4.0 CONFIRMATORY TESTING PROGRAM FOR THE ACC

The design requirements and specifications of the ACC for the US-APWR that were discussed in Sections 2 and 3 are the same as that for the APWR. The core power and the size of the reactor vessel are the main parameters used to determine the design requirements and the specifications of the ACC which are common to both the APWR and the US-APWR. Therefore, the ACC confirmatory test program previously performed for the APWR is applicable to the US-APWR. This test program was conducted as a joint study among five utilities[Note] and MHI, from September 1994 to September 1996.

Note: Japan Atomic Power Co., Hokkaido Electric Power Co., Kansai Electric Power Co., Shikoku Electric Power Co., and Kyushu Electric Power Company.

This section of the Topical Report; (1) describes the purposes and objectives of the confirmatory test program; (2) provides a detailed description of the tests and the test results; (3) provides demonstration of the validity and scalability of the test results for the design of the US-APWR; and (4) sets, the quality assurance requirements to re-verify and confirm that the results of the test program are reliable and accurate for use in the design of the US-APWR.

4.1 Purpose of the ACC Scale Testing

Confirmatory tests were conducted to determine whether the expected performance from the operational principles of the ACC could actually be achieved. The following items were tested to verify the principles and characteristics of the flow damper:

(1) Confirmation of the principles of the flow damper:

Tests were conducted to observe the behavior of the flow in the vortex chamber of the flow damper during large flow injection, large/small flow switching, and small flow injection to confirm that their actual behavior was as expected.

(2) Confirmation of the anti-vortex function at the end of large flow injection:

As water level in the accumulator decreases after initiation of accumulator injection, it may be possible to form a vortex at the entrance to the standpipe and the nitrogen gas in the ACC gas space can be sucked into the standpipe when the water level is low. Therefore, an anti-vortex cap was designed for the large flow inlet. The tests were conducted to confirm that the anti-vortex cap prevented the vortex from forming at the standpipe inlet and that gas was not sucked into the standpipe.

(3) Confirmation of the standpipe water level transient during flow switching:

During flow switching from large flow to small flow, the standpipe water level is temporarily decreased by inertial force, and then recovers due to the differential pressure of the water level between the tank and the standpipe. When the standpipe water level decreases to the top of the flow damper, gas can be entrained in the flow damper and injected to the RCS.

However, the ACC was designed so that gas entrainment will be precluded.

A test was conducted to confirm that gas was not entrained into the flow damper by measuring the water level transient during the flow switching.

(4) Confirmation of performance during large flow:

A test was conducted to confirm that the performance of the flow damper during large flow met the design requirement (i.e. resistance coefficient for large flow injection)

(5) Confirmation of performance during small flow:

A test was conducted to confirm that the performance of the flow damper during small flow met the design requirement (i.e. flow switching ratio).

(6) Confirmation of flow switching water level:

It is assumed that the injection flow rate shifts from large flow to small flow when the tank water level decreases to the lower edge of the standpipe anti-vortex cap. However, in the actual tank, the flow switching level may have some variations. Therefore, the actual switching level was confirmed through testing.

(7) Confirmation of the effect of dissolved nitrogen gas:

Since the accumulator is compressed by nitrogen gas, nitrogen gas may dissolve in the water. If the water in the accumulator contains dissolved nitrogen gas, it is assumed that the gas comes out of solution and affects the flow characteristics of the flow damper. Therefore, a test was conducted with nitrogen-rich water to confirm that the effect of nitrogen gas did not significantly impact the ACC performance.

(8) Confirmation that the ACC flow characteristics are represented by dimensionless numbers (cavitation factor and flow rate coefficient):

The throat portion of the ACC is located at the outlet of the vortex chamber in order to form a strong vortex in the vortex chamber during small flow. Therefore, it is assumed that cavitation could occur and affect the flow characteristics during large flow. The cavitation phenomenon can be evaluated by utilizing a cavitation factor. The tests were conducted to confirm that the flow characteristics obtained through the tests were a function of the cavitation factor for large flow and independent of cavitation factor for small flow.

