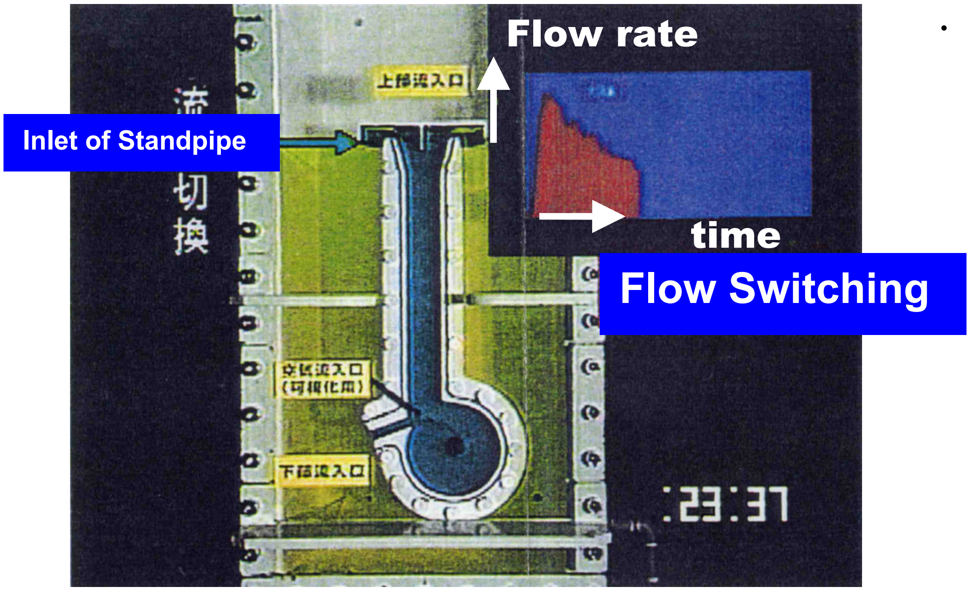
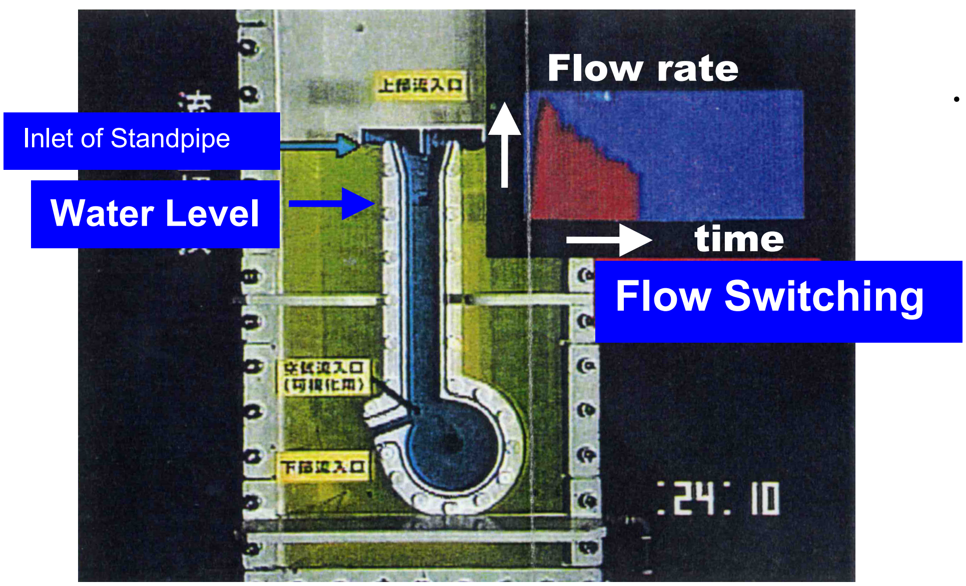


