DEVELOPMENT OF AUTOMATIC STEEL PIPE INSPECTION AND ACCEPTANCE SYSTEM APPLICATION OF A CONSTRUCTION ROBOT TO CONSTRUCTION SITE "D"

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ABSTRACT

Repeated studies have been conducted on the automatization of construction work and for greater efficiency in processing of informations and the operation of the Equipment Center, that serves many construction sites, is dealt with as one study. Temporary construction materials which flow between jobsites and the Equipment Center and the amounts of information involved have been increasing enormously. To cope with such a situation, we have been undertaking the study of automatization for quantity inspection/acceptance of incoming and outgoing materials. The device for automatic inspection and acceptance, presented here, of steel pipes for temporary construction use selects, sorts, repairs, inspects and accepts steel pipes automatically. The purpose for the development of this system was to reduce not only labor in performing operations at the Equipment Center but to greatly reduce labor in performing material inspection and acceptance work at jobsites as well, by automatizing critical points among a series of operations between jobsites and the Equipment Center for smooth overall operation flow, resulting in great labor-saving. This paper deals with the outline and development of the system.

1. History of Development

Temporary materials play crucial roles in executing construction work smoothly. Of the various temporary materials, steel pipes are greatest in frequency and quantity. Table 1 shows dimensions.

Type	Cross section	Weight	Length
Round pipe	Diameter: 48.6ø Wall thickness: 2.4mm	2.7 kg/m	Approx. 16 types ranging from 0.9 to 4.5m

Table 1. Types and dimensions of steel pipes for temporary construction work

Temporary steel pipe has wide usage in scaffolding, concrete forms, and handrails. For this reason, steel pipes are available in several types of lengths. These steel pipes are lent out, together with other temporary materials, from the Equipment Center to jobsites. After use by jobsites, they are turned in to the Equipment Center where they are properly maintained, inspected, accepted, and then stored at the storage yard. Fig. 1 shows the conventional flow of temporary materials.

The temporary steel pipes lent out currently to the company's jobsites in the Tokyo area total about 2,200,000 linear meters in length or about 6,000 tons in weight and about 850,000 to 900,000 pieces. In the past this enormous quantity of steel pipes were cleaned of concrete coatings, straightened, and classified for lengths and quantities manually at the Equipment Center. These works took place outdoors, generating intense dust, as well as requiring heavy manual labor, so for these reasons, their automation has long been desired.