The cavitation factor, σ_v , is defined by the following equations.

$$\sigma_v = \frac{P_D + P_{at} - P_v}{\Delta P} \qquad (4\text{-}1)$$

where
P_{at} : Atmospheric pressure
P_D : Outlet pressure of flow damper [gage]
P_v : Vapor pressure of the water
ΔP : Total pressure drop of flow damper

With regard to flow rate coefficient, the definition is described in Section 4.2.3.

(9) Confirmation that flow characteristics (cavitation factor and flow rate coefficient) are not significantly impacted by scaling:

To confirm the validity of applying the similarity law to evaluate the actual flow damper by using the scale model test results of the flow damper and to acquire the required data.

These test items are summarized in Fig.4.1-1.

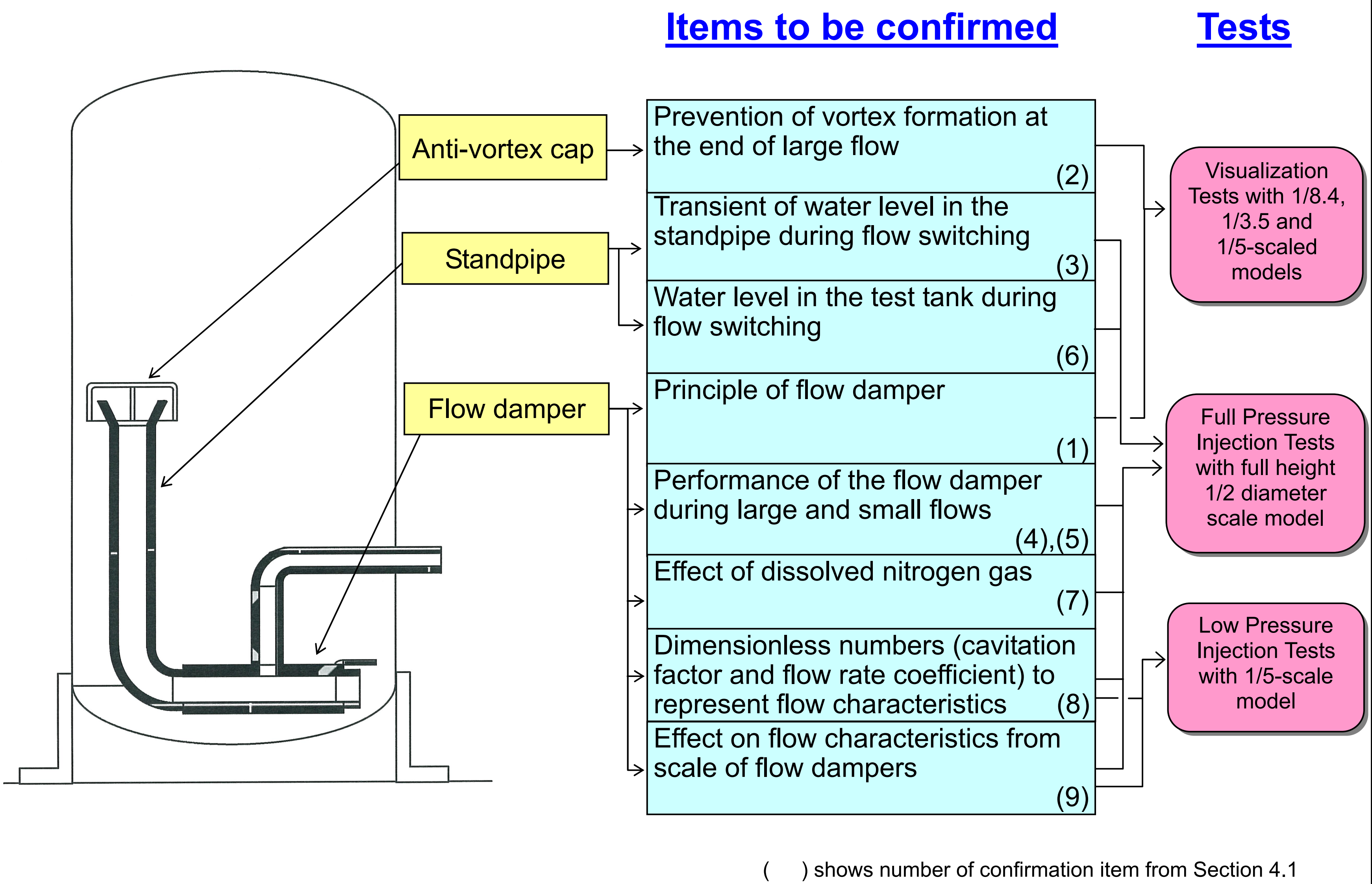


Fig. 4.1-1 Confirmation Items by Test

4.2 Detailed Description of the Test and Results

4.2.1 1/8.4 Scale Test

1) Objectives

A 1/8.4 scale flow visualization experiment was designed to examine the basis of operation of the ACC and to understand the injection flow characteristics. Items to be confirmed by this test are as follows:

- **Confirmation of operating principles of the flow damper**

  Visualize the behavior of flow in the flow damper and the standpipe during large flow injection, large/small flow switching, and small flow injection. Confirm the behavior and stability of the flow in the vortex chamber and flow switching. From this test, it was confirmed that: (1) a vortex was not formed in the vortex chamber during large flow, (2) a vortex was formed and flow rate decreased during small flow, and (3) injection flow rate was sharply switched from large to small flow.

- **Confirmation of behavior of the water level in the standpipe at flow-switching**

  Visualize the behavior of the water level in the standpipe at flow-switching and confirm the behavior of the flow.

2) Test Apparatus

The visualization test of the operating principles of the flow damper was conducted using the test apparatus shown in Fig. 4.2.1-1 and Photo. 4.2.1-1. The test apparatus consisted of an ACC model, exhaust tank, and injection pipe. The scale of the flow damper was 1/8.4 and the vortex chamber is upright. One side of the vortex chamber and the standpipe was integrated into the front of the ACC model which was made of transparent acrylate so that the flow behavior inside of the ACC, the standpipe and the flow damper could be observed. The shape of each part of the apparatus was simplified while ensuring that the operating principle of the flow damper was not affected.

