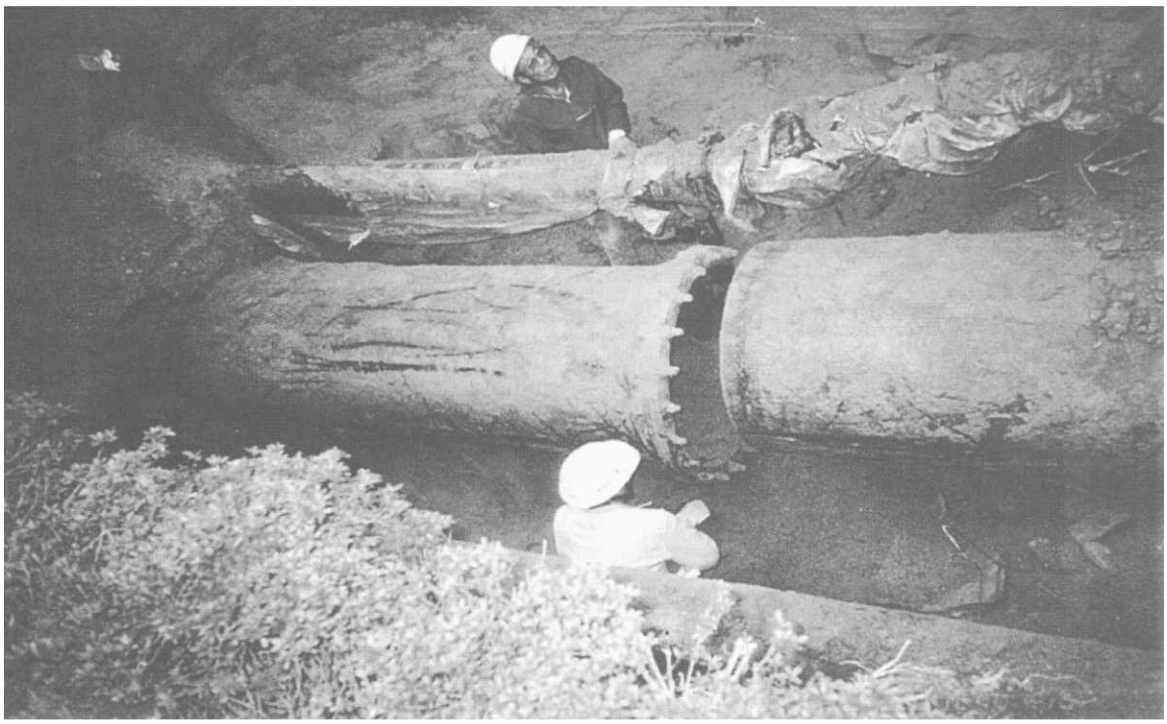
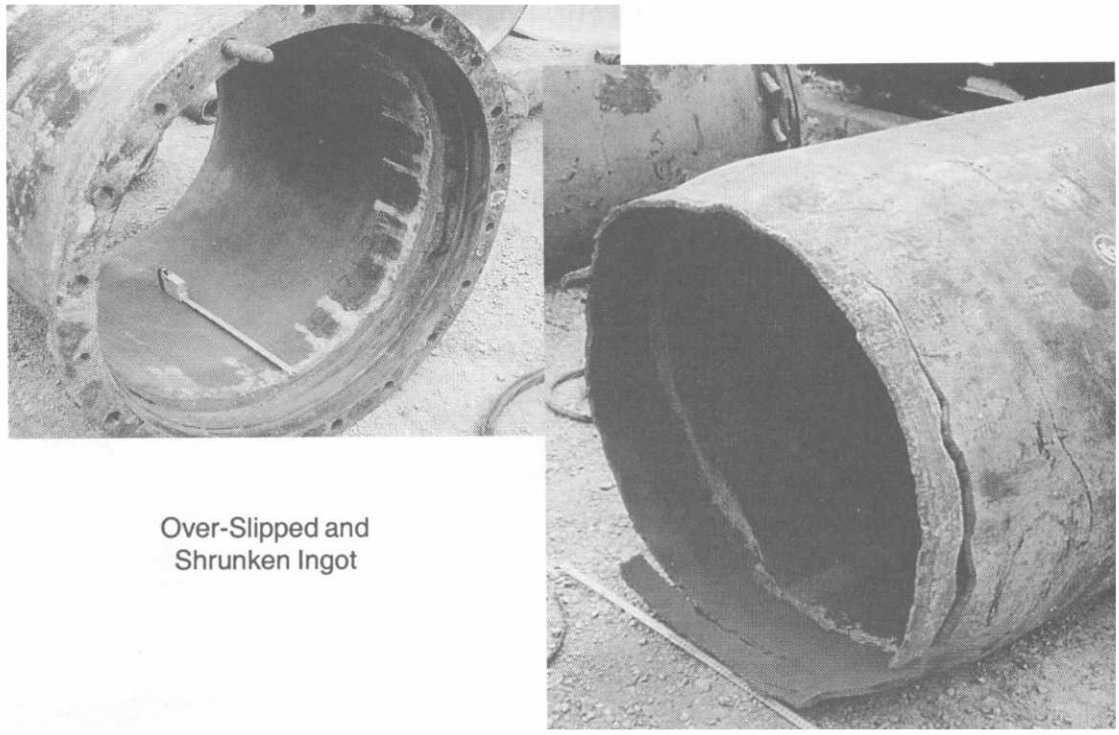
Damaged Rubber Gasket (ϕ800mm)

