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OUTLOOK OF SYSTEM ENGINEERING IN OIL PIPELINES

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I. PIPELINES AS A METHOD OF OIL TRANSPORT

The development of pipelines as a means of transporting various types of oil from crude oil to petroleum products has been remarkable in the past few years and the overall length of pipelines throughout the world has reached 500,000 km. There are very few examples of oil pipelines in Japan and only 2～3 cases have been reported. This is considered to be due to the differences in industrial and land conditions between America and Europe where oil pipelines have been widely developed, and Japan. The main points are as follows:

1) Almost 100% of Japan's crude oil is imported and processed in refineries along the sea coast.
2) The consumption of petroleum products in Japan is mainly in the coastal areas. Therefore, coastal tankers and tank lorries are used to transport these products over the short and medium distances required.

However, the amount of oil used in Japan, which is the world's third largest consumer, is increasing greatly and the transport distances are also becoming longer as inland requirements grow. Therefore, pipelines with high capacities for transporting oil over medium and long distances in place of the coastal tankers and tank lorries or cars which are limited in both distance and capacity are attracting attention in Japan. The main features of such pipelines are follows:

1) The initial costs are high but the operation costs are generally lowered if the operation is rationalized and the effects are especially remarkable for large capacity transport over long distances.
2) Since the transport is in fixed pipes, there is no traffic delay on land or sea such as that caused by ships and tank cars.
3) Because there is on high speed movement such as that involved with ships and tank cars, there are no sudden accidents and almost no danger of fires or explosions caused by such accidents.
4) There is no environmental contaminiation such as that caused by the disposal of sludge in the sea when tanks are cleaned.
5) The transport is stable and is not influenced by weather such as in the case of ships and tank cars.

II. CONTROL TECHNIQUES FOR OIL PIPELINES

Pipelines which as such an excellent means of large capacity transport over long distaness require a high level of system measurement and control techniques. The basic techniques are as follows (refer to *Fig. 1*):

1) Scheduling techniques for minimum power consumption and contamination for switching in accordance with demands, timing and types in the receiving station and with stocks and transport capacities in the transport station.
2) Information processing techniques to process the large amount of information collected and to issue control commands in accordance with the operation plan compiled.
3) Remote communication techniques for reliable, rapid, long distance transmission of large amounts of information required for data processing.
4) Remote control techniques for rapid, reliable operation of various types of equipment over long

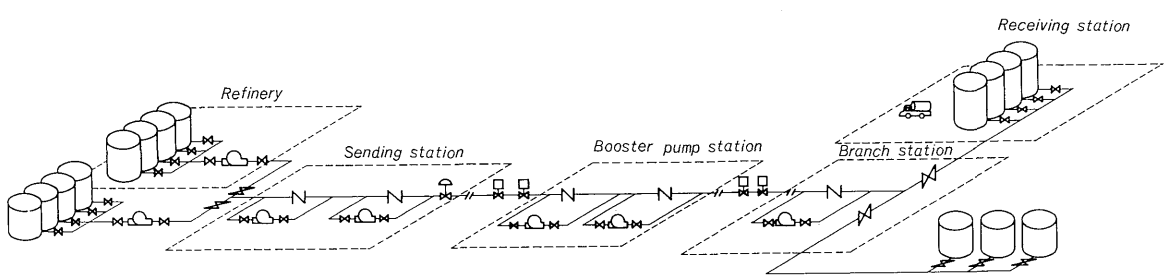


Fig. 1 System composition of pipeline

distances in accordance with the control commands.
5) Leakage detection techniques for rapid detection of very small leaks.
6) Fluid control techniques to prevent surges and air/liquid separation in the control of valves and pumps.

III. PROBLEMS CONCERNING CONTROL TECHNIQUES

The main problems in the control of pipelines are (1) sequence control operations of valves, pumps, etc. including starting, stopping, direct tank change-over, etc. in the piping system of pumps, valves, tanks, etc.; (2) scheduling for economic transport plans for different products and customers; and (3) stable and reliable control so that the entire system can be operated normally.