Fig. 4.2.1-1 1/8.4 Scale Test Apparatus

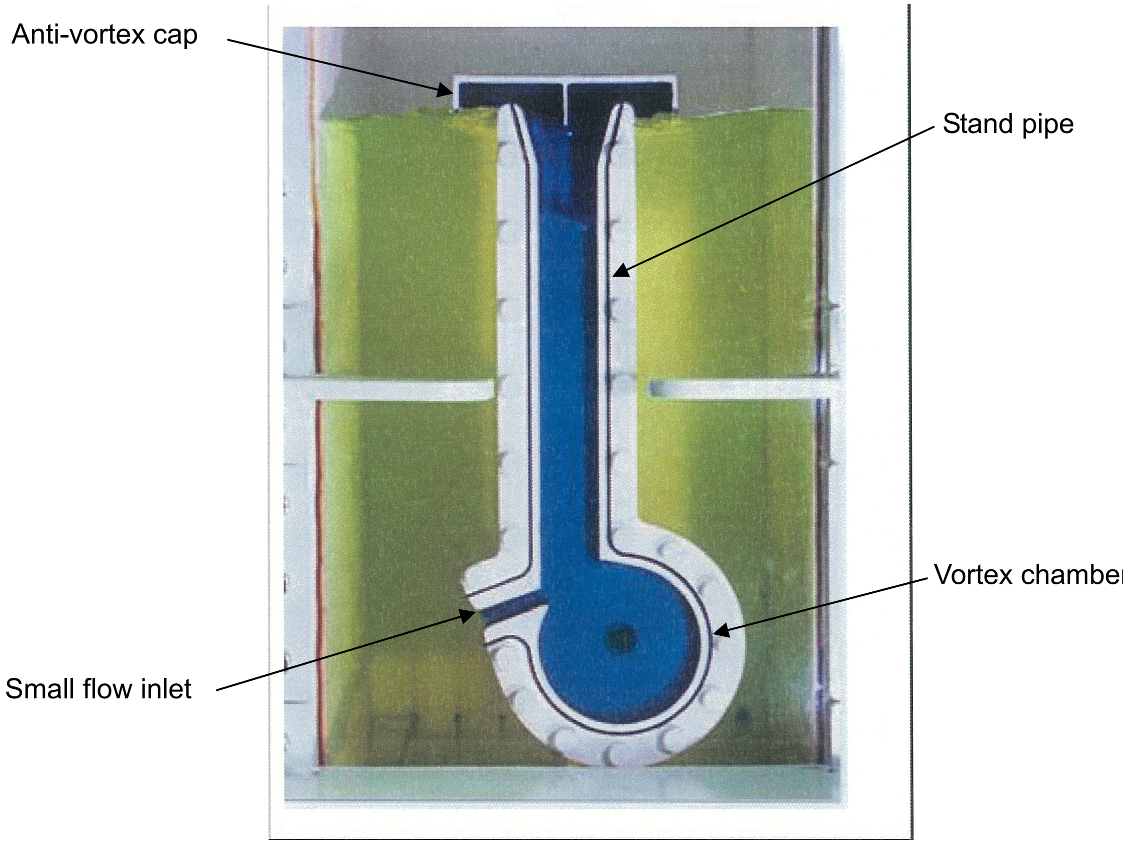


Photo. 4.2.1-1 1/8.4 Scale Test Apparatus

The major specifications of the test facility are as follows:

(1) ACC Model

Design Pressure	:	[ ]
Width	:	[ ]
Length	:	[ ]
Height	:	[ ]
Volume	:	[ ]

(2) Flow Damper and Standpipe

Dimensions : 1/8.4 of actual tank
(Flow damper inner diameter: [ ]) Simplified shape

(3) Injection Piping

Diameter : [ ]

(4) Exhaust Tank

Design Pressure : [ ]
Width : [ ]
Length : [ ]
Height : [ ]
Volume : [ ]

3) Test Conditions

The pressure of the gas space is [ ] (Max pressure of test facility)

4) Parameters to be Measured

The behavior of flow in the standpipe and the flow damper was observed. Also, flow-switching was observed on a CRT as shown in Fig. 4.2.1-1.

5) Measuring Equipment

The behavior of flow in the standpipe and the flow damper was confirmed by visual inspection. Flow switching was confirmed by visual tracking of flow rate using the flow meter as shown in Fig. 4.2.1-1.

6) Test Results and Considerations

The behavior of the flow and the flow transient in the standpipe and the vortex chamber during flow switching are shown in Photos. 4.2.1-2 to 4.2.1-7, respectively. The following items were confirmed from the test:

(1) The behavior of the flow in the vortex chamber during large flow conditions is shown in Photo. 4.2.1-3. It was confirmed that a vortex was not formed in the vortex chamber since the air, which was injected as a flow tracer, directly drifted from the point where the flow from the inlet of standpipe and the flow from small flow pipe collided to the outlet.

(2) By comparing the water level in the standpipe shortly after the flow switching (Photo. 4.2.1-5) and during the small flow condition (Photo. 4.2.1-6), it was found that the water level during small flow is higher than the water level during flow switching. This observation confirmed that the water level in the standpipe was temporarily reduced and then recovered.

(3) It was confirmed that the flow switched sharply from large to small flow in a short period of time as shown in Photo. 4.2.1-6.

(4) It was confirmed that following the initiation of small flow, the stable vortex was formed since the air that was injected as a flow tracer was swirling into the outlet as shown in Photo. 4.2.1-7.