Pulling out of Mechanical Joints

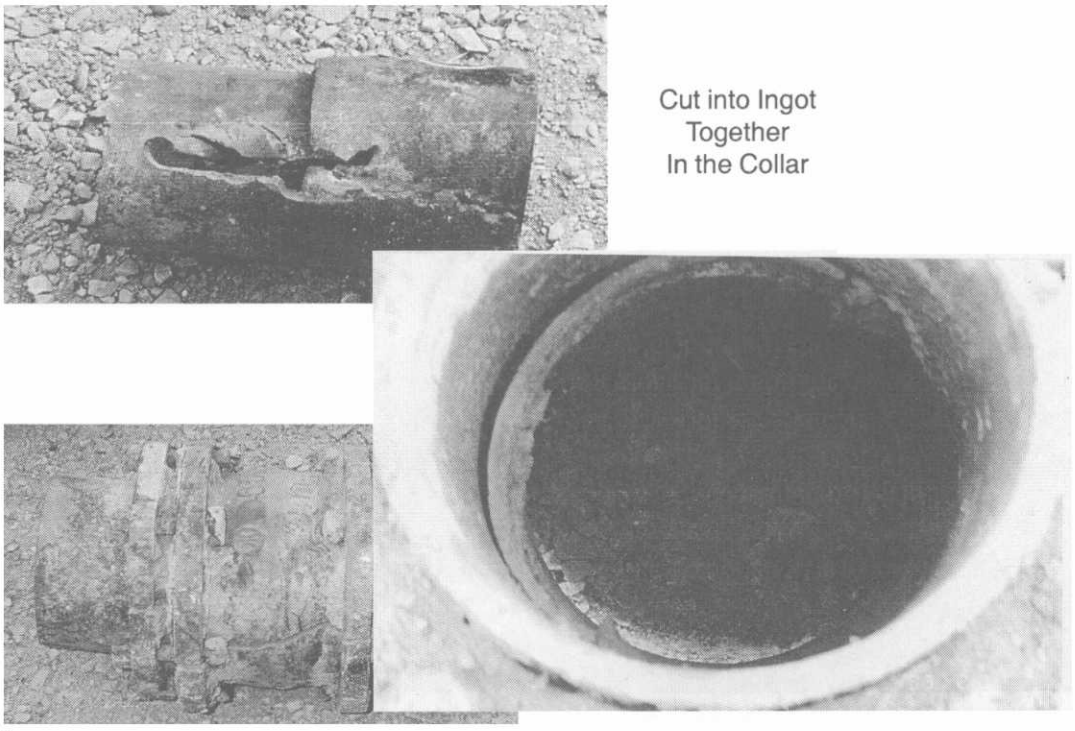


- This photograph shows an example of the pulling-out damages in the mechanical joint.
- The pipe's diameter is 800-mm and made of the ductile cast iron.



