20. Security Measures Against Terrorism and Seismic Reinforcement Measures of Existing Buried Large-Diameter Pipeline in Tokyo

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1. Security Measures Against Terrorism

Water works facilities play an important role such as supplying tap water that is indispensable for lives of residents and for almost every phase of industrial and economic activities in Tokyo. Therefore, when water supply is suspended by terrorism, significant influences would be caused for the society.

Each main purification plant in Tokyo cover 2 or 3 million customers. However sedimentation basins and filtration basins are open-air, therefore security measures for the purification plants are very important.

The occurrence of the 1995 sarin gas attack on the subway system and the September Eleventh Terrorist Attacks in USA last year enhanced security of Tokyo Metropolitan Waterworks (TMW) such as measures to prevent trespass to the purification plants etc.

It is expected as terrorist attacks that waterworks facilities are destroyed and the toxic substances are thrown into filtration basins etc. When a waterworks facility such as a purification plant and a water supplying station is destroyed, supply lines will be changed immediately and other facilities will support it. Prevention measures against trespass and installation of water quality detectors have been implemented against the attacks with toxic substances.

This paper reports sensors into purification plants, detectors with fish for toxic substances in raw water or treated water, and covering the filtration basins. The sensors for detecting trespass were recently installed in the purification plants of TMW. Further more an experiment on automatic-type detectors with fishes is proceeding for installing in next fiscal year. Covering the filtration basins are on planning. These are the works in response to the recent terrorist attacks.

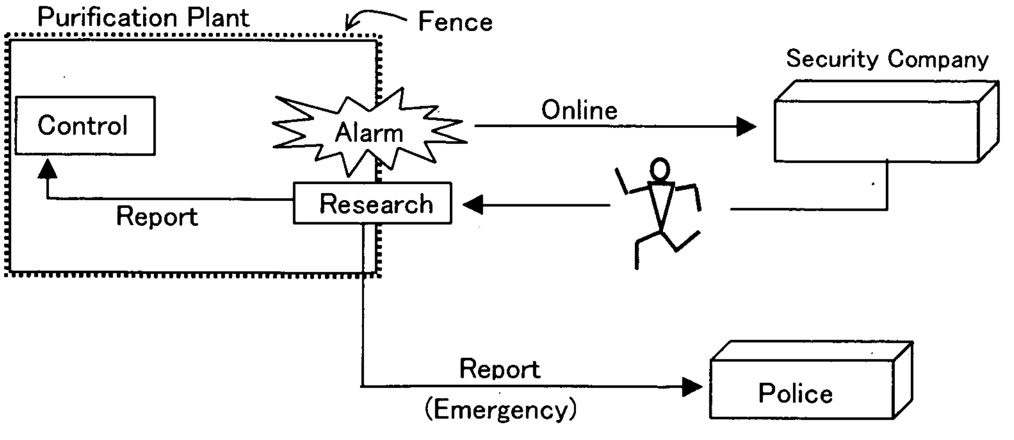
(1) Sensor for Detecting Trespass

Effectiveness of the measure with observation by human against the trespass is limited, because a purification plant occupies large area. Therefore sensors for detecting trespass were installed on the top of outskirts fences and the entrances of the purification plants of TMW, in addition to surveillance TV. The sensors were connected to the security company through online system, to cope with trespass immediately. (Figure- 1)

The preventive sensors for detecting trespass have been installed at the nine out of the ten purification plants of TMW. It was planned to install sensors in the rest of purification plants in this fiscal year.

There are two types of sensor, one is a infrared rays-type and the other is a trap-type.

