Integrity of UF6 Cylinders for Outer Pressure

Y. Gomi[1], *S.Ozaki*[1], *N.Watabe*[1], *K.Sato*[2], *K.Noguchi*[3], *H.Suzuki*[3]

[1]Central Research Institute of Electric Power Industry, Abiko, Chiba, JAPAN

[2]Central Research Service Co., Tokyo, JAPAN

[3]Mitsubishi Research Institute Inc., Tokyo, JAPAN

INTRODUCTION

According to IAEA regulations, type B packages should be tested for outer pressure equal to 200m depth and simulating an accident condition. Two types of cylinders are used for uranium-hexafluoride transport cylinders in Japan, which are 48Y-cylinder for natural uranium-hexafluoride and 30B-cylinder for enriched uranium-hexafluoride.the present IAEA regulations have required fire resistance for packagings for enriched uranium-hexafluoride but not for natural uranium-hexafluoride. Considering that uranium-hexafluoride is transported from abroad to Japan by vessel, external pressure tests and some analysis were carried out, with a view to ensure the safety margin of uranium-hexafluoride transport packagings.

Methods

Test cylinders

Two types of cylinders were provided in the test.One is 30B-cylinder and the other is 48Y-cylinder. The specifications of the cylinder are shown in table 1. A 30B-cylinder containing enriched uranium-hexafluoride is usually shipped with protective overpack. But, with the view to the pressure resistance, the regulations have not required pressure resistance for the protective overpack. So a 30B-cylinder without protective overpack was used in the tests. To prevent the cylinders from floating in the pressure vessel, steel balls(150kg) were put in the 30B-cylinder and water(60% of the volume) in the 48Y-cylinder.

Table 1. Specifications of the cylinder (unit:mm)

	30B-cylinder	48Y-cylinder
Nominal Diameter	762	1219
Nominal Length	2070	3803
Wall thickness	12.7	16
Nominal Tare Weight	635	2359
Basic Material of Construction	Steel	Steel

Test Apparatus

The pressure resistance tests were carried out at the Yokosuka Laboratory of the Central Research Institute of Electric Power Industry. Fig 1 shows the outline of the high pressure test facility. Its specifications are shown in Table 2.

Table 2. Specifications of the high pressure test facility

Maximum Test Pressure(kgf/cm^2)		500
Dimensions of the pressure test vessel	Inner Diameter(m)	3
	Outer Diameter(m)	6
	Inner Volume(m^3)	50

Measurement

The measured subjects in the pressure resistance tests were displacement and strain of the cylinders. Displacement was measured by a displacement sensor (strain transducer type) and strain by a strain gauge. The measured points are 14 for the displacement, 36 for the strain on the 30B-cylinder and 23 for the displacement, 66 for the strain on the 48Y-cylinder.

Moreover, to evaluate the deformation of the cylinders, dimensions of the cylinders were measured by using measurement system of a three dimensional coordinator before and after tests and to evaluate the leaktightness of the cylinders, containment tests were carried out before and after tests.

Tests

Several tests were carried out in accordance with the test procedure as is shown in Fig 2. In the pressure resistance tests, cylinder were tested for external pressure which is required for type B packages by the IAEA regulations (under pressure which is equal to 15m depth for eight hours and 200m depth for one hour). After these tests, to evaluate the safety margin of the cylinders, they were pressurized until buckling pressure. This test is not required for the cylinders by the IAEA regulations.

Results

Results of the pressure resistance tests are shown in Fig 3. Fig 3 shows the pressure-stain correlation. This result shows that maximum stress occurring during the tests are below the yield stress of the structural material and leaktightness tests showed no leakage. As a result of the tests, the integrity of the cylinders was proved when the hypothetical accidents occur that a vessel would sink during transport.

In the buckling pressure test, buckling of the cylinders occurred at the body. Fig 4,5 shows the pressure-strain correlation and pressure-displacement correlation and in Fig 6, the displacement distribution of the test cylinders after buckling are shown. Table 3 shows the analytical results and the experimental results. In Table 3, the results obtained by the theoretical solution and the analysis code (Bosor/5) are larger than the experimental results. On the other hand, the results obtained by ASME Code agree with the experimental ones. It seems to be that the roundness of the cylinders causes the difference between analytical ones and experimental ones. In the theoretical and analytical solution, it is assumed that the cylinders are truly round but in practice, they aren't.

Fig 7 shows the measured value by measurement system of three dimensional coordinator. In Fig 7, near the weld joint part, the measured value deviates from the round. This fact supports the above-mentioned idea.

Table 3. Critical Buckling Stress (kgf/cm^2)

	30B-cylinder	48Y-cylinder
ASME Code Boiler & pressure vessel code	60(body) 78.2(enclosure)	55.7(body) 67.0(enclosure)
Theoretical solution JASME handbook	99.0	154.9
Analysis Bosor/5	83.5	------
Experiment	61.0(body)	62.0(body)

Conclusion

Pressure resistance tests were carried out for a 30B-cylinder and 48Y-cylinder. They were tested for outer pressure which is equal to 15m depth for eight hours and 200m depth for one hour. It became clear that the maximum stress during the tests was below the yield stress of the structural material and there were no leakage after the test. As a result, the integrity of the cylinders was verified when the accidents were assumed that a vessel would sink during transport at sea.

