INVESTIGATION OF AVAILABILITY OF RIGID POLYURETHANE FOAM AS SHOCK ABSORBING MATERIAL FOR HEAVY CASK

Jun OKADA	HITACHI ZOSEN CORPORATION
Satoshi ASHIDA	HITACHI ZOSEN CORPORATION
Akihiro ARAI	HITACHI ZOSEN CORPORATION
Akio OIWA	HITACHI ZOSEN CORPORATION
Masayuki TANIGAWA	HITACHI ZOSEN CORPORATION

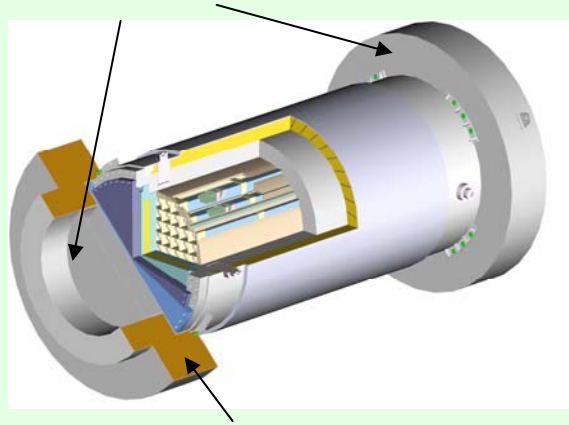
Proceedings of the 16th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2010
October 3-8, 2010, London, UK

Background

The size of an impact limiter of a transportation cask is limited by operational condition.

Wood has been mainly used as shock absorbing material because it has enough capability in the limited volume.

It has become difficult to procure wood in large quantities constantly, which satisfies the characteristics specified by design.



Hitz
Hitachi Zosen

Purpose

Rigid Polyurethane foam(R-PUF) was chosen as shock absorbing material for two reasons

- Its characteristic of crush strength is adjustable
- R-PUF can be prepared at low cost which is almost the same as that of the lowest-priced wood.

The purpose of this work is to confirm whether R-PUF has enough performance to adopt it as shock absorbing material for heavy cask.

Hitz
Hitachi Zosen

Contents of this study

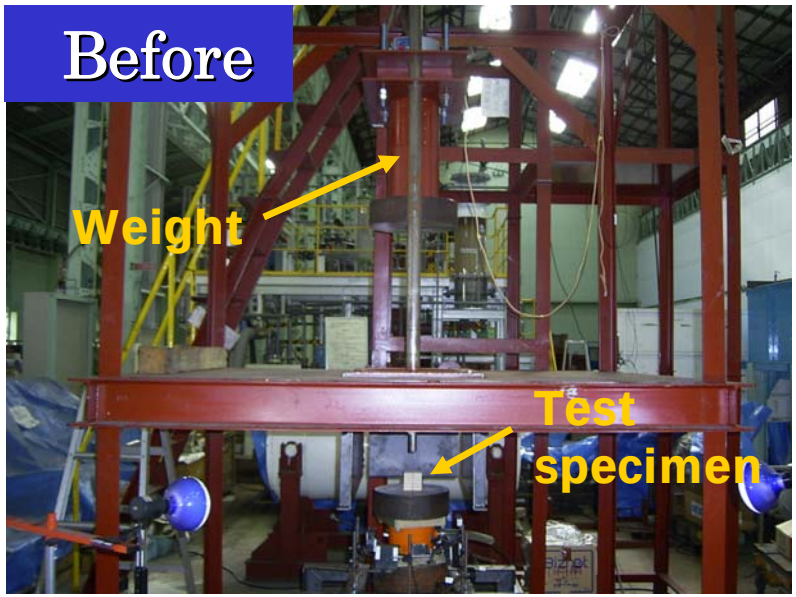
Availability of R-PUF as shock absorbing material for cask were investigated by following experiments.