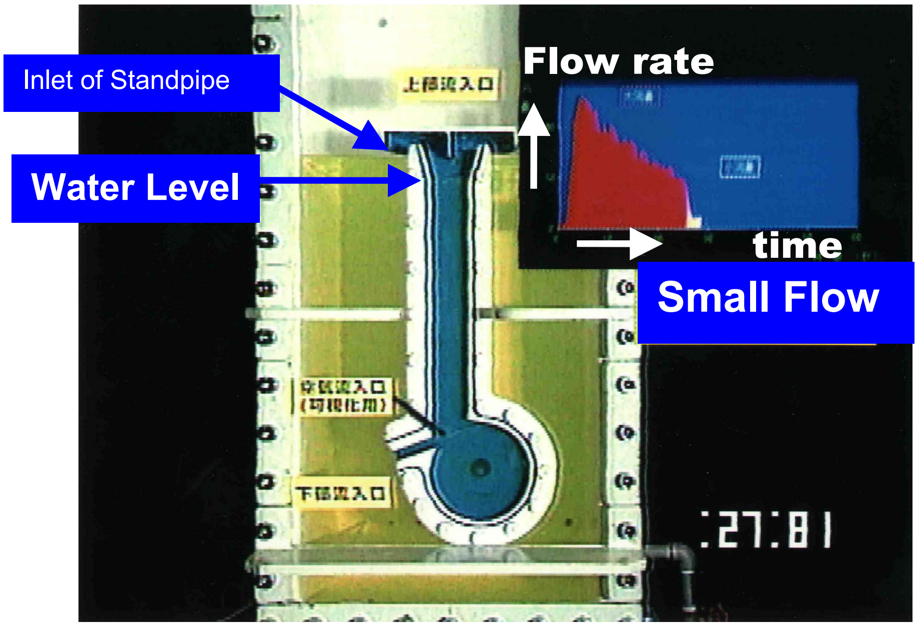
- 23.37 seconds after initiation of the test

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



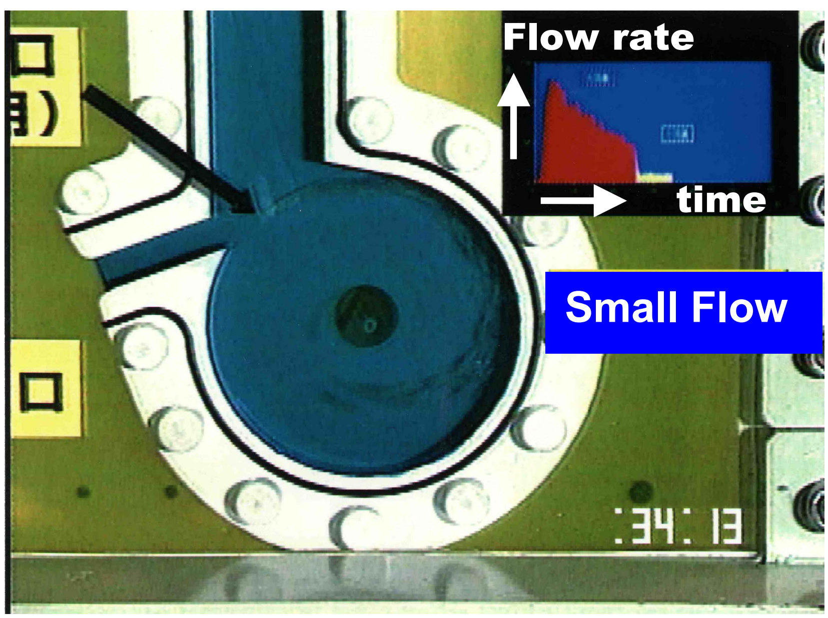
- 24.10 seconds after initiation of the test

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

4.2.2 1/3.5 Scale Test

1) Objectives

The ACC design uses an anti-vortex cap at the top of the standpipe to prevent the formation of a vortex as the flow drains from the tank such that the flow will only switch from a high flow to a lower flow when the level in the ACC drops below the top of the standpipe.

Without the anti-vortex cap it is possible for supercritical flow to form at the standpipe inlet as the water level approaches the top of the standpipe. Under these conditions and gas could be entrained, and the flow rate would not switch smoothly. The purpose of these experiments was to demonstrate that the inclusion of the anti-vortex cap will promote smooth flow switching as the tank water level decreases.

The test was conducted to confirm the flow behavior and potential for vortex formation in the ACC and to confirm the effect of the anti-vortex cap.

2) Test Apparatus

The outline drawing of the test facility is shown in Fig. 4.2.2-1. The test apparatus consists of the standpipe, test tank, pump, and piping. The anti-vortex cap that is installed at the top of the standpipe was made of transparent acrylate such that the flow can be observed at the standpipe inlet. The scale of the standpipe inlet is 1/3.5 of the actual standpipe design.

