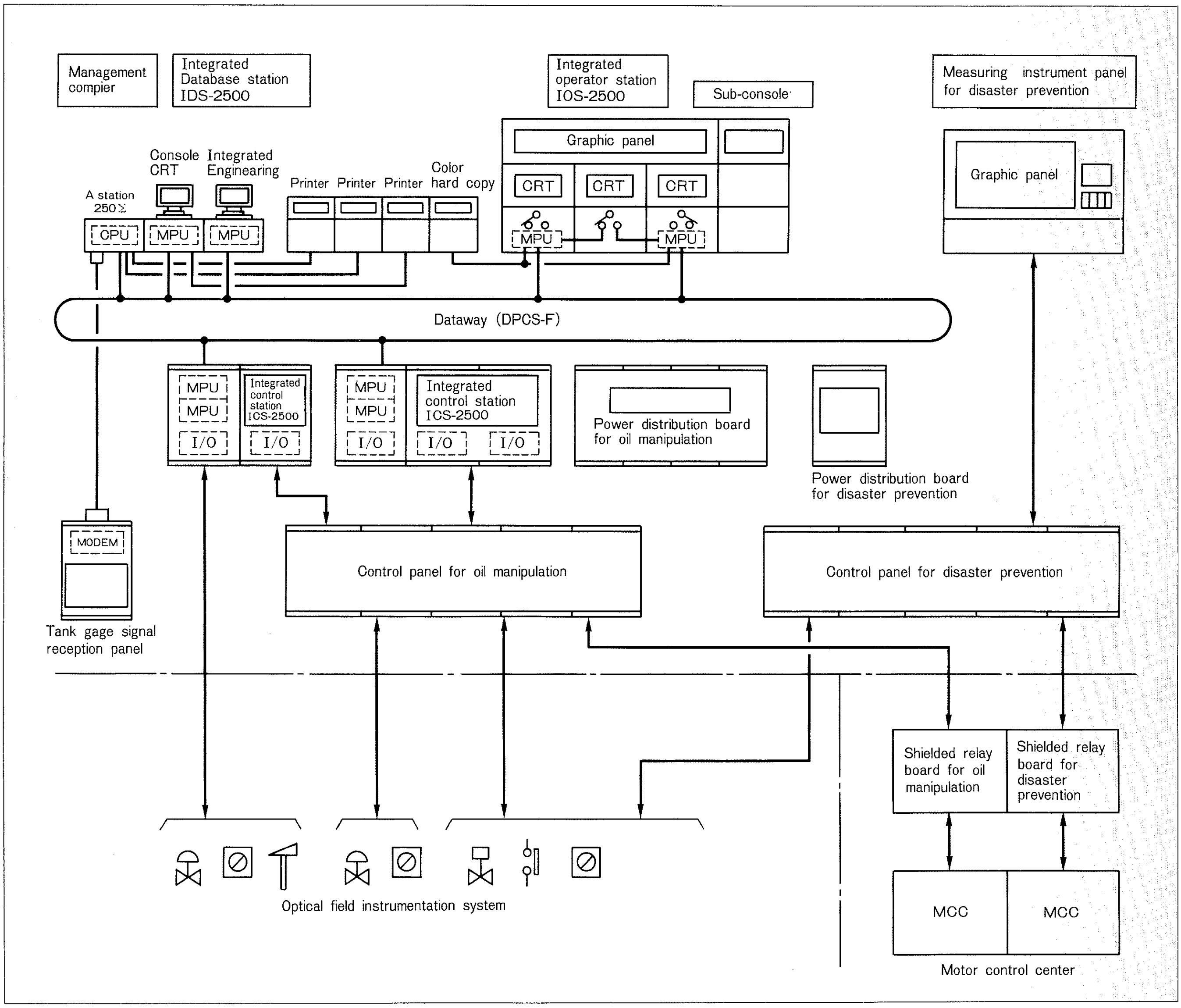


Fig. 3 System configuration



the cave higher than that of the crude oil stored therein and the evaporated gas so that it can be sealed in the cavity. **Figure 1** shows the principle involved.

Kikuma Base is equipped with three underground tanks and four ground shift tanks for oil storage, and can potentially store a total of 1.50 million kl of crude oil. **Table 1** outlines the major facilities, and **Figure 2** shows their conceptual diagram.