1. Drop Weight Test
2. Drop Test of 1/3 Scale Model Cask
3. Fire Resistant Test

Hitz
Hitachi Zosen

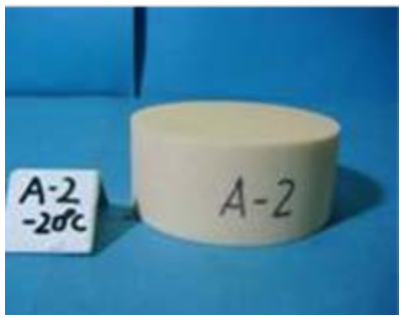
1. Drop weight test

Before



After

Test specimen



R-PUF
High density
ρ=0.52g/cm^3

R-PUF
Middle density
ρ=0.33g/cm^3

R-PUF
Low density
ρ=0.12g/cm^3

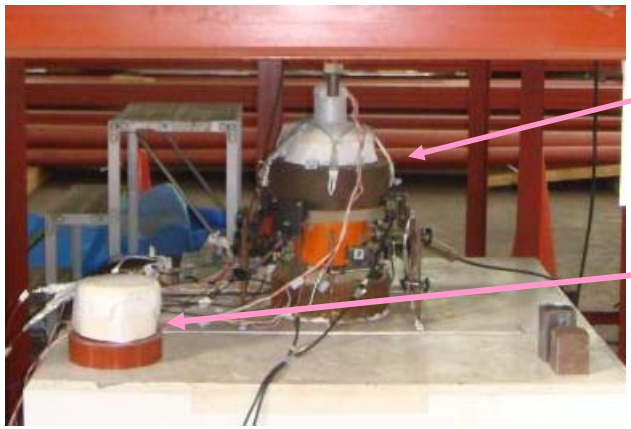
Direction of falling weight

Test specimen: column shape sized
Diameter 80mm Heights 70mm

Temperature condition of drop weight test

Constant-temperature bath

Temperature condition
-40, -20, 0, 25, 50, 75, 100 ˚C

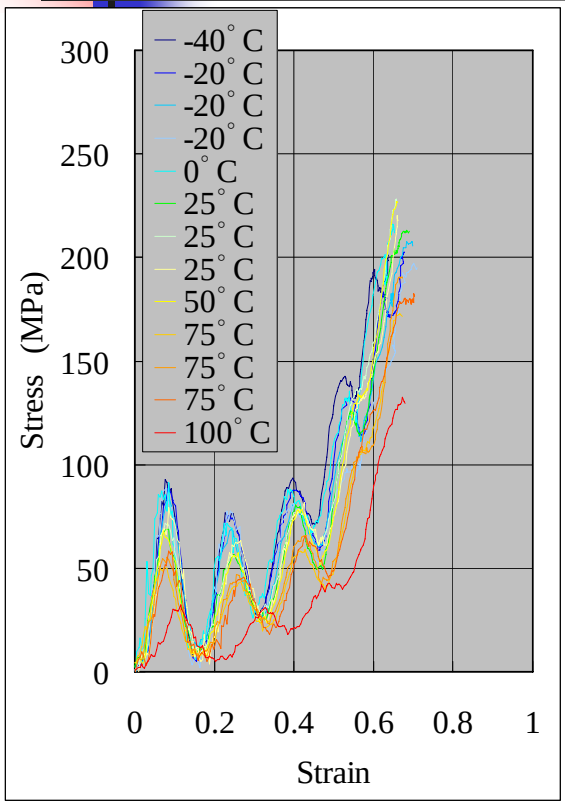


Test specimen

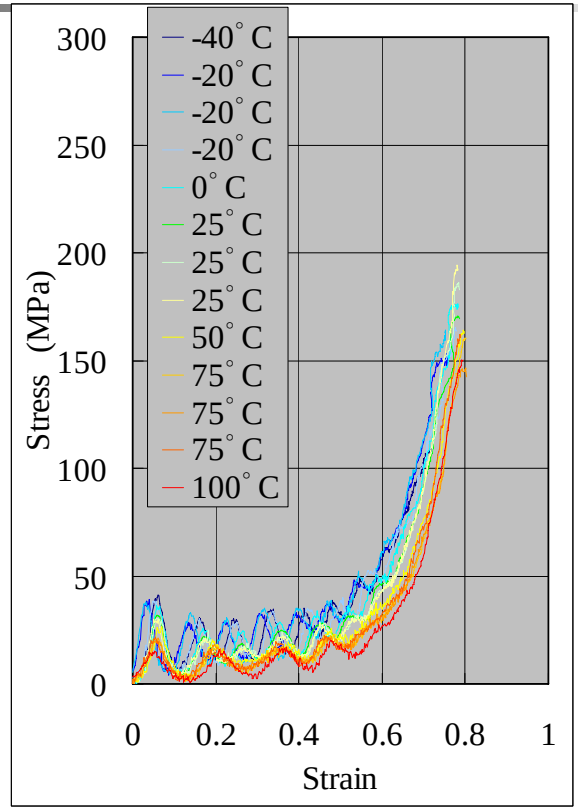
Dummy specimen to measure temperature of test specimen