Figure-1 Sensor System against Trespass

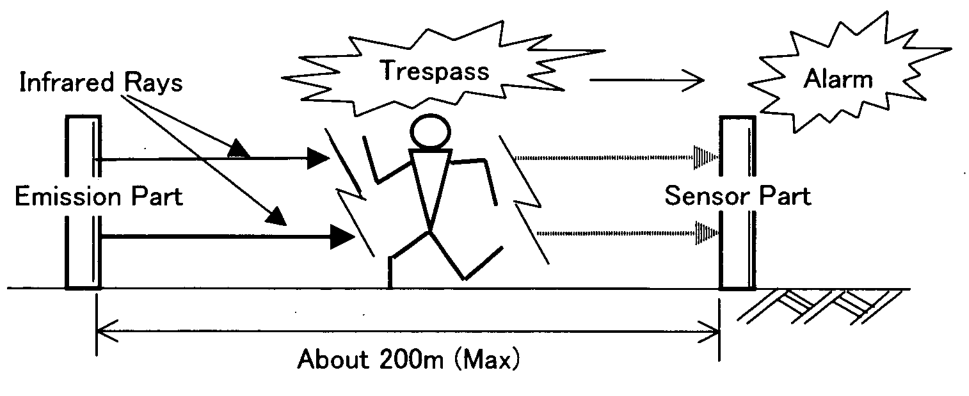


① Infrared Rays-type Sensor (Figure- 2)

A infrared rays-type sensor catches the trespass when the rays are cut. The sensors were installed on the top of outskirts fences to detect the trespass.

The sensor sends two or more rays and give a warning in the case of cutting plural rays at the same time to prevent miss judgement from a little living thing passing. The sensor can cover the distance of about 200 m. Since infrared rays are not obstacle to passing, this style can be installed at entrances.

Figure-2 Infrared Rays -type Sensor

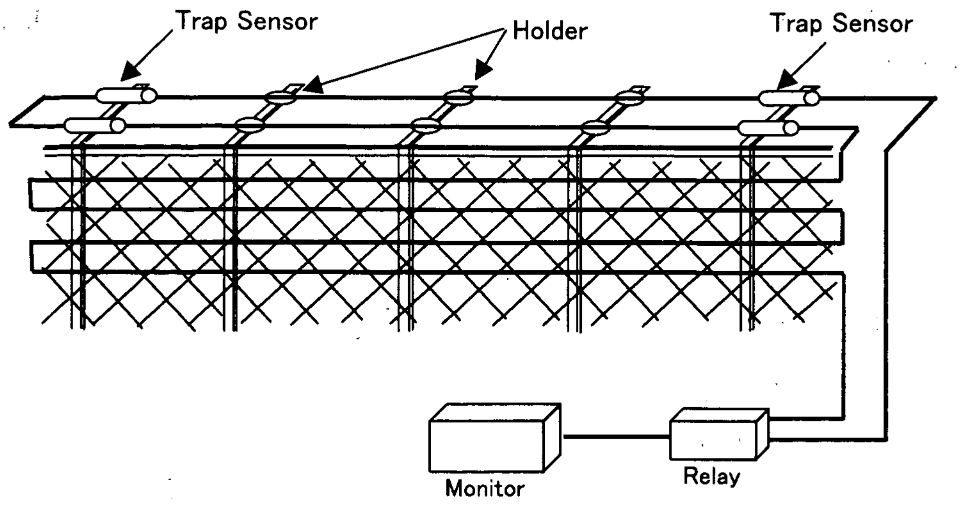


※ Sensor sounds alarm in a case of cutting two rays.

② Trap-type Sensor (Figure-3)

When someone touches the warning wire installed on the top of the outskirts fence to trespass, the sensor catches the stress caused by the contact and gives a warning. By stringing the warning wire in the net fence, the sensor also can respond to cutting the net of the fence.

Figure-3 Trap-type Sensor



③ Added Measures

It enhances the effect of preventing the trespass by giving threat and discovering quickly to install the surveillance TV and the alarm.