3. System Configuration

3.1 Outline

The instrumentation and control system adopted for the Kikuma Base is the key to the oil manipulating facilities for receiving, shipping and shoring crude oil, and for the safety systems including fire extinguishers and oil or gas leak detection equipment. It consists of a management computer, DCS (Distributed Control System), instrument panels, and field instruments as shown in **Fig. 3**.

The oil manipulation system uses an A station 250 Σ minicomputer and a MICREX-IX integrated control system, which are tightly organized via the DPCS-F dataway. MICREX-IX is Fujitsu's next-generation Integrated Control System upgraded from the conventional DCS MICREX.
DCS MICREX.

IOS-2500, which is the integrated operator station for this system, has featured the Extended Computer Linkage Function to share the same man-machine interface (MMI) between the DCS and related computers. This makes the IOS-2500 available for diverse applications ranging from processing and controlling oil manipulation data to monitoring and controlling plant operations. (See **Fig. 4**.)

In addition, the operator station, power supply unit, control processor unit, and communication unit, which

Fig. 4 Integrated operator station

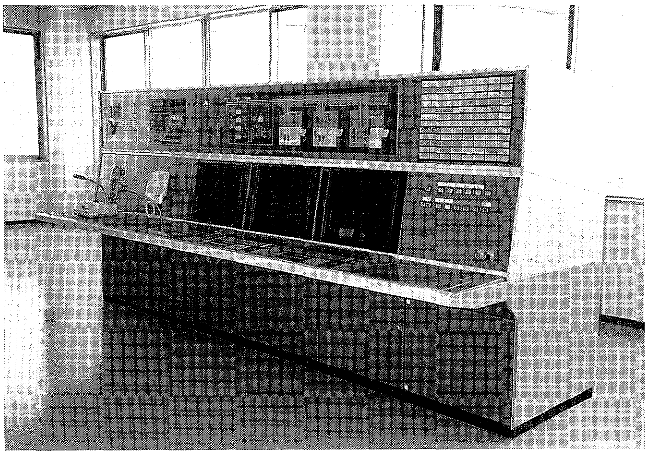
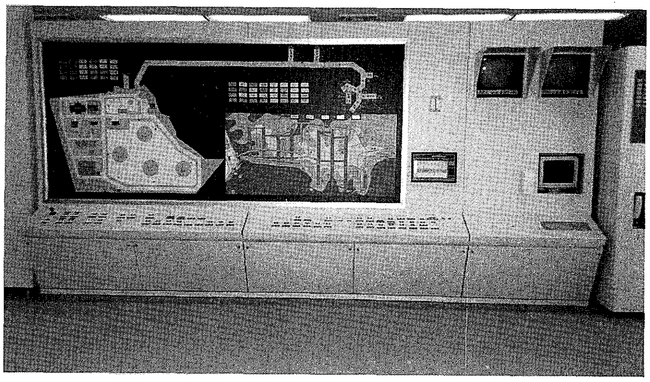


Fig. 5 Measuring panel for disaster prevention



are the major components of the DCS, are duplicated for improved reliability.

The high alarm indicators and emergency stop operation switches are compactly arranged on a console panel of the same type as that used for the IOS-2500, and the upper CRT units of the two tiered CRT's are used as the graphic panel. All these contribute to making an easy-to-monitor and highly cost effective operator console.

The disaster prevention system describes the entire Kikuma Base site, underground tanks, and all related facilities displayed in mosaic-type graphics on the bench-board type instrument panel. The fire alarm, smoke sensor, oil or gas leakage alarm, and water table alarm on the graphic panel help the operator instantly pinpoint where an abnormality has occurred. In addition, abnormalities can be also checked through the ITV monitor, and extinguisher operations depending on the location can be controlled from the same panel. All these lead to a perfect configuration for taking easy and proper measures should any disaster occur. (See **Fig. 5**.)

3.2 Features

(1) Integrated MMI system linking DCS and computers

Conventionally, the DCS and related computers used their own CRT's; however, this system has adopted a single-window configuration in which the IOS-2500 operator station of the MICREX-IX can also be used as a terminal via the extended computer linkage function, thereby eliminating the need for a CRT for each computer. The new integrated MMI system offers excellent ease of operation and reliability because it ensures system operation irrespective of the difference between DCS and computers, and all the CRT's have both DCS and individual computer functions.