Hitz
Hitachi Zosen

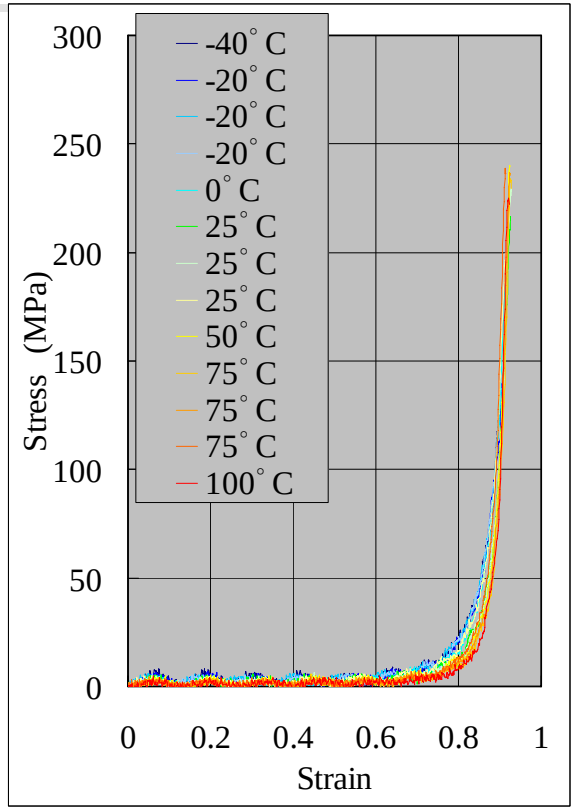
Result of drop weight test



High density R-PUF



Middle density R-PUF

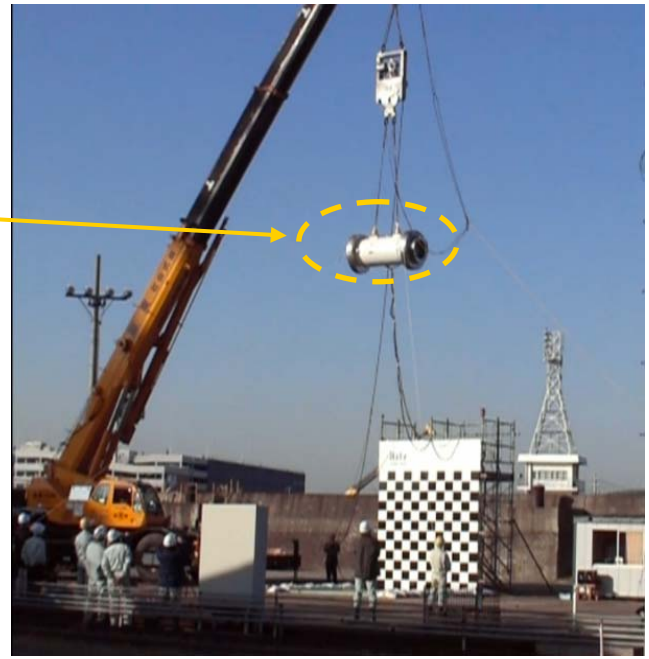


Low density R-PUF

Middle and low density R-PUF, the temperature effect is few.

2. Drop test of 1/3 scale Model Cask

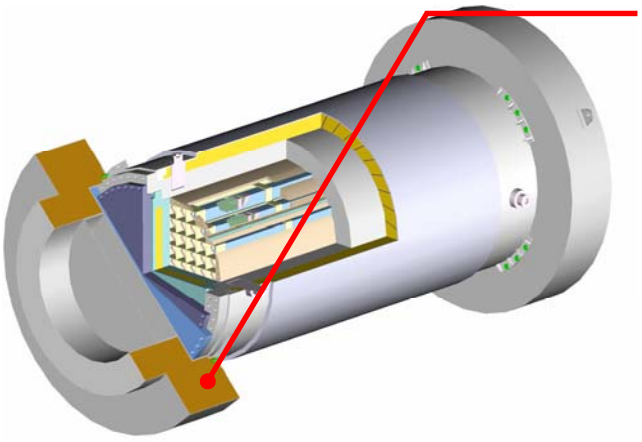
1/3 scale
model cask



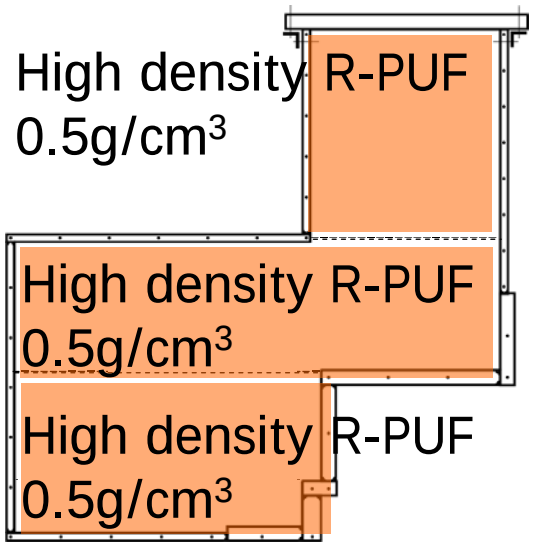
Test model of 1/3 scale cask

- Shock absorbing material :
  R-PUF
- Diameter of the cask body :
  0.8m
- Diameter of the impact limiter :
  1.2m
- Total height :
  2.2m
  (including impact limiters)
- Total mass :
  4950kg
  (including impact limiters)