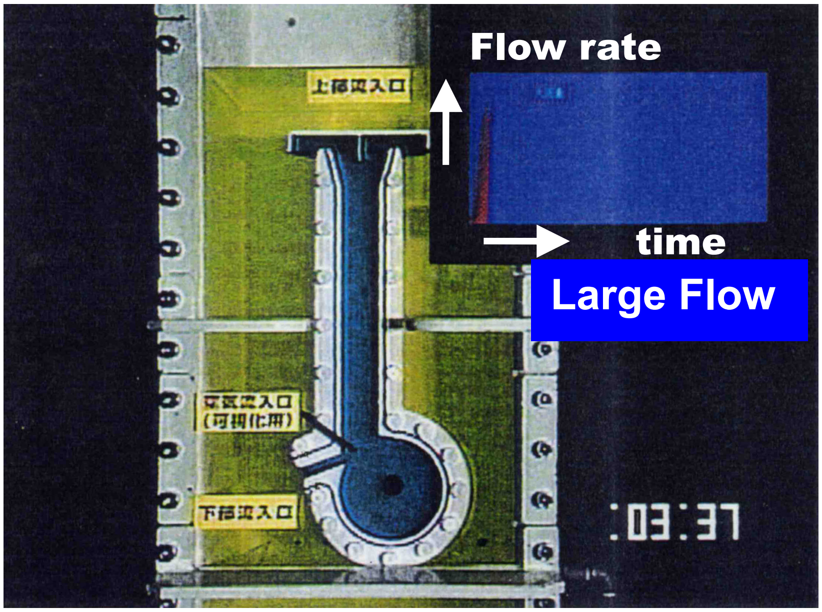
From the test results above, the basic principle of the flow damper was confirmed as follows:

(1) When the water level in the accumulator is above the upper end of the standpipe, the flow from the standpipe and the small flow inlet collide in the vortex chamber and flow directly to the outlet. A vortex is not formed in the vortex chamber. Therefore, the resistance is small and the large flow rate is available.

(2) When the water level in the tank is reduced below the upper end of the standpipe, the flow from the standpipe almost stops and only the flow from the small inlet flows into the vortex chamber. A strong vortex is formed. Therefore, the flow resistance is large and the injection flow rate becomes small. No cavitation was observed at the center of the vortex.

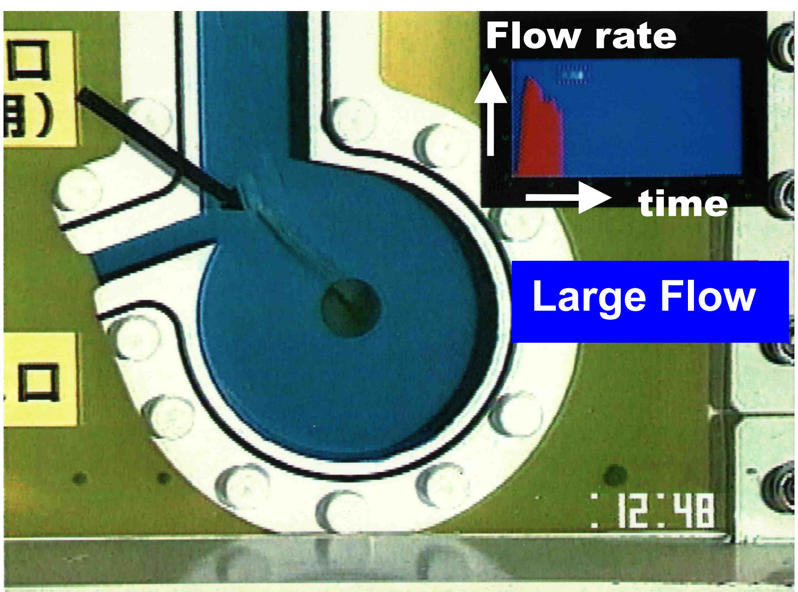
(3) When the water level is close to the flow switching level, it was confirmed that the anti-vortex cap on the standpipe prevents a vortex from being drawn into the standpipe. The lower end of the anti-vortex cap is almost at the same level as the upper end of the standpipe. If the water level in the tank is reduced below the lower end of the anti-vortex cap, the flow from the standpipe almost rapidly comes to a near-stop.

(4) During the flow switching, the water level in the standpipe is temporarily reduced by inertial force. However the water level recovers quickly, the flow in the standpipe comes to a near-stop, and the water level in the standpipe is maintained. Therefore, gas does not enter into the vortex chamber from the standpipe.