(2) Highly functional MMI

The IOS-2500 integrated operator station is provided with the following display functions, as well as excellent visibility and ease of operation:

(a) High-resolution screen [1,120 x 750 (dots)]
(b) Multi-color display [32 basic colors and the specified background colors may be used for multi-colors]
(c) High-quality Japanese character display [24 x 24 (dots)]

This MMI system is easy to operate and provides a large amount of information by using multi-window functions including a dynamic window, guidance window, and the instrument diagram window, the functions of automatically reporting the alarm contents and guidance message, the virtual screen scroll function, and the touch-screen function.

(3) Fiber-optic Field Instrumentation System

The Fiber-optic Field Instrumentation System (FFI) is adopted to link the field instruments with the DCS or signal-receiving instruments via optical fibers. Such a linkage ensures freedom from electrical interference or lightning shocks, while making it possible to conduct remote maintenance, reduce field work by eliminating wires through the use of duplex signals, and enhance maintainability.

4. Major Functions of Each Component

Figure 6 shows the functional configuration of this system.

4.1 Management computer

The management computer occupies a key position in the operation of the Kikuma Base by scheduling oil manipulation jobs, calculating result data, outputting records, communicating with the tank gage system, and calculating the current tank storage, etc. Its major functions are as follow.

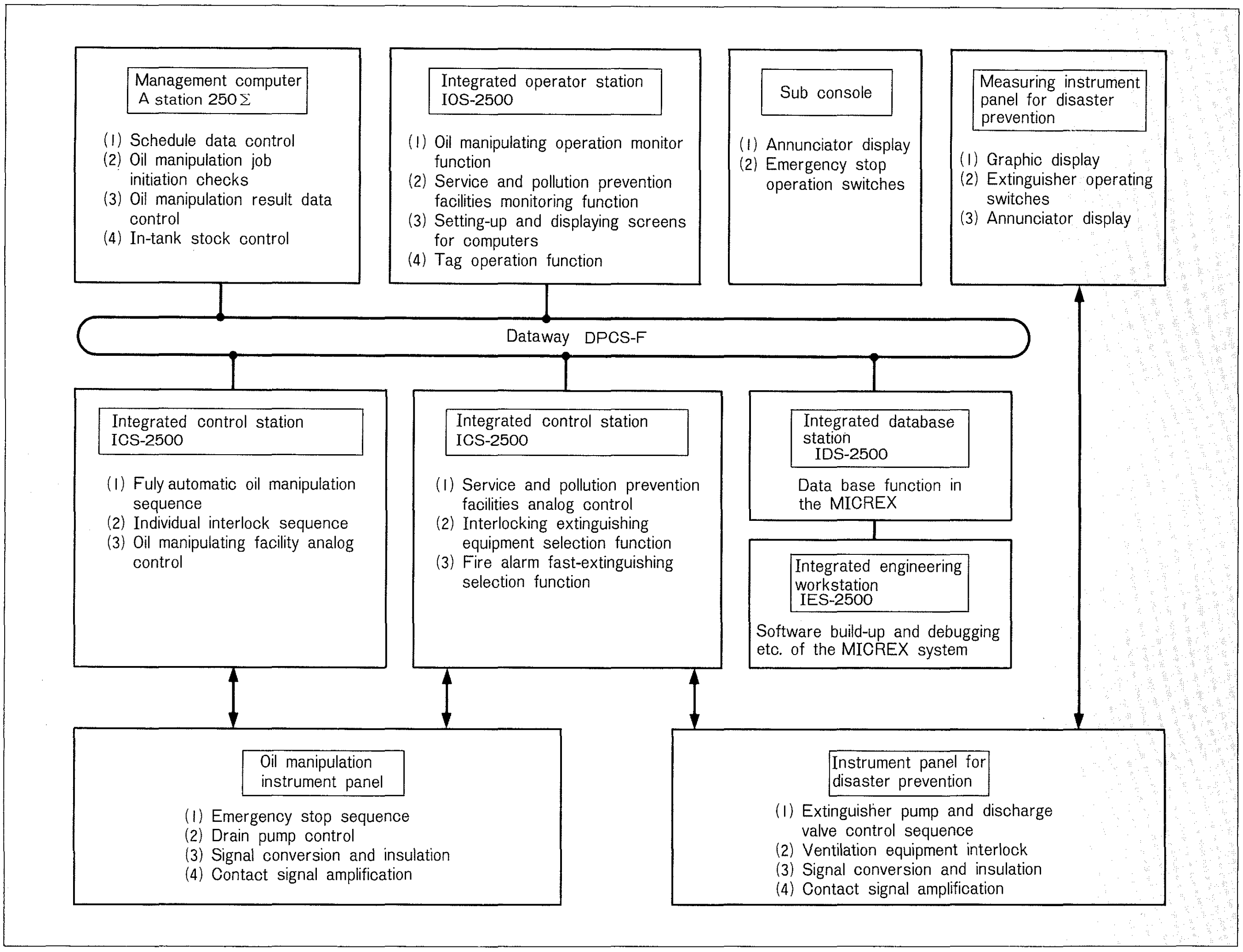
(1) Oil manipulation control function

(a) Controlling the data of the fully automatic oil manipulation operation

Registers and saves data related to the job No., job schedule, oil type, specific gravity, vapor pressure and amount of crude oil to be shifted. Such data can be displayed as summarized in a job schedule table or separately for each individual job. This function is also available before interlock checks using the software keys on the screen are begun.

(b) Calculating various setting values for the fully auto-

Fig. 6 System functions schematic diagram



matic oil manipulation operation

Batch amount data such as the pre-batch amount and the total batch amount is related to crude oil shifting, thermal expansion coefficient, flow rate compensation coefficient and pressure values of the pipes for protecting the pump, as well as the alarm setting values for the tank storage level can be calculated automatically and the results can then be transmitted to the DCS prior to starting the job.

(c) Interlock check before starting oil manipulation

Job connection check, maintenance equipment checks, reception/shipping acceptable amount check, tank level check, etc. are performed to determine whether the respective job can be started safely.

After the check, if the job is found to be impossible to initiate, a possible reason and remedy will be displayed as an interrupt message on the CRT to inform the operator of the interruption.