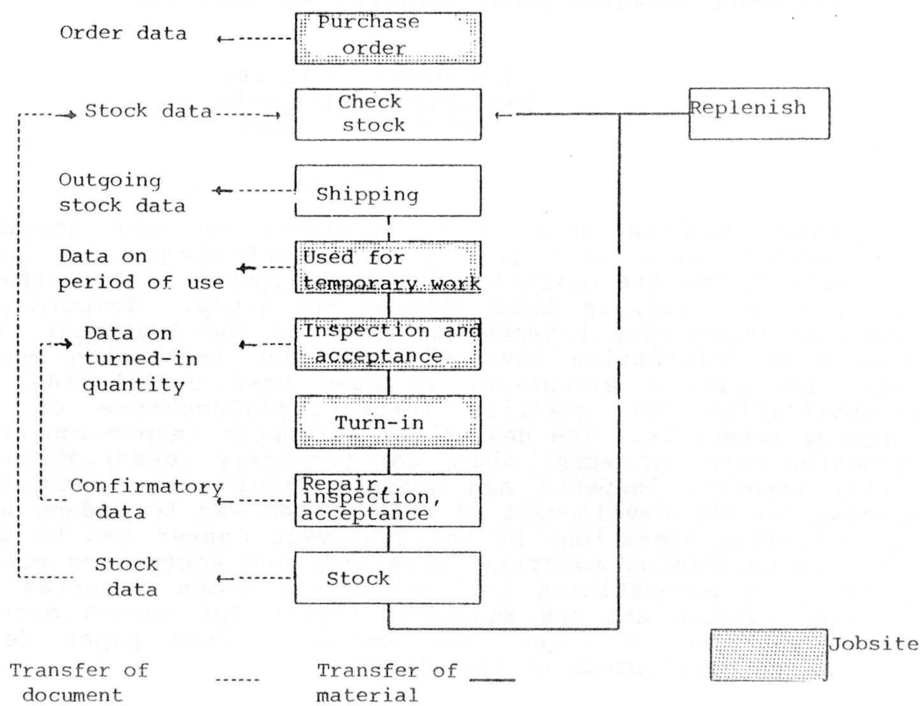

Fig. 1 Flow of temporary steel pipes and data

Based on the above requirements, this system has been developed by combining the technologies of robot, computer and sensor. The following are the functional requirements of the system:

① To count quantities by length.
② To sort and store by length.
③ To remove coatings.
④ To straighten pipe bends.
⑤ Ship by the unit of 100 pieces.
⑥ To accumulate as data the turned-in quantities by jobsite.
⑦ To prepare a work report based on the inspection/acceptance data.
⑧ To transfer the accumulated data to the host computer.

The operation of this system can reduce not only labor in performing operations in the Equipments Center, but also greatly reduce jobsite operations involved in collecting, sorting, inspecting and accepting temporary materials turned-in to the Equipment Center. Furthermore, the data outputted from the system is incorporated in the overall management system including the Equipment Center and jobsites. The flow of operations shown in Fig. 1 will be the configuration of the system shown in Fig. 3. This is not intended merely for the automatization of operations but also for the automatization of the materials/data flow mechanism.

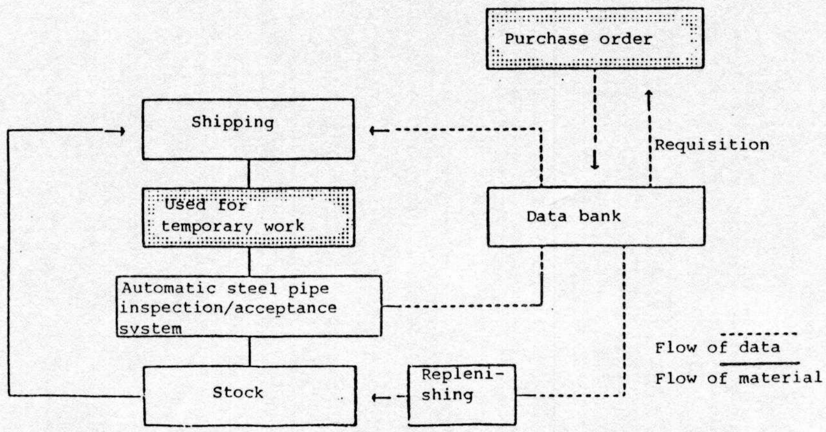

Fig. 2 New flow system

2. Outline of the Automatic Steel Pipe Inspection/Acceptance System

Fig. 3 shows the composition of the system and Photo 1 shows its external view.