The first two problems are extensions of existing techniques and require such conditions as the use of telemeters and tele-controllers over long distances and considerations of unmanned operation. All of these problems, however, can be solved. In the case of the third problem, considerable research and investigations are required so that disasters such as fires or environmental contamination do not occur because of leaks through breaks caused by unexpected accidents or operational mistakes in the pipeline.

In this article, the main points described will be investigations by simulation analysis using a computer concerning the problems related to stability such as leak detection and the prevention of surging during operation, as well as the problem of compiling the optimum transport program.

Therefore, the items given so far have been as reference for the planning of pipelines for use in Japan. However, the following points require logical support although there is not operation problem, or must be solved technically.

1. Leak Detection

1) Leak detection under unstable conditions

The detection of leaks during periods when the flow of liquid in the valves or pumps is unstable because of changes in pump delivery pressure or valve changeovers often results in large errors since the ordinary operations are disturbed.

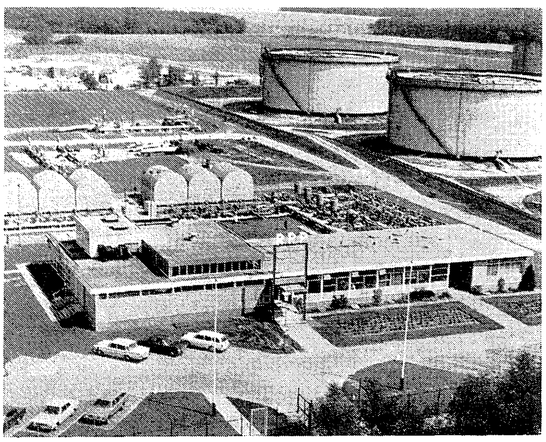


Fig. 2 General view of booster pump station

2) Estimation of amounts of leaks

The estimation limitations on the amounts of the leaks even under normal conditions have not yet been determined. The correct calculation of the estimation limits (error limits) of the amount of leaks from such parameters as the locations of the various measuring points, the operation pressure and the temperature are particularly required in pipelines where the operating conditions are changed frequently.

3) Estimation of leak locations

The estimation of the location of a leak at the same time as it occurs or very quickly after is extremely important for subsequent procedures. Such systems as inserting the leak detector in the pig have been developed but these systems have not reached the level where they are practical from the standpoints of speed and economy.

2. Prediction of the Occurrence of Surges

In order to determine how surges occur and propagate when valves and pumps are operated optionally, simulation is performed for a pure line and experimental values are obtained. However, the results are not sufficiently clear in complex cases with large numbers of stations connected. Accurate prediction of the occurrence and propagation of surges is naturally very important in preventing damage to the pipelines by increases of the oil pressure above normal and also in increasing the accuracy of leak detection.

3. Scheduling (Compilation of operation plans)

There are already large numbers of pipelines under operation but the on-line use of operation plans which include minimizing costs and contamination and optimizing tank inventories is still in the investigation stage. In products pipelines, there are many cases when the minimizing and optimizing plan as well as a simple time plan are difficult because of the large number of types of oil, sending refineries, branch stations and receiving stations.

IV. OUTLOOK CONCERNING CONTROL TECHNIQUES

In relation to the above-mentioned technological problems, the authors are conducting investigations through simulation using computers and also by means of results obtained from equipment supplied by Fuji Electric, cooperative research with customers and estimate activities, as well as data from Europe and elsewhere supplied by Siemens, Co. and experimental data from Japan. The construction of standard model concerning the problems of safety guard such as leak detection and the elimination of surges as well as the problem of compiling operation plans has already been solved and parts of these results will be mentioned here.

1. Leak Detection Technique

The rapid detection of the occurrence and location of relatively large leaks is possible with the line pattern method and the line surge method. The occurrence of relatively small leaks can be detected by the line balance and line pack methods, but is necessary to use the sound recording method simultaneously to detect the location of the leak. The limits of the amounts of the leak detected by these methods and the estimated error in the leak location vary in accordance with the line equipment conditions (distance) and the operating conditions (pressure, kinds of oil), but it has become possible to estimate the limits of the amount detected and the degree of error in estimating the location through the establishment of a simulation technique and the application of the above conditions.