(d) Outputting the oil manipulation result records

The type, specific gravity, temperature, and shift amount of the crude oil, the tank level before and after the shift, and the current storage amount will be outputted through a printer as a result record.

(2) In-tank stock control

Because the ground shift tanks of the Kikuma Base play act as gages to measure the amount of shifted crude oil, it is necessary to strictly control the current amount stored therein. To further this purpose, the A station receives raw data on the levels of oil in the ground shift tanks and underground tanks and their temperatures from the tank gage systems. Then it converts the data according to the tank table, positional compensation of the floating roof, and ASTM correction so that the net storage can be properly calculated.

The current storage amount of each tank, together with the data used to conduct compensatory calculations, will be automatically printed out every day as the record of the hourly data of each tank, variation per day of each tank, stock amount at the end of the work day, and stock amount of each oil type. It is of course possible to output the records as required.

Table 2 Outline of fully automatic oil manipulation

Name	Description
Reception of crude oil	Receiving crude oil from the tanker to the ground shift tank or slop tank. The cargo pump in the tanker is used to shift the crude oil.
Shipping I of crude oil	Operation of the shipping crude oil from the ground shift tank to the tanker using the reception/shipping pump. Shipping begins on all the ground shift tanks for which such shipping is specified.
Shipping II of crude oil	Operation of shipping crude oil from the ground shift tank to the tanker using the reception/shipping pump. Shipping is divided into two processes; the first and the second shipping. Tanks which finish the first shipping can receive crude oil from underground tanks. Such an operation is known as an emergency shipping operation.
Shift operation between ground shift tanks	Operation of shifting crude oil from one ground shift tank to another using the reception/shipping pump.
Reception/shipping pump maintenance operation	Operation to conduct a periodic check and performance check of the reception/shipping pump. Means of circulating oil in a ground shift tank. This refers to the performance of an circulation operation in an identical shift tank.
Shift operation from the ground shift tank to the underground tank	Operation of shifting crude oil from the ground shift tank to the underground tank using a reception/shipping pump.
Shift operation from the underground tank to the ground shift tank	Operation of shifting crude oil from the underground tank to the ground shift tank using a shift pump.
Shift operation between underground tanks	Operation of shifting crude oil from one underground tank to another using a shift pump.