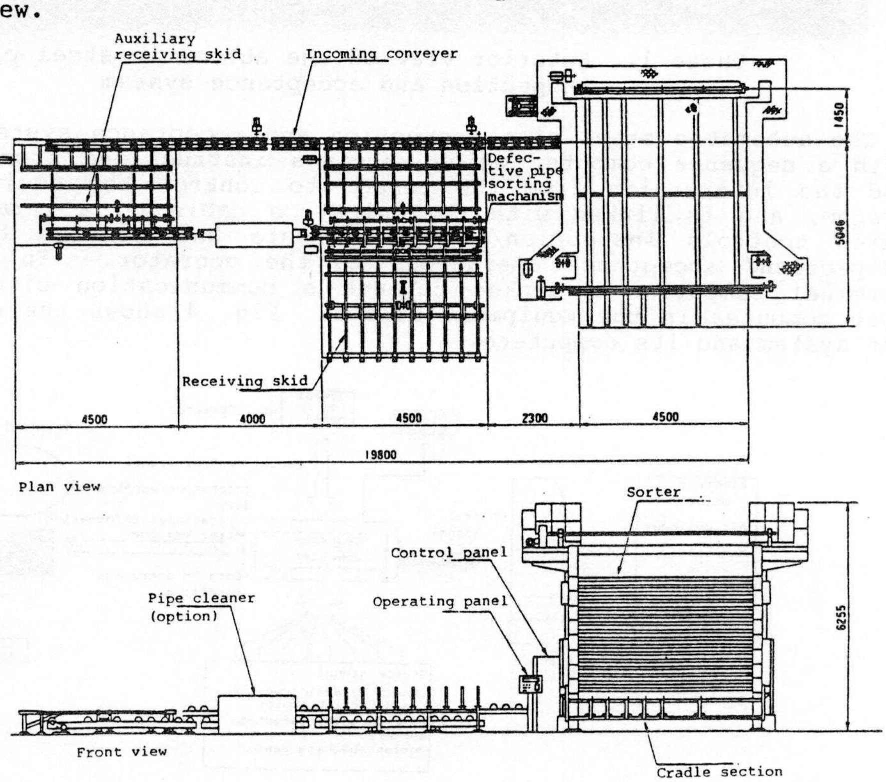

Fig. 3 Composition of the automatic steel pipe inspection and acceptance system

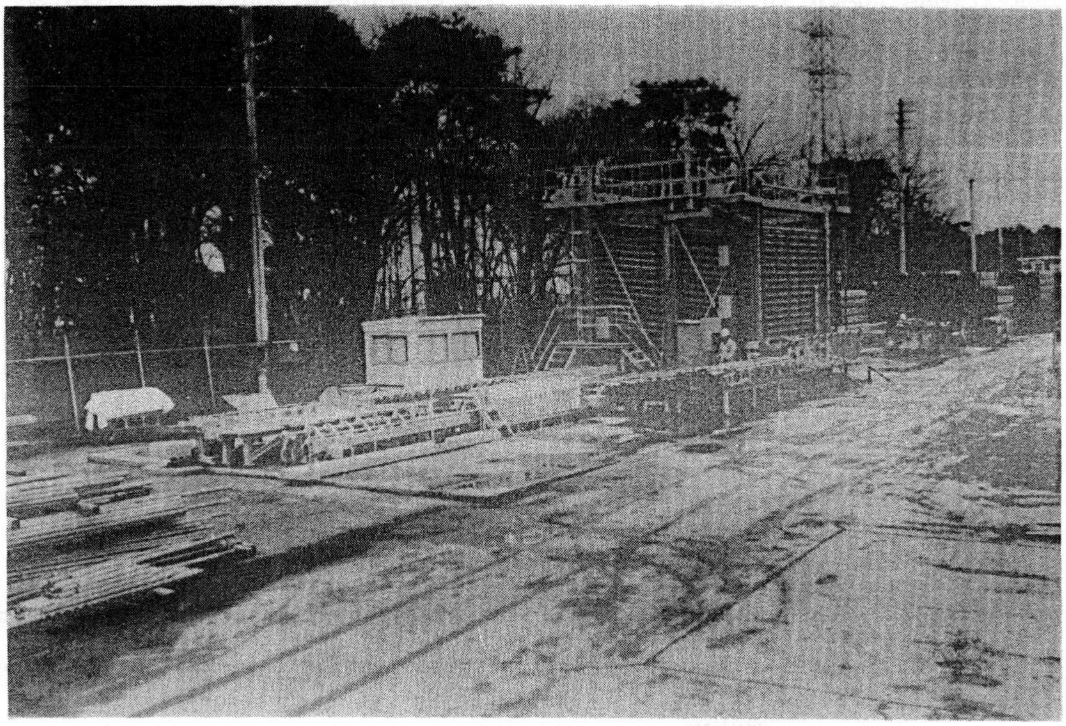

Photo 1. Exterior view of the automatic steel pipe inspection and acceptance system

The automatic steel pipe inspection and acceptance system is equipped with a sequence computer which receives instructions from the operator and the information from the sensor to control the equipments in the system, and is linked with communication cable to a terminal computer which controls inspection/acceptance data and conveys the status of inspection/ acceptance operations to the operator. In addition, the terminal computer is linked through a communication circuit with the host computer in the Equipment Center. Fig. 4 shows the composition of the system and its computers.