Two types of impact limiter

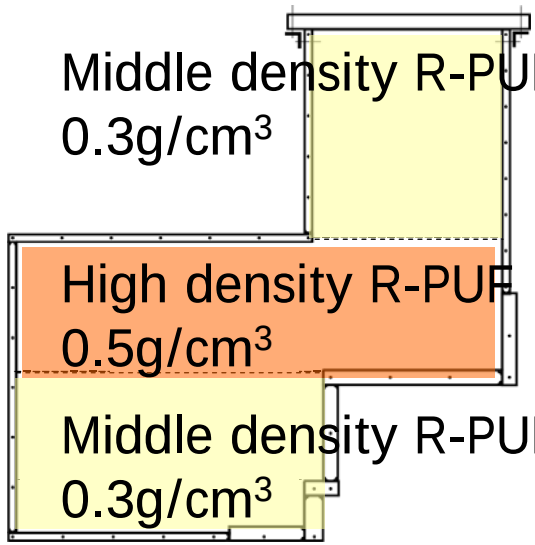


Impact limiter



Type-A

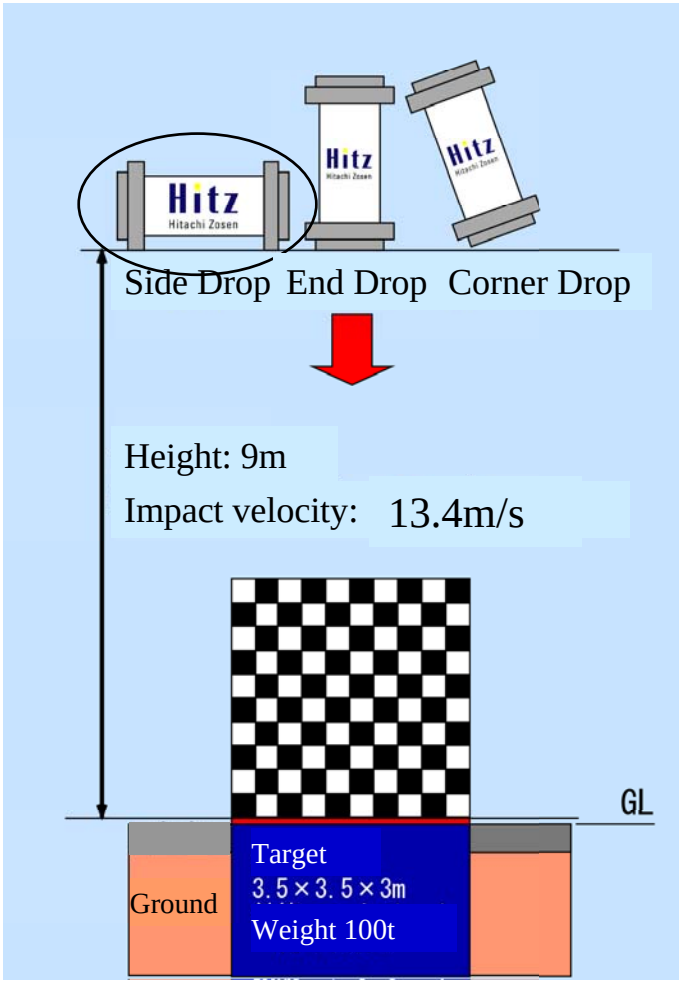
(High density)



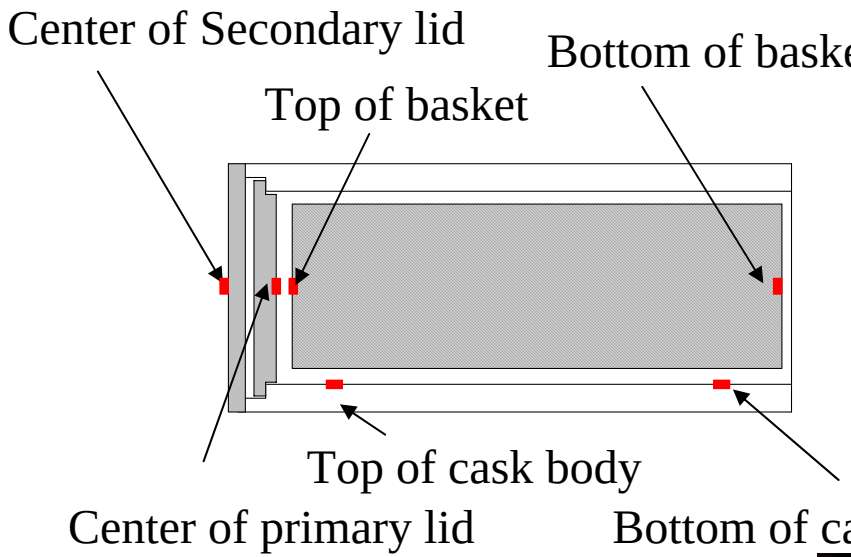
Type-B

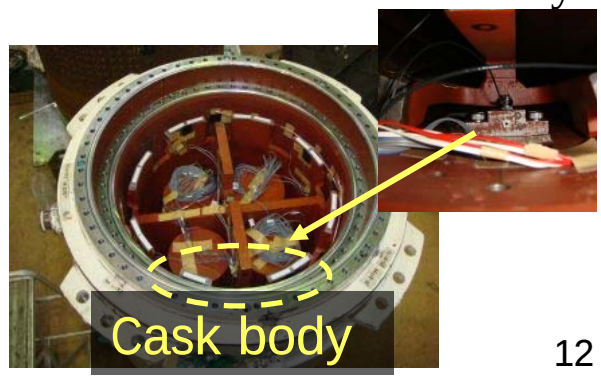
(Composed High and middle density)