Over-Slipped and
Shrunken Ingot

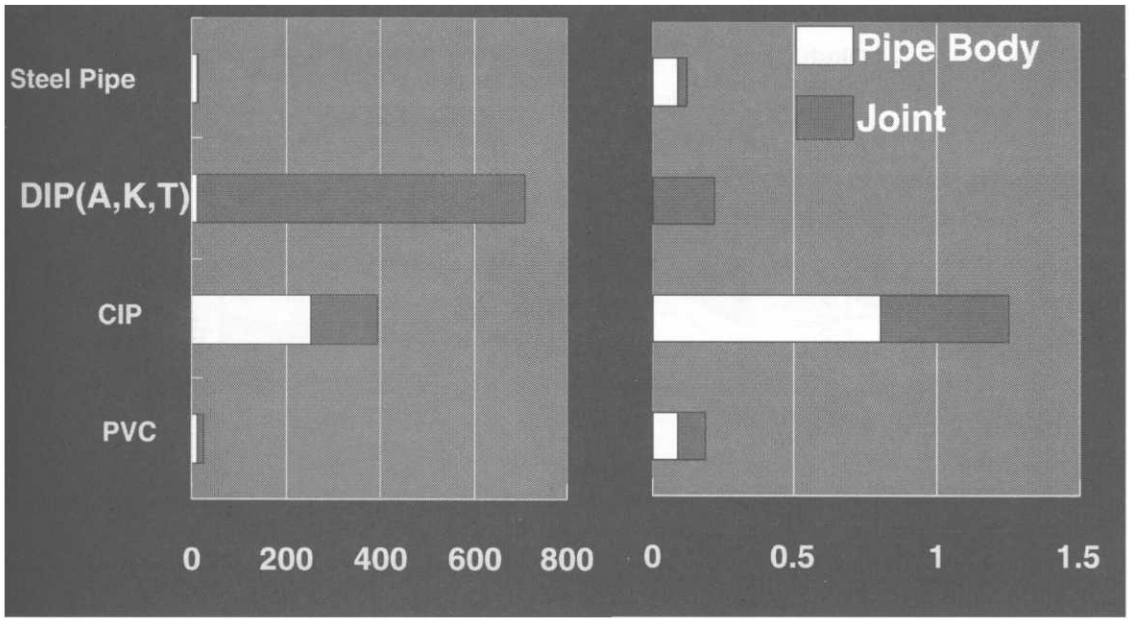
- This photographs shows that the ingot part of pipe was over-inserted through the socket and the diameter of it was shrunken.
- The flaw put to the socket in the earthquake is clearly left, and as for the pipe on the ingot side, a crack was stored in the radial direction.
- This damage tells us how big the earthquake energy is.



Cut into Ingot
Together
In the Collar

- The ingots of the pipe body to be connected with the collar ring are biting each other.
- It was damaged in this way, because pipe centerlines were each other shifted.

Damages Number and Rate(cases/km)



- During the earthquake, water supply distribution pipes were severely damaged, in as many as 1757 cases of damages, and 15 damages occurred due to aqueduct bridge falure.
- We suspected that cast iron pipes would suffer damages from the earthquake; therefore, we have been replacing the cast iron pipes with ductile cast iron pipes.
- Beyond our expectation, there were so many damages caused by pulling out of mechanical joint in the ductile cast iron pipes.
- The damages of pulling out joints in ductile cast iron pipe counted up to 700 cases. These damages were the most common ones.
- As for the damage rate, the rate of cast iron pipes was up to 1.25 cases per km(394cases/ 316km)

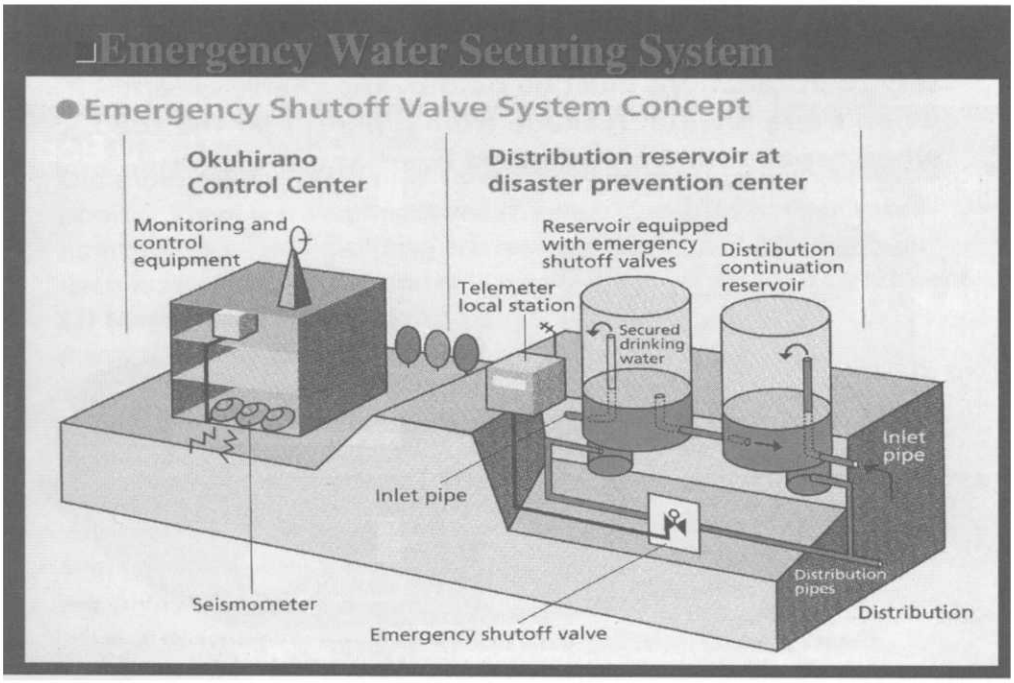
1.5 Anti-Seismic Design of Water System

1. For anti-seismic design of water supply systems, these are prerequisites:
   a) Earthquake damage should be located as much as possible at specific places.
   b) The damage should be easily repaired.
   c) Measures to prevent secondary disasters as result of an earthquake must be provided.