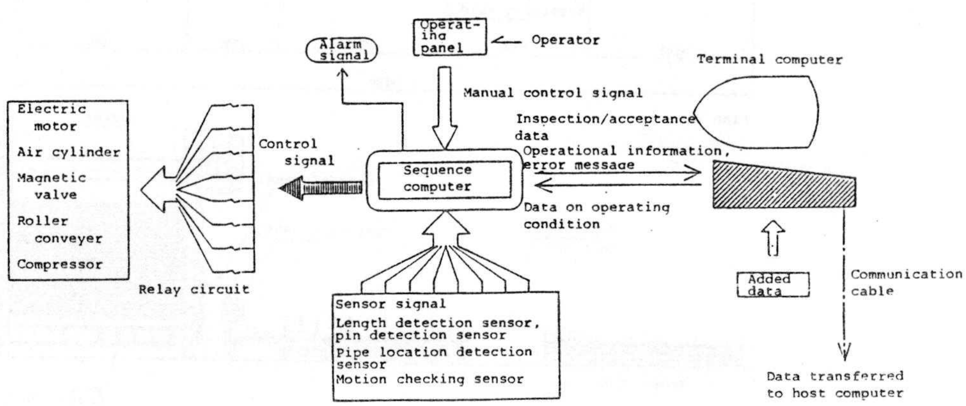

Fig. 4 Composition of the system and its computers

Fig. 5 shows the flow of repairs/inspection/acceptance flow of the system

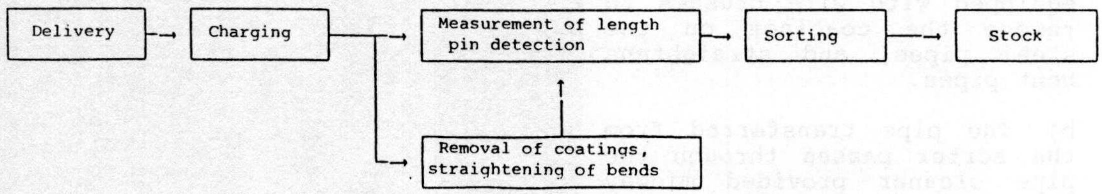

Fig. 5 Flow of repair/inspection/acceptance flow of the system

The details of the equipment composing the system are shown below:

1) Receiving skid (Photo 2)

a) The receiving skid is composed of a skid, a charger, and a defective pipe sorter.

b) The steel pipes delivered are lined up on the receiving skid.

c) Defective pipes (smeared with concrete or bent) are put out of the standard line by the sorter, and then transferred to the pipe cleaner.

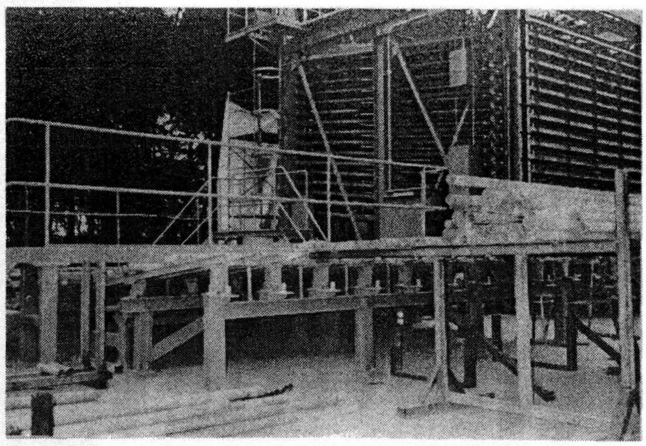

Photo 2 Receiving skid

2) Incoming conveyer (Photo 3

a) Steel pipes are transferred on the four sets of roller conveyer.

b) Standard roller conveyer speed is 60m/min, and the pipe cleaner line syncronizes with the speed of the pipe cleaner.