Test method and measurement method

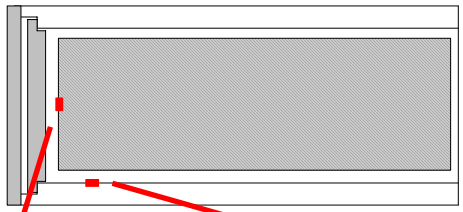


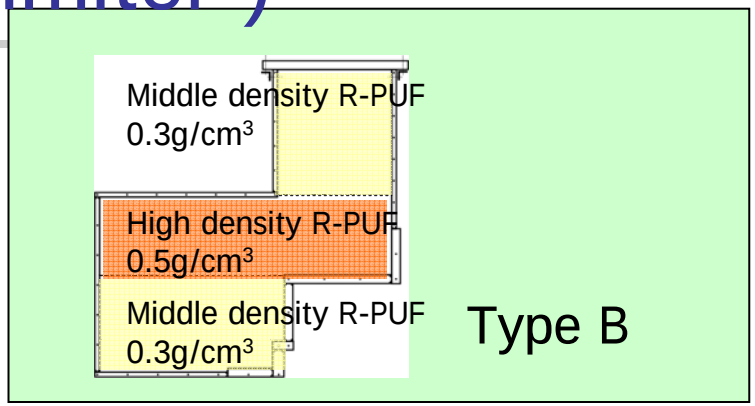
Acceleration measurement point

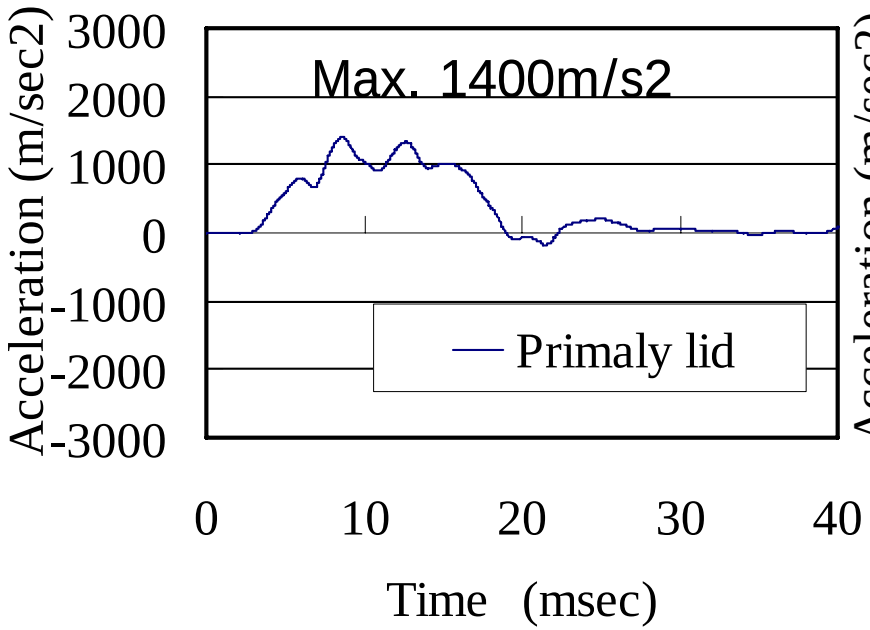


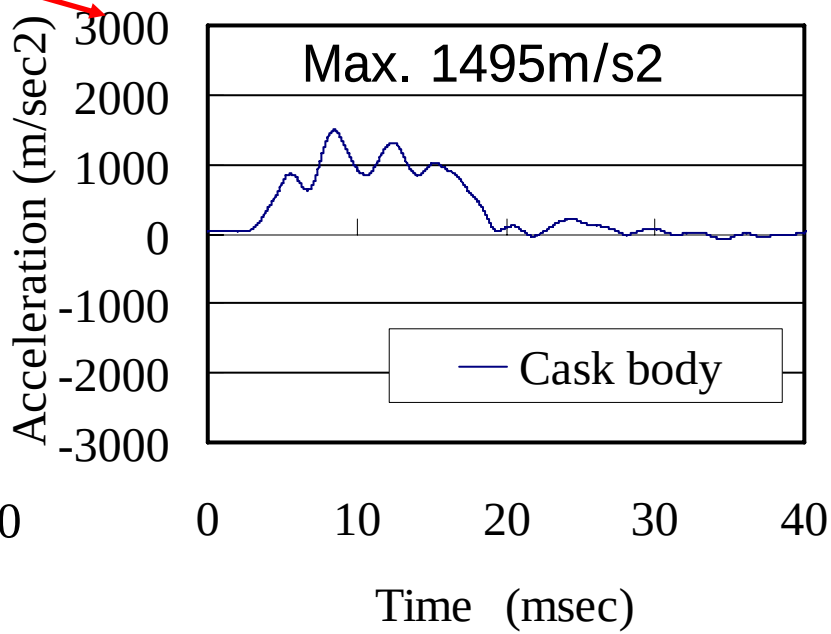


Test result of drop test of 1/3 scale model cask (Type B impact limiter)