(2) Detector for Toxic Substances with Fish

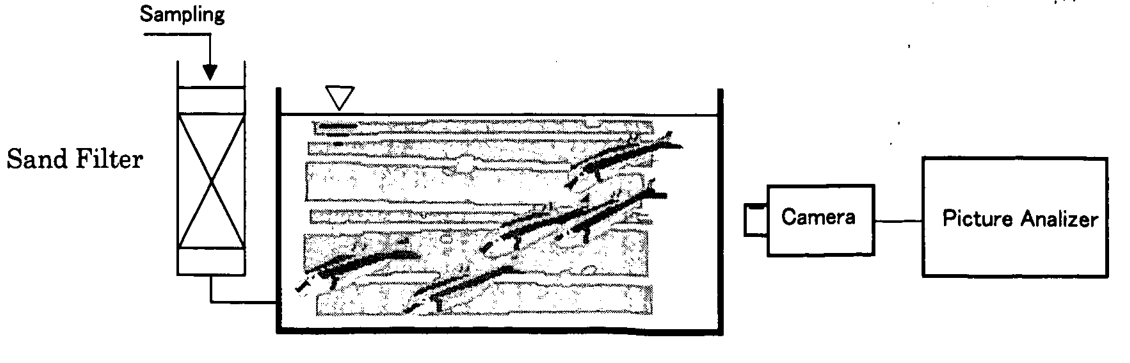
This detector catches the change of the water quality by analyses of fish behavior. Fish is sensitive to the water quality change, therefore this sensor can catch early unusual water qualities and various toxic substances quickly.

There are two types of detector. The one is observation by human and the other is by automatic observation. Automatic observation is consisted of the electric potential type and the picture analysis type.

① Picture Analysis Detector (Figure-4)

The picture analysis detector is composed of a surveillance TV and a picture analysis instrument. It observes fish behavior and catches the change of the behavior and catches the change of the behavior in response to harmful substances.

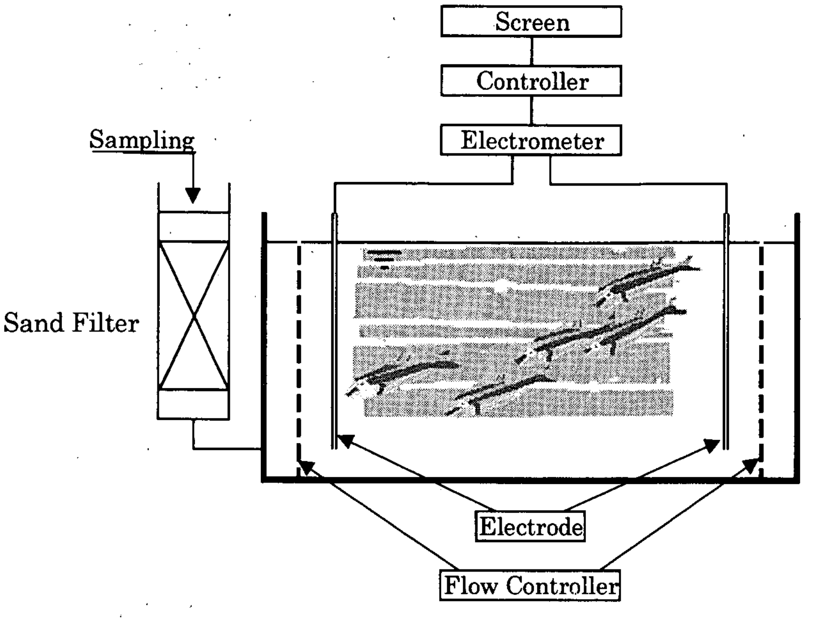
Figure-4 Picture Analysis Detector



② Electric Potential Detector (Figure-5)

The electric potential detector catches unusualness of water quality by analyzing electric potential change caused by unusual behavior of the fish in response to harmful substances mixed into the water in the tank.

Figure-5 Electric Potential Detector



(3) Covering Filtration Basin

The filtration basins of TMW are not safe from the attacks with toxic substances for the open-air structure. Covering filtration basins is effective for the security and for the restraint on algae occurrence. Furthermore it will improve the environment around the purification plant, decreasing the noise of washing filter sand. It will also be possible to use the area for the sunlight generation.

There are two covering procedures, housing-type and movable arch cover-type.