- 3.37 seconds after initiation of the test

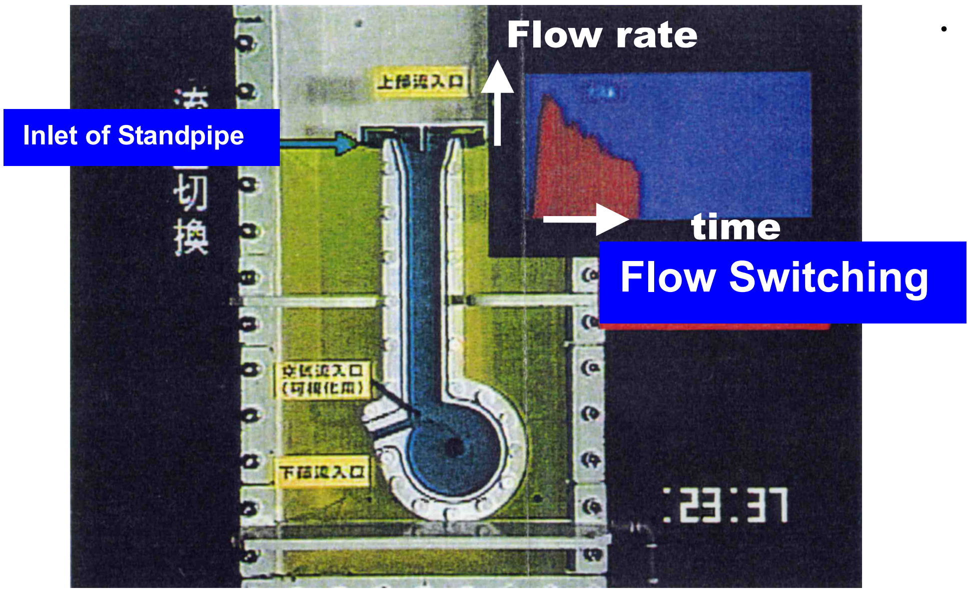
Photo. 4.2.1-2 Flow in the Standpipe and the Vortex Chamber during Large Flow



- 12.48 seconds after initiation of the test
- Air injection into the vortex chamber

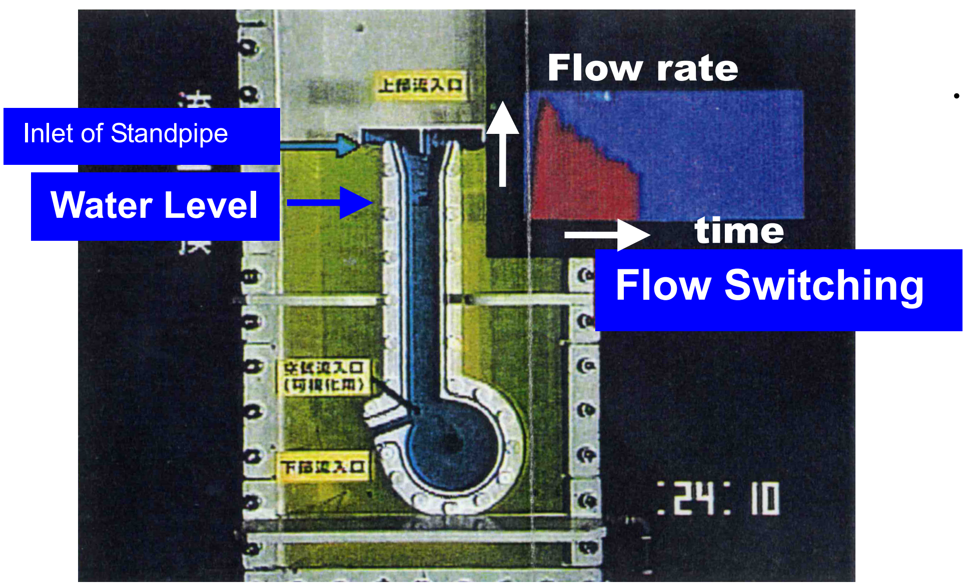
(This Photo. shows that the vortex is not formed in the vortex chamber.)