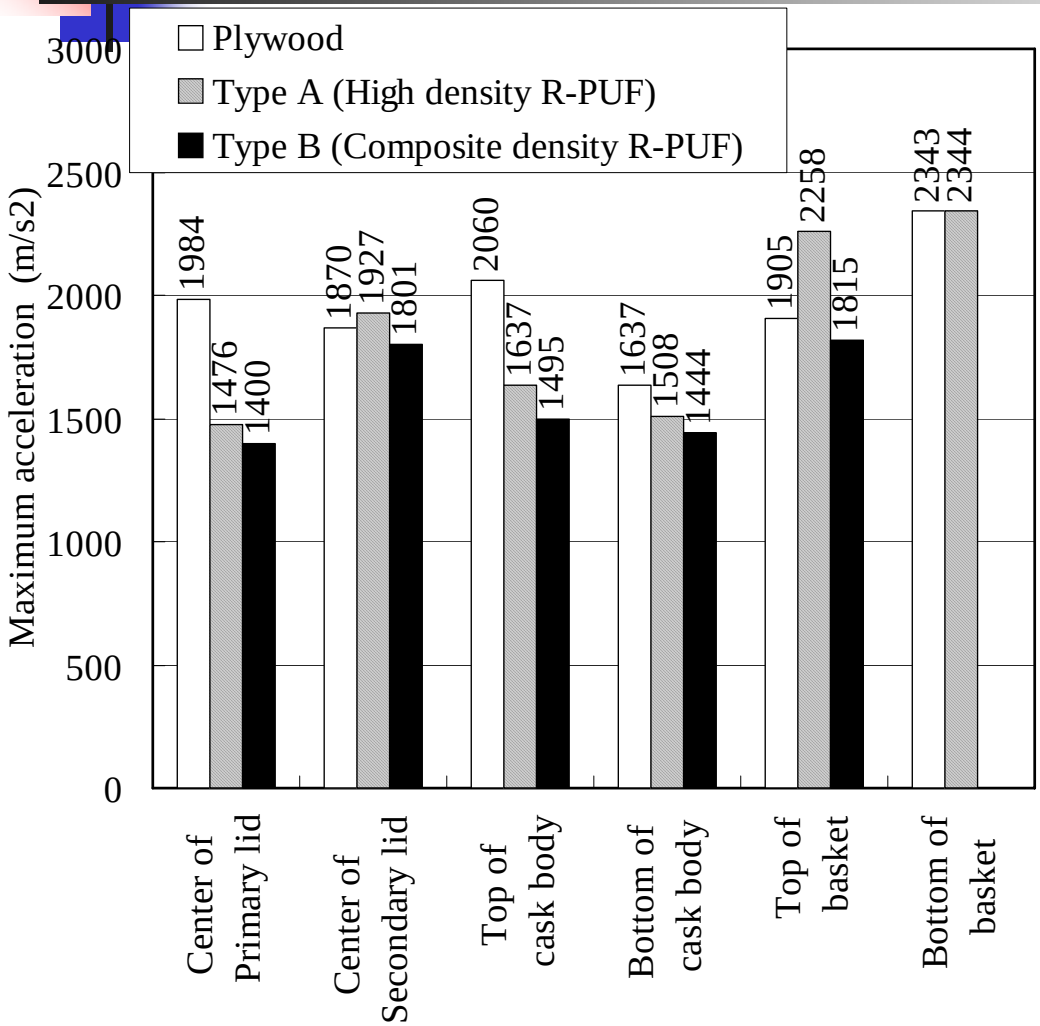








Maximum acceleration

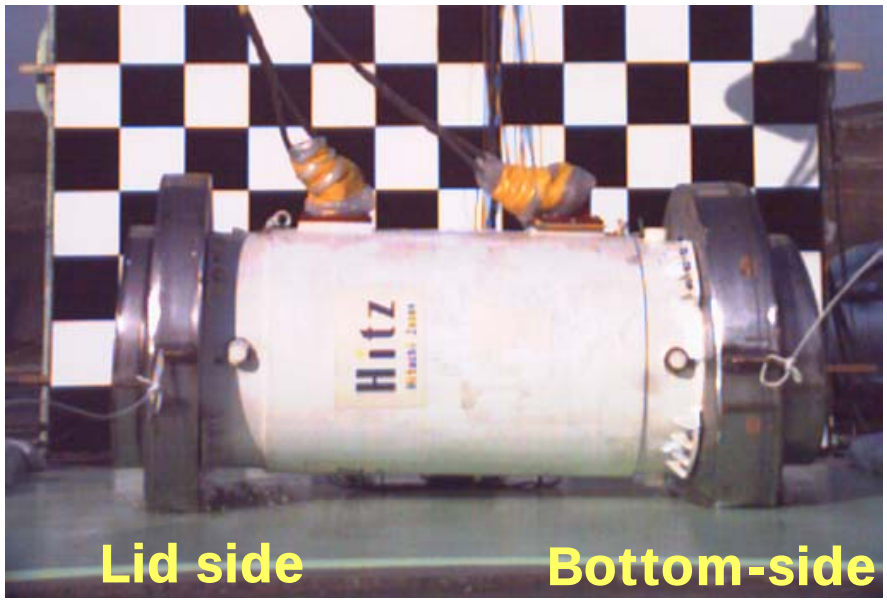


Type B R-PUF model showed a decrease by 7-20% in the maximum acceleration as compared to the plywood.

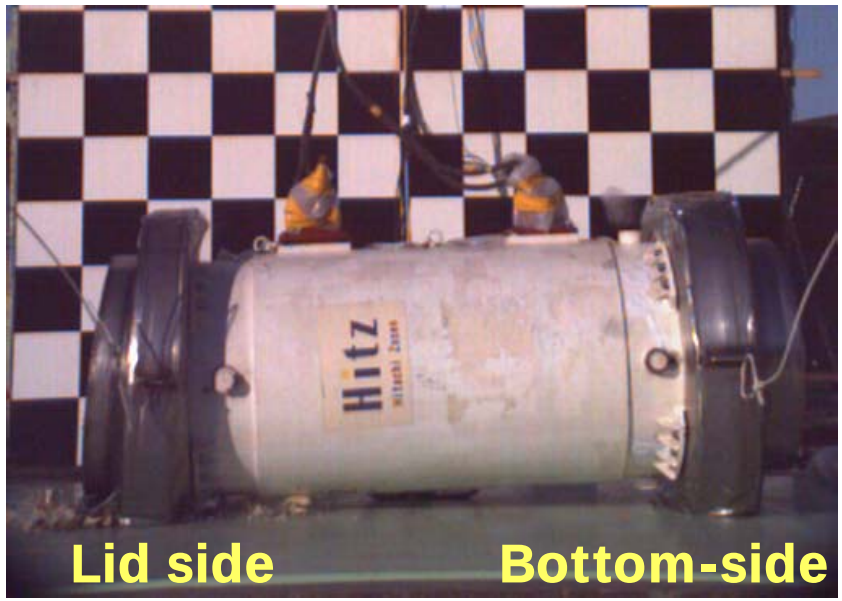
Thus, the impact limiter composed of R-PUF indicated superior shock absorbing capability to that composed of plywood.