TMW is planning to carry out covering filtration basins as soon as possible, because filtration is the final treatment process. It will be decided being based on the necessity whether sedimentation basins to be covered after completion of covering filtration basins, since there is enough time to take a means such as stopping the works of plants, in an emergency.

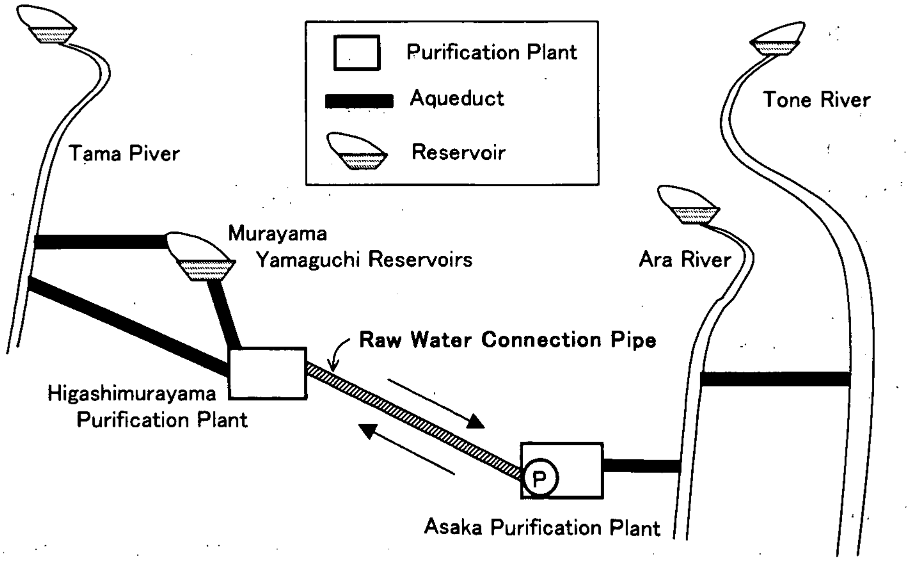
2. Seismic Reinforcement Measures of Existing Buried Large-Diameter Pipeline

The Central Disaster Prevention Conference has issued a warning that there is an urgent threat that a large earthquake may occur just below Tokyo. When a large earthquake occurrence causes suspension of water supply for a long time, citizens' lives will suffer immeasurable damage. Therefore, it is a major issue for Tokyo Waterworks to improve facility's weak points against the earthquake expected and to restore the waterworks function speedily after the earthquake occurrence.
Tokyo Metropolitan Government is proceeding with upgrading important facilities to mitigate the damages from the potential earthquake one after another. This paper reports a seismic diagnosis and a reinforcement measure of an existing buried large-diameter pipeline (ϕ2200mm) according to the result of the diagnosis.

(1) Outline of Objective Pipe

The objective of the seismic investigation is a Raw Water Connection Pipeline (RWCP) that connects Asaka Purification Plant with Higashimurayama Purification Plant. Asaka Purification Plant intakes raw water from Tone River and Higashimurayama Purification Plant intakes from Tama River, respectively. (Figure-1) The system composed of RWCP, the two purification plants and two rivers makes it possible to intake according to flow volumes of two rivers to promote water storage in reservoirs efficiently and to make up a lack of raw water of another purification plant in a drought or a raw water accident.
The diameter and the length of RWCP are 2200 mm and 16.8 km respectively. RWCP is composed of 8.9km length of steel pipeline (SP) and 7.9km length of ductile cast iron pipeline (DCIP). (Table -1)
SP has Telescope-type expansion joints and DCIP has K-type joints. (Figure-2)

Figure-1 Raw Water Connection Pipe



(2) Inner-Surface Investigation

An inner surface investigation of RWCP was carried out while the pipeline was suspended.