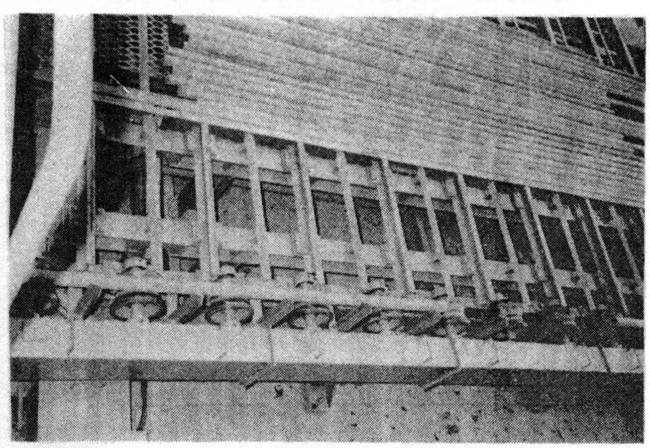

Photo 3 Incoming conveyer

3) Pipe cleaner (Photo 4)

a) The pipe cleaner is equipped with wire brushes to remove the coatings on the steel pipes, and straightens bent pipes.

b) The pipe transferred from the sorter passes through the pipe cleaner provided midway on the roller conveyer. From the cleaner the pipe rides the roller conveyor from sub-skid and goes to the sorter and joins other pipes already sorted.

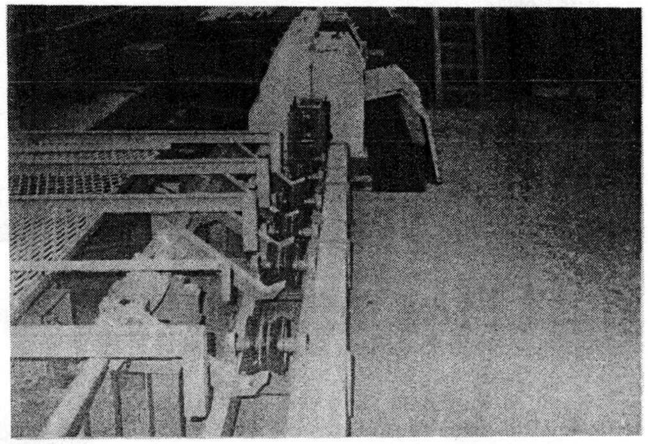

Photo 4 Pipe cleaner

4) Sorter (Photo 5)

a) The sorter consists of a pipe receiving unit, an aligning unit, a lower skid, a chain conveyer, and a storage rack.

b) The pipe transferred onto the lower skid has its ends aligned by the air cylinder. In this instance, the sensor checks whether the pipe has its lock pin.

c) The pipe aligned is then transferred onto the chain conveyer and passes the optical sensor that measures the pipe length.

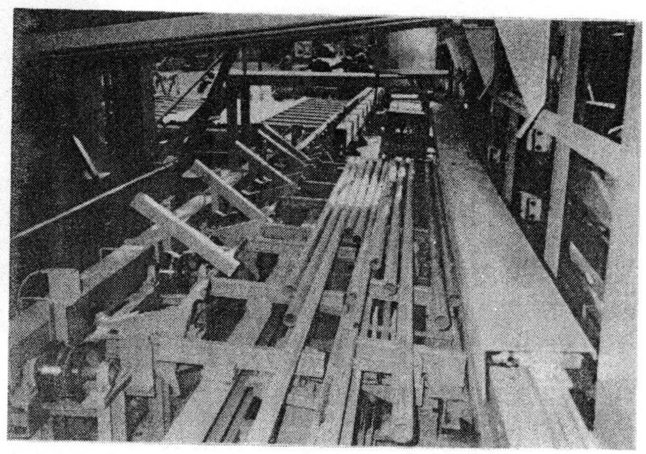

Photo 5 Sorter

d) torage racks are allotted automatically by computer. In case there are many steel pipes of the same type, multiple racks can be used. Furthermore, racks less than the number of types of steel pipes can be used. By this system (called "free rack system"), racks work more efficiently. (Photo 6)