Photo. 4.2.1-3 Flow in the Vortex Chamber during Large Flow



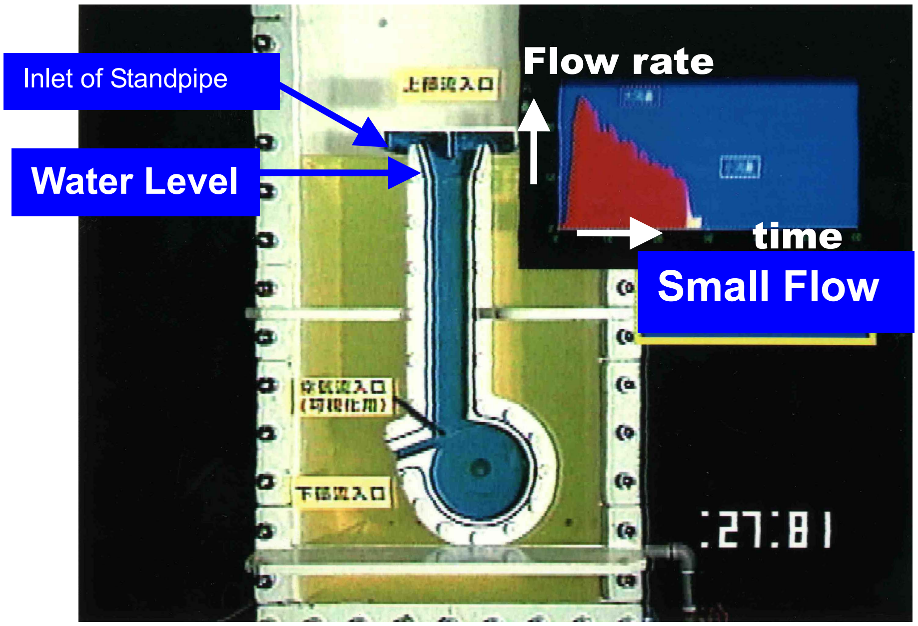
- 23.37 seconds after initiation of the test

Photo. 4.2.1-4 Flow Just before Large/Small Flow Switching



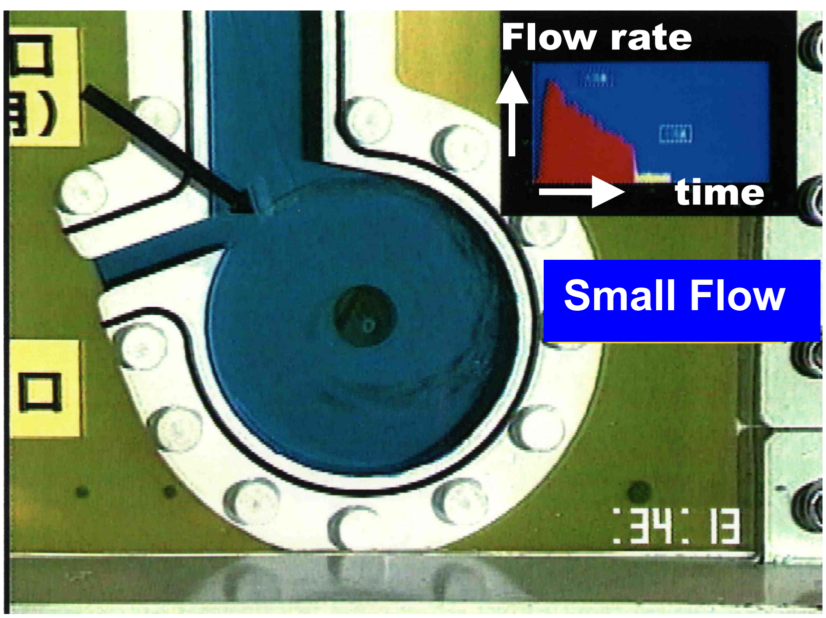
- 24.10 seconds after initiation of the test

Photo. 4.2.1-5 Flow Shortly after Large/Small Flow Switching



- 27.81 seconds after initiation of the test

Photo. 4.2.1-6 Flow during Small Flow



- 34.13 seconds after initiation of the test
- Air injection into the vortex chamber

(This Photo. shows that the vortex is formed in the vortex chamber.)

Photo. 4.2.1-7 Flow in the Vortex Chamber during Small Flow