Deformation of impact limiter at the most destructive state

Type A (High density R-PUF)



Type B (Composite density R-PUF)

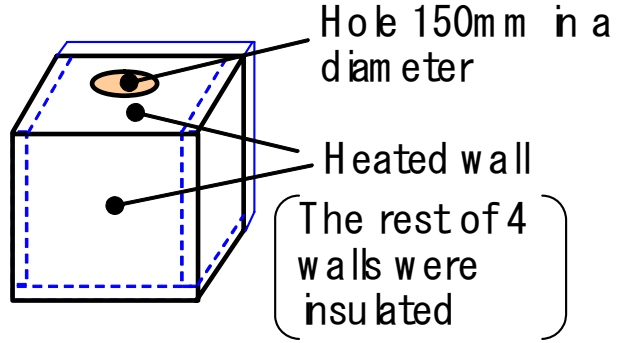


Both lid-side and bottom-side of impact limiters were damaged. However, the cask body remained intact.

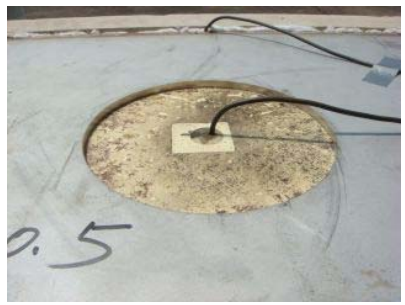
3. Fire resistant test

The fire resistant capability was examined by keeping the test specimens in the furnace of 800°C for 30 minutes.

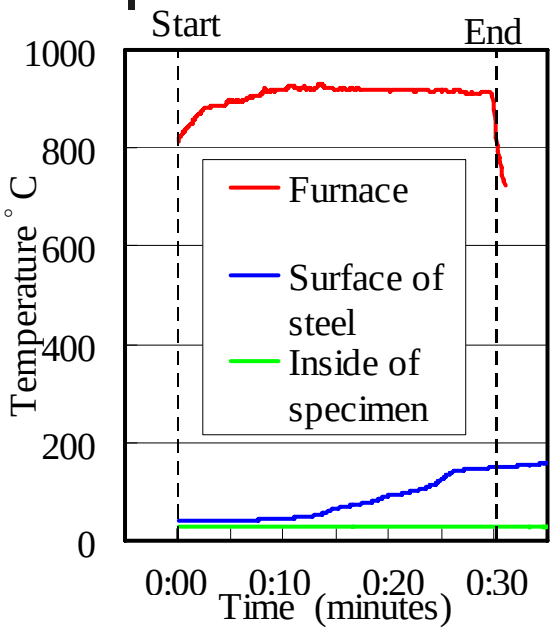
Test specimen of fire resistant test

Type of Test specimen	Density (g/cm^3)	Size of Test specimen	Thickness of cover plate	Structure of test specimen
High density R-PUF	0.52	400mm x 400mm x 400mm	Heated wall :6mm Insulated wall :3.2mm	
Middle density R-PUF	0.31			
Plywood	0.54			

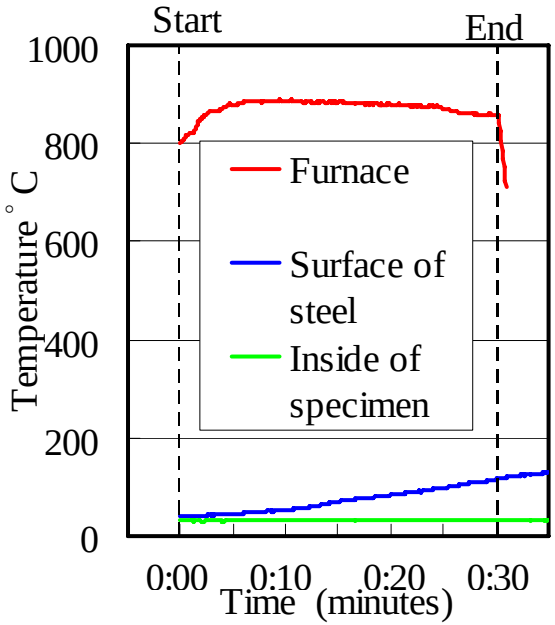
Heat sensor



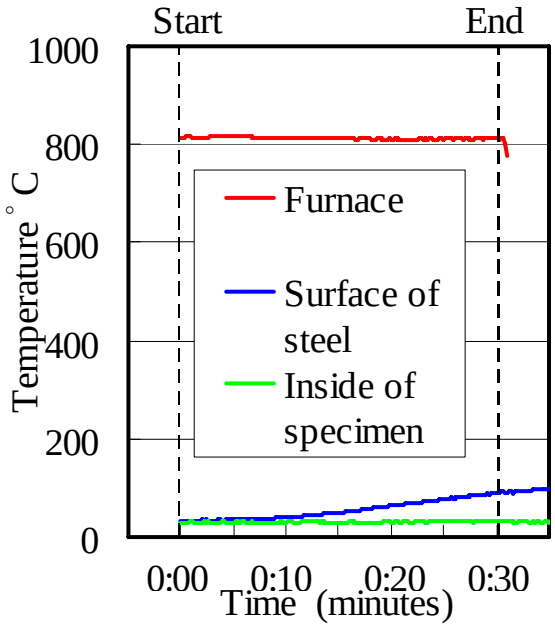
Time history of temperature in fire resistant test



High density R-PUF



Middle density R-PUF



Plywood

Temperature of all the test specimens were kept in less than 40 ˚C constantly.

Overview of fire resistant test

State of test specimen taken out from furnace

after 12 min.

after 8 min.

after 3 min.