Table - 1 Outline of Raw Water Connection Pipe

Diameter	2200 mm
Length	16.8km
Kind of Pipe	DCIP : 7.9km SP : 8.9km
Type of Joint	K-type Joint(DCIP) Telescope-type Expansion Joint (SP)
Year Completed	1964

DCIP : Ductile Cast Iron Pipe

SP : Steel Pipe

① Investigation of Corrosion and Coating

Measurement of corrosion depth with depth-gauge, pipe-body thickness with supersonic wave-type measuring instrument and coating depth with electromagnetic-type measuring instrument, were implemented at the inner surface of pipe fittings of DCIP without mortar lining parts and at the weld parts of SP, that got rusty.

② Investigation of Mortar-Lining (DCIP)

Mortar-Lining chips were sampled and a solution of phenolphthalein was applied on the chips to measure neutrality depth. Exfoliation and crack on the mortar-lining surface were searched by human eyes.

③ Measurement of Pipeline Level

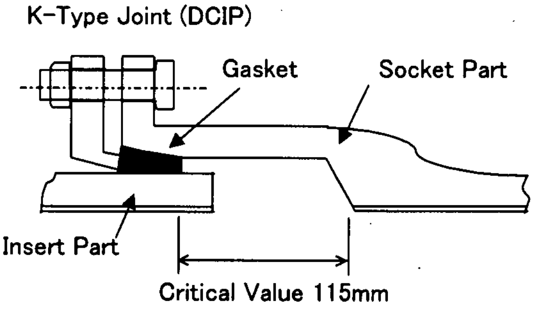
Level measurements were carried out to inspect subsidence of the pipeline.

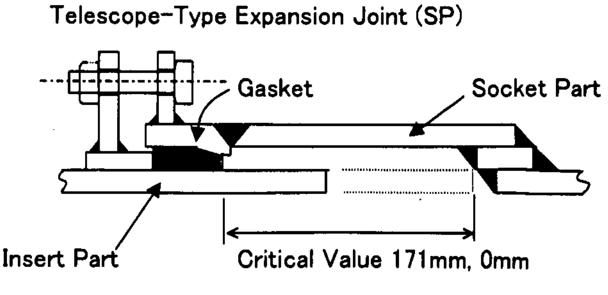
④ Investigation of Joints Clearances

Clearances of joints at four points (up and down, right and left) in cross sections of the pipeline were measured. An critical value of the K-type joint was defined as the length between the gasket surface and the bottom of the socket .

Two critical values of the Telescope-type expansion joint were defined as the length between the gasket surface and the bottom of the socket and as zero that represents no clearance. (Figure-2)

Figure-2 Detail of Joint





(3) Seismic Diagnosis

Stress and strain of the pipe body and the joint clearances in the case of earthquake motion of Level 1 and Level 2 were estimated with the response displacement method according to the Seismic Design Code for Water Facilities by JWWA. Level 1 represents an earthquake level to occur once or twice during the facility's life. Level 2 represents a level which occurs with a very low probability but causes considerable damage.

The result of the boring research indicated that the depth of the base layer under the steel pipeline varied significantly. Therefore the steel pipeline was divided into five blocks in the seismic analysis. (Figure-3)

The estimated axial displacements of the joints with the seismic analysis were added to existing clearances of the joints. The composite clearances of the joints were compared with the critical values. The joint displacement caused by bending was also considered in the seismic analysis, because of the large diameter of the RWCP.

The ground was composed of several layers such as buck-fill soil, loam, clay, sandy soil, sand with gravel etc. The layer of sand with gravel was defined as the base layer in the seismic analysis. (Table-2)

Figure - 3 Depth of Base Layer in Each Block

	Ductile Cast Iron Pipe ← 8 km	Steel Pipe → 9 km				
No. of Block	①	②	③	④	⑤	⑥
N-Value	50	50	50	50	50	50
Depth of Base Layer	8.9m	9m	17m	10m	34m	34m

Table - 2 Ground Condition

Kind of Soil	N-Value	Thickness of Layer
Back-Fill Soil	3~5	0.9~3.8m
Loam	2~6	3.0~5.65m
Clay	1~8	1.75~3.55m
Sandy Soil	12	1.10m
Sand with Gravel	18~≧50	4.25~13.25m
Clay	5~18	0.85~3.95m
Sand with Gravel	32~≧50	7.45~14.05m
Sand	17~43	0.50~1.90m
※ ***Sand with Gravel***	***≧50***	***0.52~0.78***
Clay	≧50	3.30

※ : Base Layer

(4) Result of Investigation

① Corrosion on the ductile iron and the steel pipe proceeded slightly. The surface condition of mortal lining and coating was almost well.