(3) Facility data control

The key control data related to the service facility and pollution prevention facility that are associated with the oil manipulating and disaster prevention facilities will be logged into the control system, and then output as a utility report or environmental report. These reports include seepage water reports, drain amount reports, and sealing water reports which are specific to the reserve bases that use underground tanks.

4.2 DCS

DCS is a core of the important functions of the oil manipulation facility operations by featuring continuous control functions such as the feed back control, sequential control functions of the fully oil manipulation sequence and individual interlock sequence, and collective remote monitoring and operating functions over operation controls for the purpose of ensuring the safety of oil manipulation facilities, preventing operation mistakes, and saving manpower. The key functions are as follows.

(1) Fully automatic oil manipulation sequence function

In order to safely and properly receive, ship and conduct tank-to-tank shifting (shift) of crude oil at the site, eight types of fully automatic oil manipulation procedures are provided, as shown in **Table 2.** These sequences are made up of various processes including auto-line-up, batch control, line-up check, pump startup and stop controls, tank status check, and pause/resume/stop controls, and all operation processes from startup to the end can be controlled via the CRT screen.

In addition, messages offering guidance can be displayed at any time on the CRT as an automatic interruption to inform operator of the progress of various processes and operational requests. When an interruption occurs, one of these messages will be automatically displayed in the top two lines of the CRT and a voice message will be activated. This greatly reduces the load on the operator.

(2) Individual interlock sequence

Besides the fully automatic oil manipulation sequence function, an individual interlock sequence function is provided to prevent operation mistakes, improve safety, and save on manpower. The following are typical functions.

(a) Startup/stop interlock for the reception/shipping pump

This is used to monitor the pipe pressure, valve status, minimum flow circulation period, etc. to ensure safe operation of the reception/shipping pump. This remains active during control from the Central Instrumentation Room.

(b) Flow rate and pressure control of the crude oil shipping pipes

This is an override control to control pressure and flow rate and keep the pipe pressure during crude oil shipping to within the rated value, and carry out batch control over the total amount of oil flow.

(c) Pressure control setting value switching sequence

This is used to switch the setting values for pressure control as described in (b) when the reception/shipping pump is running. This is aimed at improving the stability of the control systems.

4.3 Measuring instrument control systems

There are basically two measuring instrument control systems in this system – one for the safety and disaster prevention facilities and one for oil manipulation facilities.

(1) Control panel for disaster prevention

In order to prevent disasters at the site and to allow the operator to pinpoint the location of any accident, should one occur, and to allow the operator to take prompt and appropriate measures, this panel is provided with a measuring instrument panel for disaster prevention on which all the major equipment and buildings at the base, underground tanks and related facilities, and water table measuring pit are all displayed on a map created by mosaic graphics. The instrument panel also has alarm indicators, annunciator lamps, and extinguisher operation switches. Should a fire occur, the respective indicator will flicker to allow the operator to grasp the location of said fire. In the interlock extinguishment mode, pressing the extinguish operation start button, after confirming the situation through an ITV monitor, automatically activates the corresponding extinguishers. A single-action extinguishing mode for each extinguisher is also available.

(2) Measuring instrument panel for oil manipulation

The measuring instrument panel used for oil manipulation is provided with relay logic circuits to activate the emergency shut-off system when a critical abnormality is discovered in the pressure, level, or oxygen concentration of the underground tank, in the pressure of crude oil reception/shipping pipes, or in the bed water drain tank level. The relay logic circuits also serve to control the bed water drain pump so that the water bed will remain at a constant level.

5. Conclusion

The above introduces the instrumentation and control system of the petroleum stockpiling base. As the petroleum stockpile with underground tanks offers a number of advantages – it requires a smaller ground area less than any other reserve method, is resistant to natural catastorphes, and it ensures that the stored oil will have a low potential for dispersion or leakage – it has been widely adopted in the Northern Europe. I would be pleased if this article would prove to be a useful reference for the operation and safety of petroleum stockpiling bases in Japan.

I would like to express my gratitude to Chiyoda Corp. and all the individuals who have offered their kind advise and cooperation in building and testing this system.