Buckling pressure tests were also carried out for each cylinder and it was ensured that the each cylinder has sufficient safety margin for outer pressure.

Furthermore, when it is necessary to evaluate the critical buckling stress of the cylinder, it was proved that the calculating method of ASME code gave good agreement with the experimental results.

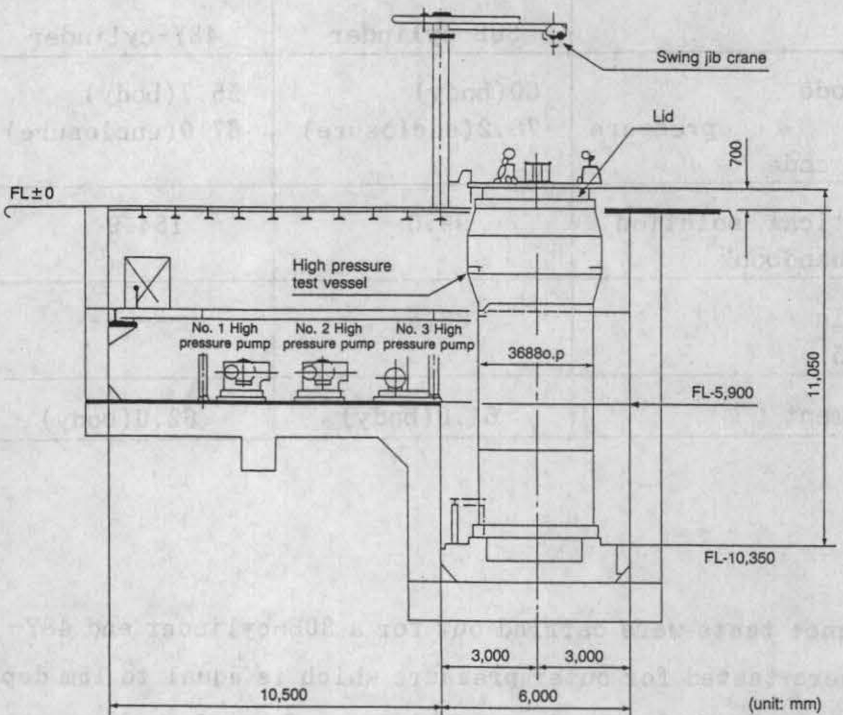

Fig 1. High Pressure Test Facility

Measurement of the dimensions

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Leaktightness test

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Pressure Resistance Tests
$1.5\ kgf/cm^2$, eight hours
$20\ kgf/cm^2$, one hour

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Buckling Pressure Test

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Measurement of the dimensions

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Leaktightness Test

Fig 2. Test Procedure

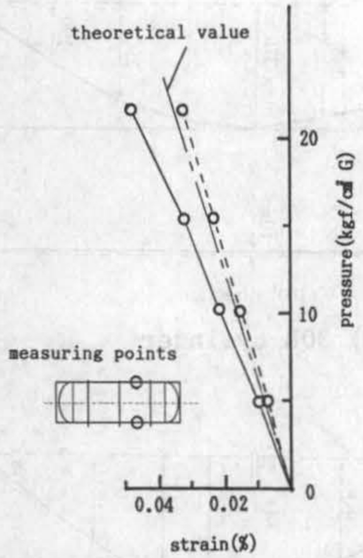


Fig 3. Pressure-Strain correlation(48Y-cylinder)
(Test condition:21 kgf/cm², one hour)

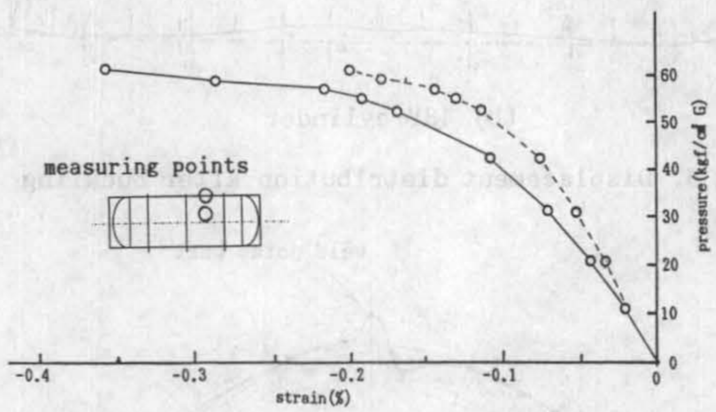


Fig 4. Pressure-Strain correlation(48Y-cylinder)
(buckling pressure test)