② Whole of the pipeline subsided. Some clearances and bending angles which exceeded critical value were found at some existing joints.

③ The result of seismic analysis as follows.
Clearances of three joints of SP and one joint of DCIP exceeded the critical value in the case of Level 1, and clearances of twenty four joints of SP and three joints of DCIP exceeded in the case of Level 2.
(Table-3)
Stress caused in the DCIP body and strain caused in the SP body were less than the critical value.

Table - 3 Number of Joints Whose Clearances Exceeded Critical Value

	Level 1	Level 2	Number of Joints
DCIP	1	3	1977
SP	3	24	35
Total	4	27	2012

DCIP : Ductile Cast Iron Pipe
SP : Steel Pipe

(5) Seismic Reinforcement Measures

Four joints whose clearances caused by Level 1 motion were over the critical value, were reinforced seismically. When alternatives of reinforcement were adopted, it was considered that the suspension term of RWCP should be as short as possible.

① Reinforcement Measure of DCIP

The joint which needed to be reinforced, connected a steel pipeline passing under a rail road with a ductile cast iron pipeline.
The socket part of the joint was the ductile cast iron pipe and the insert part was the steel pipe. The purpose of the reinforcement measure was to make insert pipe length longer by welding a steel pipe to the edge of the existing insert steel pipe.
Before welding, the new steel inner-pipe was divided into three parts in the cross section and eleven parts in the axial section as shown in the Figure-4.
The each piece was carried into the existing DCIP through a manhole and to the objective joint in the pipeline. The pieces were assembled and welded there. A special instrument was used to assemble the pieces before welding.
The space between the existing pipes and the new steel inner-pipe was filled up with air mortar. A rubber gasket was installed between existing pipes and the edge of the new inner pipe to prevent leakage. The inner surface of the new pipe was coated with liquid epoxy resin.

② Reinforcement measure of SP

Telescope-type expansion joints of SP which needed reinforcement measures, were cut off, and steel bands were welded to the outer surface of the existing pipe to change the objective parts into continuous body.
Before welding, the new steel band was divided into three parts in the cross section.
The each piece was carried into the maintenance room through a manhole and welded

to the existing pipe as shown in the Figure-5.

Figure-4 Measure for Reinforcement (K-type Joint)