Fig. 4.2.2-1 Outline Drawing of 1/3.5 Scale Test Apparatus

3) Testing Method

(1) The experiment was scaled using the Froude Number as the basis since there was an open tank with a fluid surface. The relationship between the model tank (m) and the actual accumulator (p) is given below assuming the Froude Number is defined as

$$Fr = \frac{V}{(g \cdot L)^{0.5}} \quad (4\text{-}2)$$

And $Fr_p = Fr_m$ (4-3)

$$Q_p = \left(\frac{L_p}{L_m}\right)^{2.5} \cdot Q_m \quad (4\text{-}4)$$

$$V_p = \left(\frac{L_p}{L_m}\right)^{0.5} \cdot V_m \quad (4\text{-}5)$$

$$t_p = \left(\frac{L_p}{L_m}\right)^{0.5} \cdot t_m \quad (4\text{-}6)$$

where

Fr	:	Froude number
L	:	Typical dimension
Q	:	Typical flow rate
V	:	Typical velocity
t	:	Time
p	:	Subscript denoting the actual ACC
m	:	Subscript denoting the 1/3.5 scale model

(2) The flow rate was measured by an ultrasonic flow meter and the tank water level was measured by the level marking on the sidewall of the tank.

4) Test Conditions

The test conditions are shown in Table 4.2.2-1. Two types of standpipe inlet (with the anti-vortex cap and without it) were tested. The tests were performed using two flow rates in which the test and actual ACC Froude numbers were preserved. The flow rates were [ ] and [ ]. These cover the expected flow rates at flow switching for minimum and maximum initial gas pressures, respectively. The injection characteristics with test flow rates are shown in Figs. 4.2.2-2 to 4.2.2-5.

Table 4.2.2-1 Test Conditions

Test Number	Test Condition			Remarks	Corresponding Actual Condition	
	Anti-vortex Cap	Flow Characteristics	Flow Rate just before switching (gpm (l/sec))		Initial Gas Pressure (psig (MPa(g)))	Flow Rate just before switching (gpm (m^3/h))
1-1	No	Fig. 4.2.2-2	[ ]	Froude number is preserved.	[ ]	[ ]
1-2	Yes	Fig. 4.2.2-3	[ ]			[ ]
2-1	No	Fig. 4.2.2-4	[ ]		[ ]	[ ]
2-2	Yes	Fig. 4.2.2-5	[ ]			[ ]

5) Parameters and Measuring Equipment

Flow rate and water level were measured to confirm the conditions during flow switching. The flow rate was measured using an ultrasonic flow meter and the tank water level was measured by the level markings on the sidewall of the tank.

6) Test Results and Consideration

Test results are summarized in Table 4.2.2-2. The flow at the inlet for various conditions is shown in Photos. 4.2.2-1(1/2), (2/2) through 4.2.2-2(1/2), (2/2). The following observations were made during the test.

(1) In the case of the standpipe inlet without the anti-vortex cap, a slight surface dimple appeared above the inlet and the initiation of supercritical flow developed when the water level began to decrease. When the water level decreased further, the supercritical flow condition was apparent and the surface dimple reached into the standpipe, and gas entrainment occurred. (Photo. 4.2.2-1(1/2), (2/2))

(2) Below the water level where the supercritical flow condition becomes apparent, the critical depth became smaller consistent with the water level reduction. This resulted in a lower flow rate and a slower reduction of the water level.

(3) The condition described in (2) above is apparent in the wave pattern. For example, in Fig. 4.2.2-2, supercritical flow was apparent, gas entrainment started 26 seconds after initiation of the test, and the variation of the flow rate became lager. As the flow rate became smaller, it took as long as 5 seconds before the flow rate into the standpipe became zero.

(4) This qualitative condition appeared in the case of both the minimum initial gas pressure of [ ] and the maximum initial gas pressure of [ ] without any significant differences.

(5) In the case of the standpipe inlet with the anti-vortex cap, a slight disturbance appeared on the water surface as the water level decreased from just above the upper end of the cap to the lower end of the cap. However, neither a vortex nor supercritical flow occurred, and the flow rate switched sharply over a short period of time. (Photos. 4.2.2-2(1/2), (2/2))

This condition is apparent in the wave pattern. For example, in Fig. 4.2.2-3, the flow rate into the standpipe became zero in approximately 1 second. The flow rate switched much more quickly than the case without the anti-vortex cap (which was approximately 5 seconds in Fig. 4.2.2-2).

(6) Based on the data and visual observations described above, the desired effects of the anti-vortex cap were confirmed.