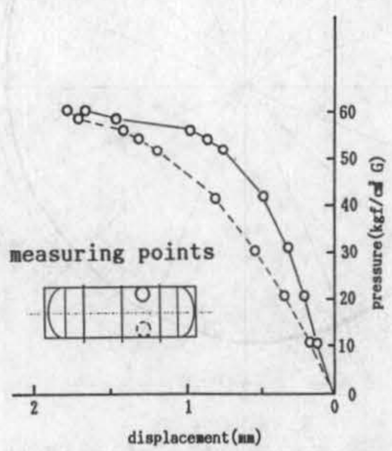
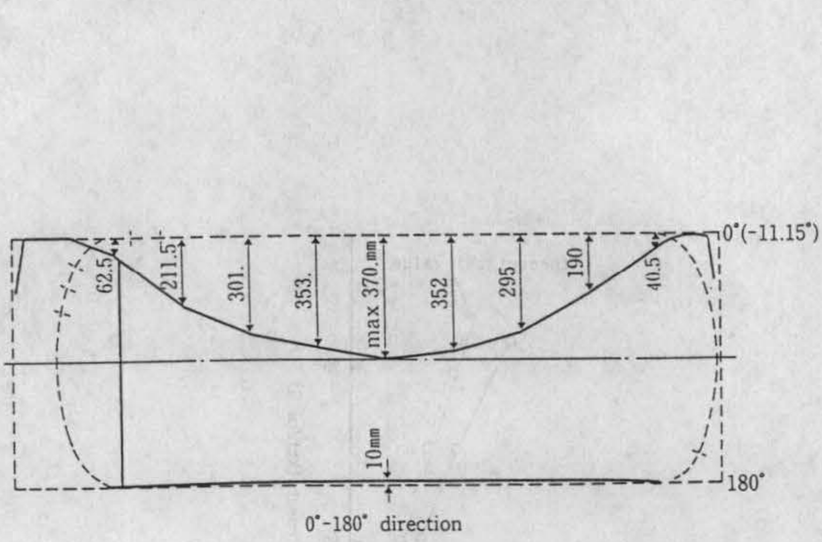
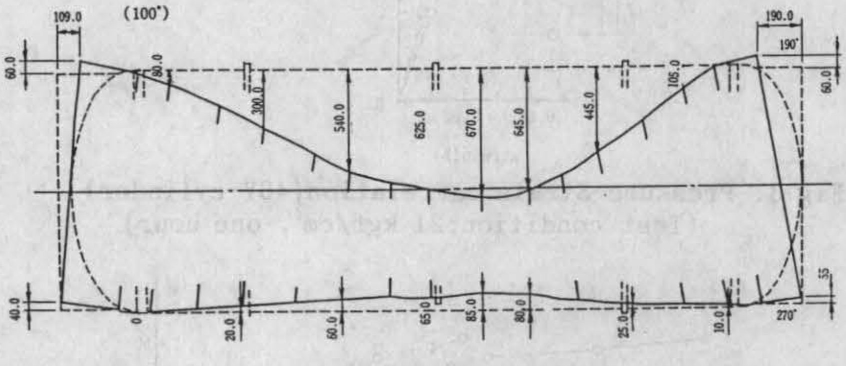


Fig 5. Pressure-Displacement correlation(48Y-cylinder)
(buckling pressure test)



(a) 30B-cylinder



(b) 48Y-cylinder

Fig 6. Displacement distribution after buckling

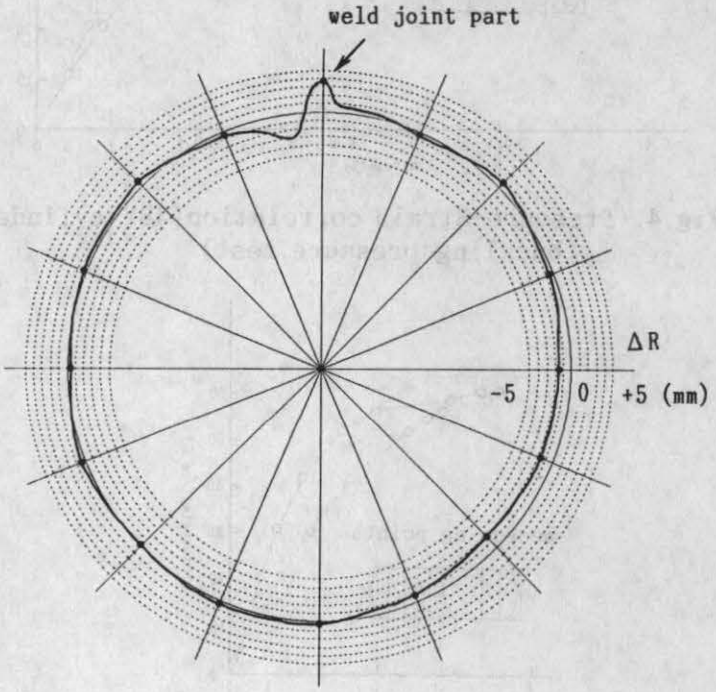


Fig 7. Measured value by measurement system of three dimensional coordinator
(cross section of the 30B-cylinder at the center)