2. To meet these conditions the following aspects should be considered:
   - redundancy in important facilities, looping and interconnection pipeline systems,
   - separation of a pipe network into blocks,
   - installation of emergency cut-off valves must be implemented.

3. It's neither technically or economically possible nor rational to build an absolutely earthquake proof facility.

4. It's more important to up-grade the entire system without depending on individual facilities.



1. It began to arrange an emergency shutoff valve at the distribution reservoir pond from 1986 as the earthquake countermeasure.
2. Before the Kobe earthquake, the shutoff valves have been installed at the 21 distribution stations. The 18 valves of them operated and a volume of water of 42,000 m3 could be secured the Earthquake occurred.
3. Immediately after an earthquake, the Water Application Control Center will automatically send out instructions to close the shutoff valves of distribution reservoirs, and to store the minimum required quantity of drinking water (3L per capita/day×7days). From the reservoirs, serving as water supply stations, water is provided to residents by wagons.
4. Shutoff valves are installed on either of paired distribution reservoirs. The water continues to be distributed from reservoirs without shutoff valves, for such purposes as firefighting.
5. With the water supply system to adopt gravity flow like Kobe and also to have a lot of distribution reservoirs. This method is effective but there is not so effective in the water supply system by the pump up.

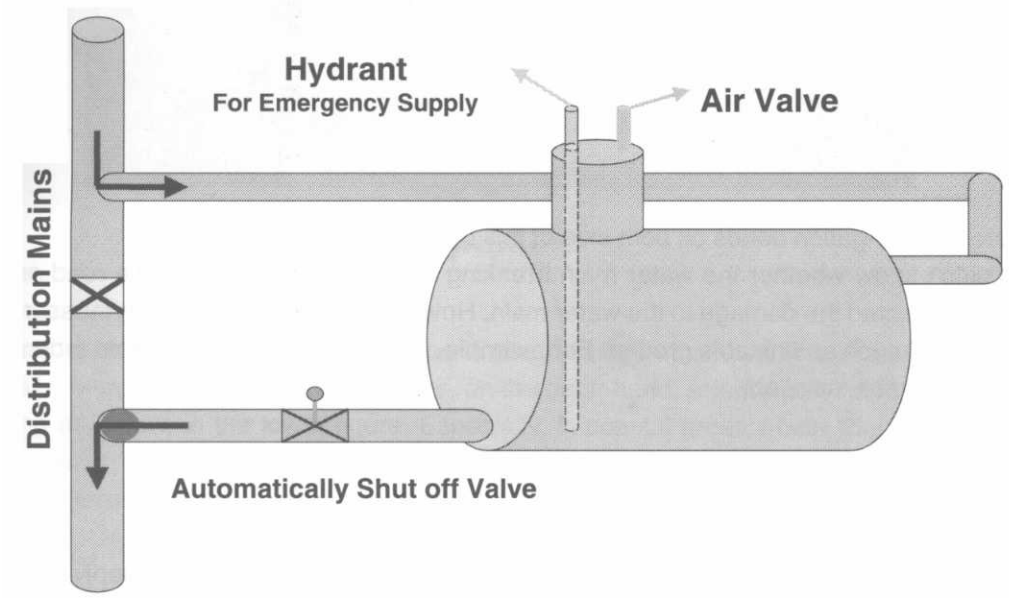
Operation Condition of the System

Seismic Acceleration	Operation of Emergency Shutoff Valve System
over than 250 gal, or 250 gal	Automatically Close all Valves of installed reservoirs
Less than 250 gal over than 80 gal, or 80 gal	Automatically closed valves of reservoirs in flowing out abnormally
Less than 80 gal	Non-operation

- This table shows the operation state of the emergency shutoff valve system during the earthquake.
- If seismometer measures the seismic acceleration over than 250 gal or 250 gal the shutoff valve would automatically closed unconditionally.

When the Kobe earthquake occurred, 17 shutoff valves of a total of 21valves installed closed and 42,000 cubic meters were secured as emergency supplying water after that.

Water Tank connecting directly for securing Emergency Water



- Additionally, a distribution reservoir is equipped with the emergency shut-off valve, this measures will be effective, especially for pump up system.
- The water supply systems with pumps doesn't need so many distribution tanks, so, depending on the emergency, shut-off valve system wouldn't be enough to secure the quantity of emergency water. Therefore, this measures of water tank connecting with the distribution pipe become to be necessary.
- In Japan, this countermeasure is most popular, since almost all the systems in other cities have not so many distribution tanks as in Kobe.

Attention Points of Pipeline Network

- In order to minimize the earthquake damages, adequately space-division valves in the pipeline network are necessary.

- Minimizing the range of water delivery failure by adequately spacing division valves in the pipeline network, making the distance between them as short as possible.