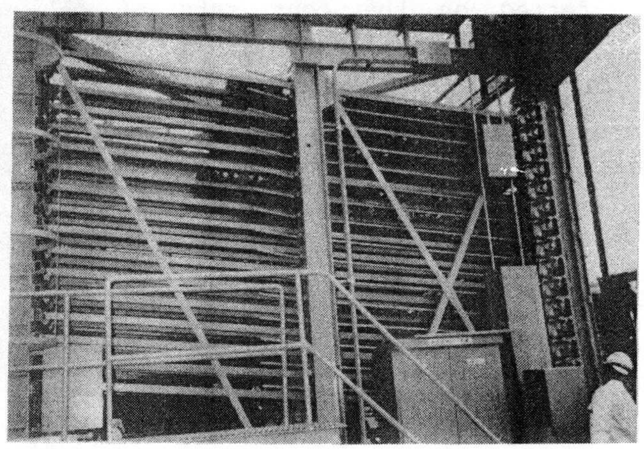

Photo 6 Storage racks

5) Cradle (Photo 7)

a) The cradle is composed of hoisting/lowering cradle and a rack gate release mechanism.

b) The cradle moves up to the rack designated by the operator, where the rack gate is opened to place the pipe onto the cradle.

c) The cradle placed with steel pipes is then lowered, and after the pipes are bundled, they are brought out with forklift.

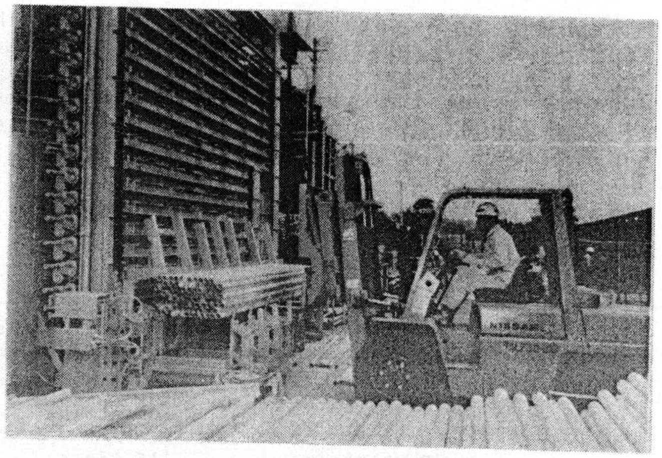

Photo 7 Cradles

6) Operating panel (Fig. 6)

a) The function of the operating panel is to transmit the instruction of the operator to the sequence computer, and to indicate to the operator the necessary informations from the data transmitted from the sensor of each equipment.

b) The operating panel's built-in computer does the work of transmitting a manual operation signal to the sequence computer, as well as checking any wrong instruction of the operator and pressing for modification.

c) Operational information includes the status of steel pipes stored on each rack, and a display "urging the discharge of the pipes on the rack because the capacity of the rack has been reached."

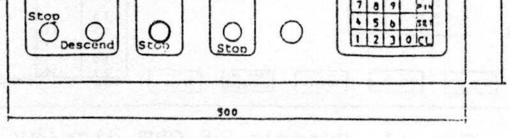

Fig. 6 Outline of operating panel

- o When the number of pipes on the rack is in excess of 80 pieces, the display lamp on the rack is caused to flash by the operating panel.
- o The lamps in the upper row flash when pipes on the rack are in excess of 100 pieces.
- o By depressing the designated button of the rack, the lengths and quantities of the pipes on the rack are displayed.
- o When the start buttons is depressed, the cradle ascends to the designated cradle.

d) Emergency stop and re-start

When the operator desires to stop the entire system in an emergency, he just depresses the emergency stop button on the operating panel. In reality, however, computer has to judge the state of each equipment to stop it at the safest position. Likewise, when re-starting the system, the function of judging the state of each equipment before the stop is necessary for smooth operation.