Table 4.2.2-2 Summary of Test Results

Test Number (T. No)	Test Condition		Test Results		
	Flow Characteristics	Anti-vortex Cap	Vortex Formation	Time to finishing switching (sec)	Remark
1-1	Fig. 4.2.2-2	No	Yes	Approx. 5	Photo. 4.2.2-1(1/2), (2/2)
1-2	Fig. 4.2.2-3	Yes	No	Approx. 1	Photo. 4.2.2-2(1/2), (2/2)
2-1	Fig. 4.2.2-4	No	Yes	[ ]	-
2-2	Fig. 4.2.2-5	Yes	No	[ ]	-

Photo. 4.2.2-1 (1/2) Visualization of Flow without Anti-Vortex Cap (T. No. 1-1) 1/2

Photo. 4.2.2-1 (2/2) Visualization of Flow without Anti-Vortex Cap (T. No. 1-1) 2/2

Photo. 4.2.2-2 (1/2) Visualization of Flow with Anti-Vortex Cap (T. No. 1-2) 1/2

Photo. 4.2.2-2(2/2) Visualization of Flow with Anti-Vortex Cap (T. No. 1-2) 2/2

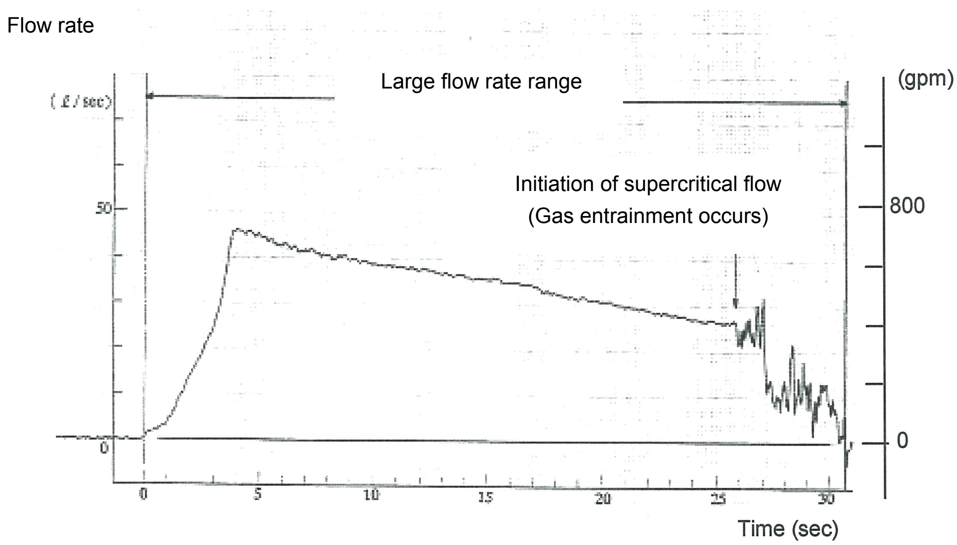


Fig. 4.2.2-2 Test Flow Characteristics without Anti-Vortex Cap (T. No. 1-1)

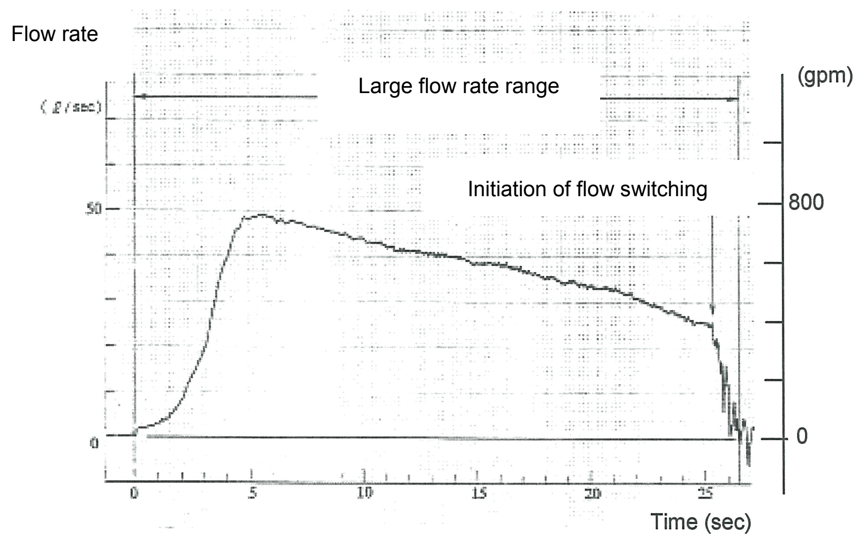


Fig. 4.2.2-3 Test Flow Characteristics with Anti-Vortex Cap (T. No. 1-2)

Fig. 4.2.2-4 Test Flow Characteristics without Anti-Vortex Cap (T. No. 2-1)

Fig. 4.2.2-5 Test Flow Characteristics with Anti-Vortex Cap (T. No. 2-2)