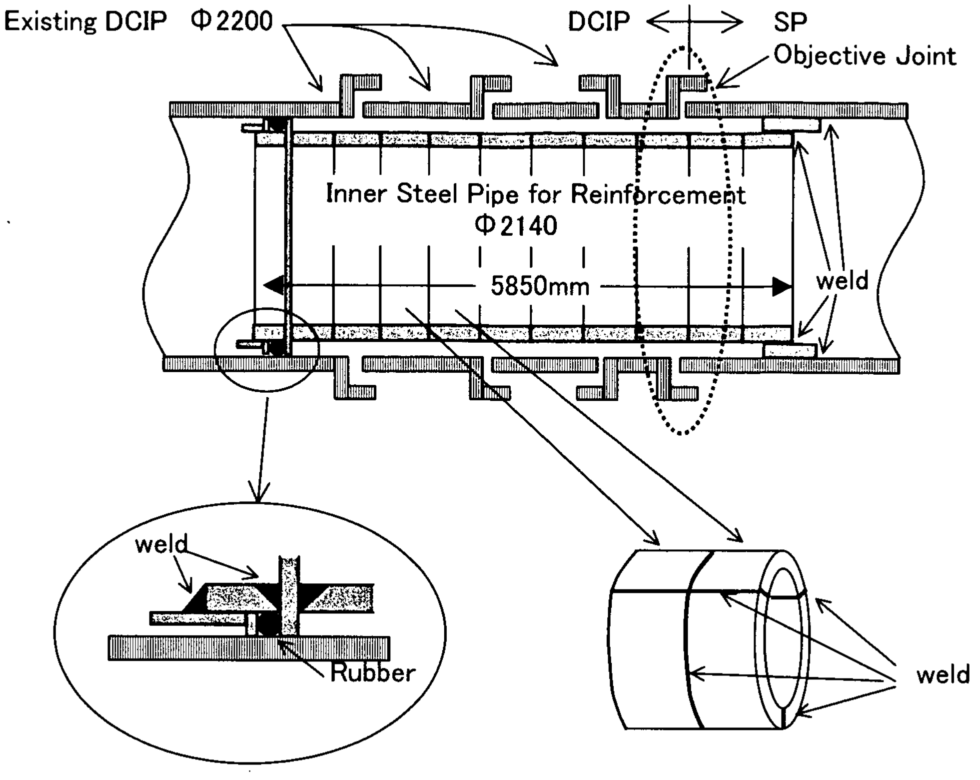
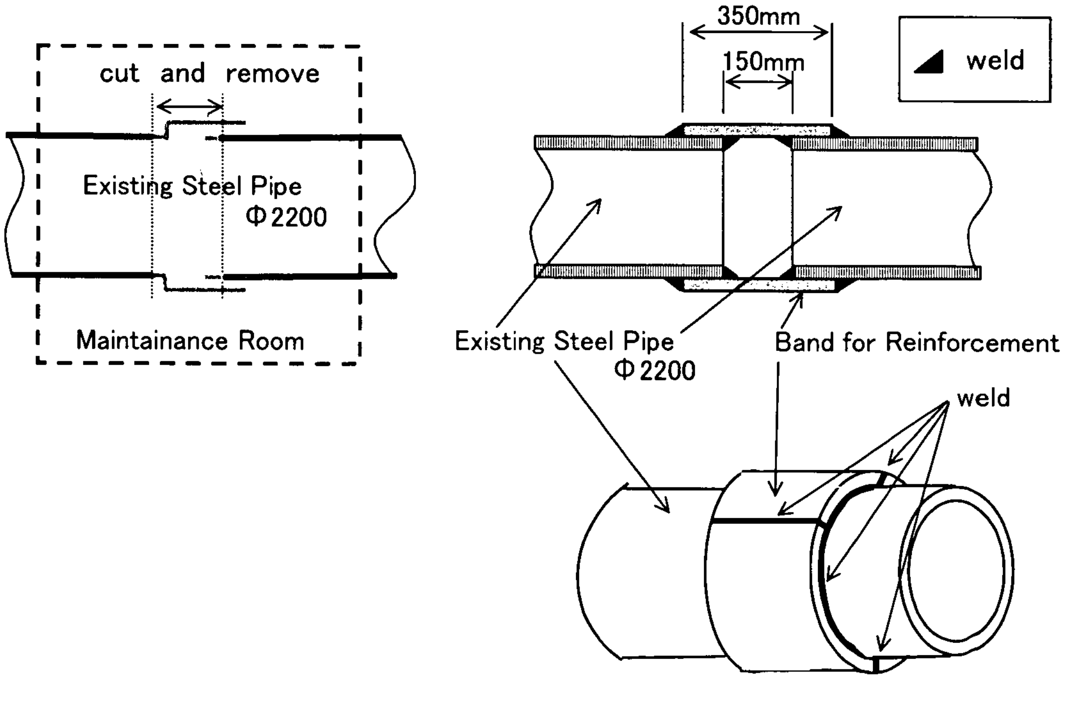


Figure-5 Measure for Reinforcement (Telescope-type Expansion Joint)



(6) Future Issue

① Seismic alternatives for the joins whose clearances caused by Level 2 motion exceeded the critical value, should be considered separately. Because the measures presented in this report needs long term of RWCP's suspension for the many objective joints.

② It should be considered how to reinforcement the large diameter transmission and distribution pipelines which can not be suspended.