7) Processing capacity of the system

Table 2 shows the performance of the system.

Item	Processing capacity
Sorting system	Sorting of length → 16 kinds, and pin detection
Rack tiers	16 tiers
Number of pipes per rack	100 pipes Total rack storage capacity: 1,600 pipes
Conveyer speed	60 m/min
Processing quantity/day	Length : 19,200 m/8 hrs. Weight : 52 tons/8 hrs. Number : 6,400 pipes/8 hrs.

Table 2 Processing capacity of the automatic steel pipe inspection/acceptance system

3. Information to be Processed by Terminal Computer

The informations to be processed by the terminal computer are shown below:

① Display of inspection/acceptance status.

② Basic establishment of operational conditions.

③ Tabulation of turned-in pipes.

④ Registering of added data (name of jobsite, turn-in date).

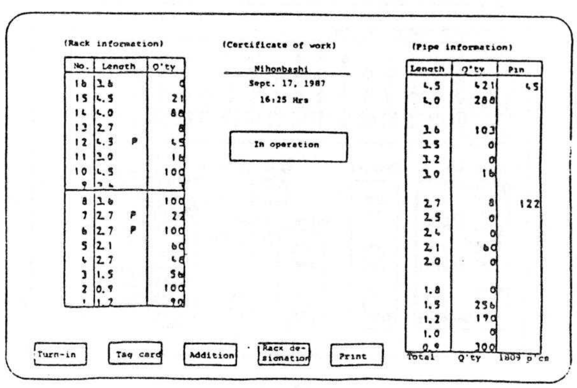

Fig. 7 Example of CRT display

⑤ Printing of operational report.

⑥ Display of messages transmitted from the system on the screen.

⑦ Communications with the host computer.

⑧ Build-up of data.

During operation, the terminal computer maintains communications with the sequence computer which controls this system, and with the operator via the CRT and the printer. In addition to receiving and supplying inspection/acceptance data, the status of failure of sensors, electric motors, air cylinders, etc. provided at various locations are displayed on CRT in the case of system stop and calls the attention of the operator to its operation. The use of such a system can greatly reduce the number of meters and display lamps on the control panel, which will result in a very simple control panel and easier operation.

4. Future Development

Unlike general expendable materials, temporary construction materials in the construction industry are used repeatedly in a use/repair cycle. Due to this, the data accompany the flow of materials. Therefore, a robot working in this flow should be not only a means for automatizing operations, but should also be a source for supplying data into the computer network.

The system developed this time was a device for repairing, inspecting and accepting steel pipes for temporary construction use. However, the temporary construction materials currently handled at the Equipment Center are in excess of 1,000 different types, and all require repairs, inspection and acceptance after use. Therefore, it would be necessary to further automatize the repair/inspection/ acceptance of these materials as well as to survey the method for their use at jobsites. Automated erection of these temporary construction materials would also be included in the study.

5. Conclusions

The robot technology introduced to the construction industry was developed with the aim of automatizing a single type of work, as well as with the aim of attaining higher efficiency by incorporating it into overall management system. In former case, the work is mainly fixed, so there remains the problem of requiring the robot to move. However at present a clue to solution of this problem is being found, so great progress can be expected in the future.

The automatic steel pipe inspection/acceptance system presented here is included in the latter case. Since, in performing the repairs/inspection/acceptance of temporary steel pipes, the work (steel pipe) can be moved, so the system itself can be fixed. For this is the reason various technologies previously developed by other industries could be utilized. The system provided at the Equipment Center was originally intended for reducing labor in performing the collection, inspection and acceptance of steel pipes not only at the Equipment Center, but also at jobsites. Incorporating the system automatic device in the flow mechanism can rationalize overall operations. In the development, it was important in the initial study of basic concept to design a system which will give effectiveness to overall flow mechanism.

In the construction industry where shortage of workmen and aging are becoming a serious problem, the development of robots is becoming more necessary in the construction industry. Under such situation, we will make great efforts to attain a more effective system flow by grasping requirements accurately, designing an overall system and locating various automatic devices at critical points and interlinking them.