On the other hand, if the minimum allowable value of the leak detection is known, then it is possible to determine equipment conditions (distance between block valves), operating conditions (pressure) and measuring conditions (plant stoppage time).

In the case of leak detection equipment operating under on-line conditions, there is the problem of operational errors occurring because of changes in the operating conditions (pressure, valve switching) and changes in measuring conditions (line packing values, temperature) but correct operation of such equipment can be expected by applying operating and measuring conditions (data) on a real time basis to the setting and discriminant circuits of the equipment.

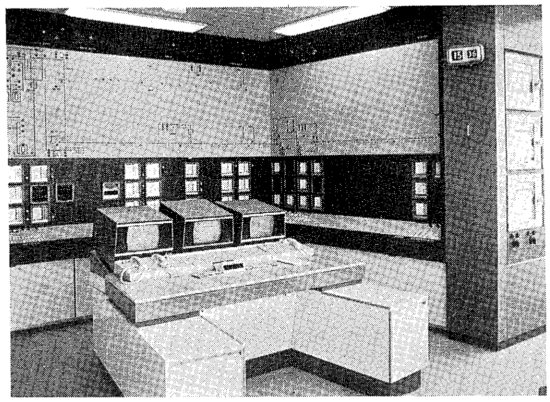
2. Prediction of the Occurrence of Surges

Various types of unit models have been completed, the occurrence of surges had been calculated by means of optional operation of the pipes, valves, of the pipeline system by assembling the models and a program with output has been completed. If the basic equipment conditions of the pipeline system (line length, number of branches) are given in the planning stage, it is possible to predict individual equipment specification (flow characteristics of valves, switching times). When the individual equipment specification are determined, it is possible to determine various types of operating conditions (valve switching sequences during start-up and shutdown).

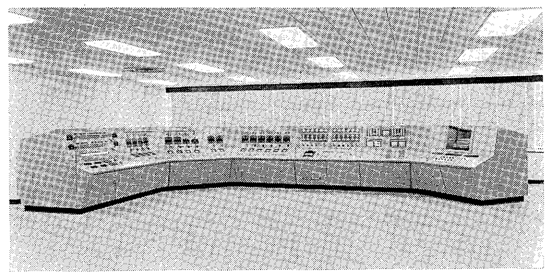
The development of this program to an on-line program is progressing through the development of a set-value correction program by menas of the transient characteristics of the above leak detection program and by combining with actual data.

3. Scheduling

A scheduling program which is connected with



(a)



(b)

Fig. 3 Two examples of control center

optional on-line data (such as tank inventory) has almost been completed. This program varies the scheduling time in accordance with the load, i.e. the amount of oil transported and is designed to minimize contamination. It automatically chooses the optimum operation method which minimizes operation costs.

If the scheduling periods are determined, either the one cycle method with few requirement prediction errors or the half-cycle method with minimum contamination can be selected. These are flexible scheduling programs which can adapt to seasonal changes in requirements.

The compiled schedule is given out by an XY plotter or some other device, and it is possible to understand changes in the tank inventory, line pressure, flow rate, surface level, etc. with time.

A program is now being developed for operation tracing in which the batch trace in accordance with the scheduling, i.e. the oil movement conditions (for example, level position) is estimated by combining the on-line data with the scheduling and is displayed on a graphic panel. This will increase the reliability of large scale and complex pipeline systems. And is also expected to facilitate operation.

4. System Safety

The systems now meet current demand levels but the basic steps to be taken to improve the system safety are as follows:

1) Design and manufacture of equipment and devices with high unit reliabilities.

2) Composition of a system against unexpected accidents.

The method of constructing equipment and devices of high reliability has been studied from several angles but it is proceeding in a direction where stress is being placed on simplicity and reliability is being harmed. For example, in the case of pressure detectors, a strain gauge type transmitter has been developed in place of the conventional force balancing type or differental balancing type with mechanically movable parts. This type of transmitter has better characteristics than other system also in respect to the response characteristics required for the line surge type leak detection. However, from the viewpoint of system construction, system duplication and unit construction for separate functions play important roles in system safety. The main objects of system duplication are the trunk line data transfer equipment and the transfer circuits. In unit construction for separate functions, the main objects are the supervisory control system in the control center (line station operating mode display, operation instructions), the sequence control equipment in each station.

V. CONCLUSION

The authors have been investigating the main problems concerning pipeline control systems from various angles as was described above. In the future, it will be necessary to consider confirmation of these techniques in actual pipelines and improved, high quality and reliable hardware through the development and improvement of measuring devices by research within Fuji Electric and also in cooperation with technical groups in other componies.

In recent years the problem of product reliability has been taken up from several angles. The authors would like to add this work to these efforts. It is hoped that this system will soon be further refined to become economical. The authors desire to hear any comments from persons in this field.

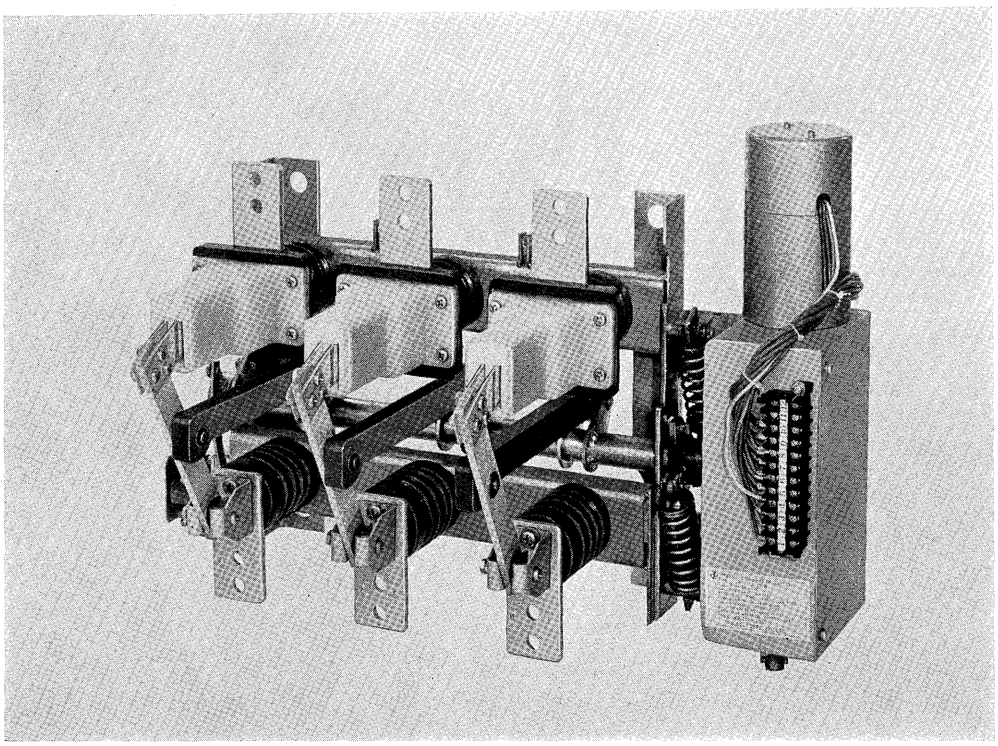
MOTOR OPERATED HIGH VOLTAGE AIR LOAD BREAK SWITCHES

The Fuji Type LB and LBF high voltage air load break switches have received high praise as 3∼6 kV class high tension line load break switch.

A new type air load break switch with motor operated controller has been placed on sale. This is ideally suited for the operations of various fields.

Features

1. A new type motor operated controller forms a single unit with the load break switch. It is very compact and lightweight.
2. The control motor is connected to AC/DC source.
3. Low operating current.



Motor operated high voltag air load break switches

Specifications

	Type (motor operated)	L B Ⅲ 6/200 M	L B Ⅲ 6/400 M
Load break switch	Rated voltage (kV)	7.2/3.6	7.2/3.6
	Rated current (A)	200	400
	Rated load switching current (A)	200	400
	Rated short time current (kA)	10	
	Rated insulation level	No. 6 A (Withstand voltage 22 kV 1 min; Impulse voltage 60 kV Wave form 1×40 μs)	
Motor operated controller	Operation voltage (V)	AC, DC, 100/110	
	Operation current (A)	5.5	
	Rated torque (kg·cm)	3	