Change of the state of test specimen (Flame was put out)

High density R-PUF

Middle density R-PUF

Plywood

Hitz
Hitachi Zosen

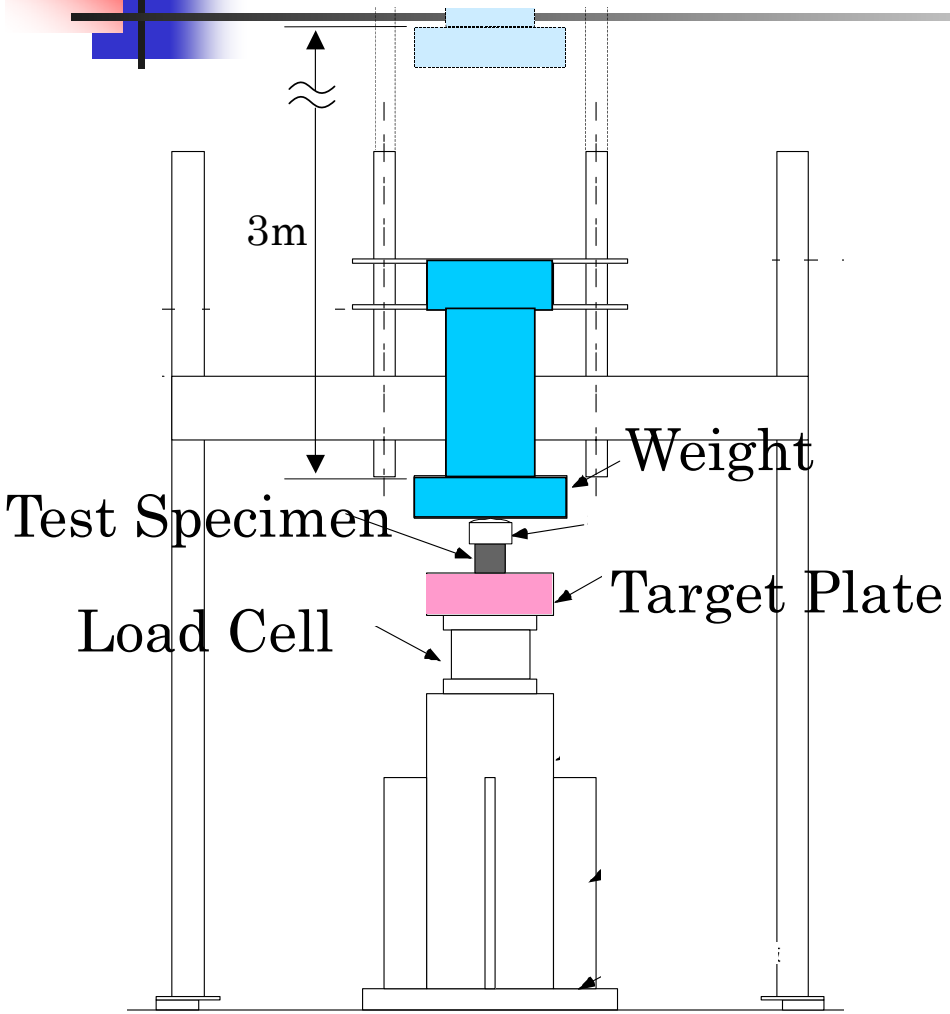
Conclusions

1. Stress strain curves of three density type of R-PUF under each temperature condition were obtained by drop weight test.

2. Results obtained by side drop tests of a 1/3 scale model cask suggested that the impact limiter composed of both high and middle density R-PUF had superior shock absorbing capability than that of plywood.

3. Results obtained by fire resistant test suggested that R-PUF showed almost the same fire resistant capability as plywood and that actual cask body was not damaged by fire accident at the level of IAEA rule.

Measurement method



Displacement

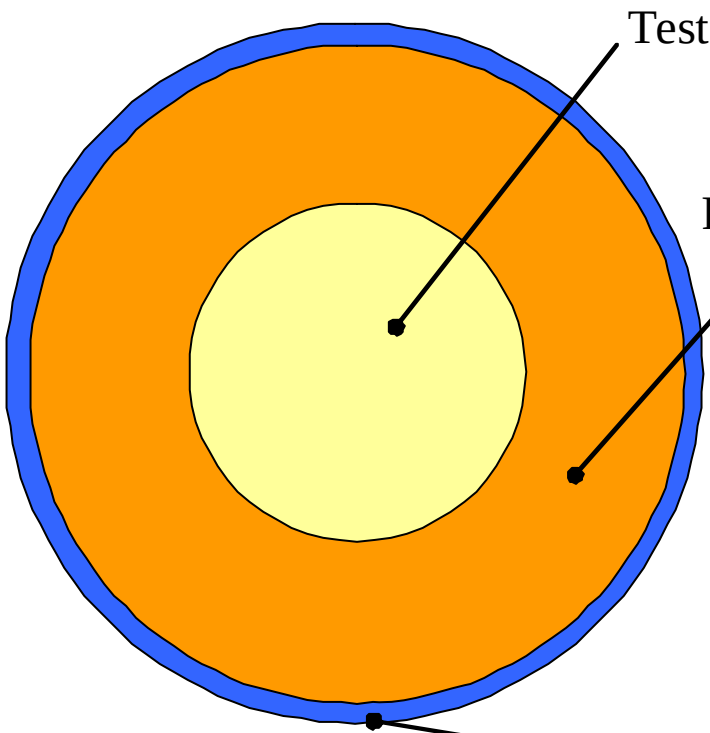
4 points under the weight
4 points under the target plate

Impact load

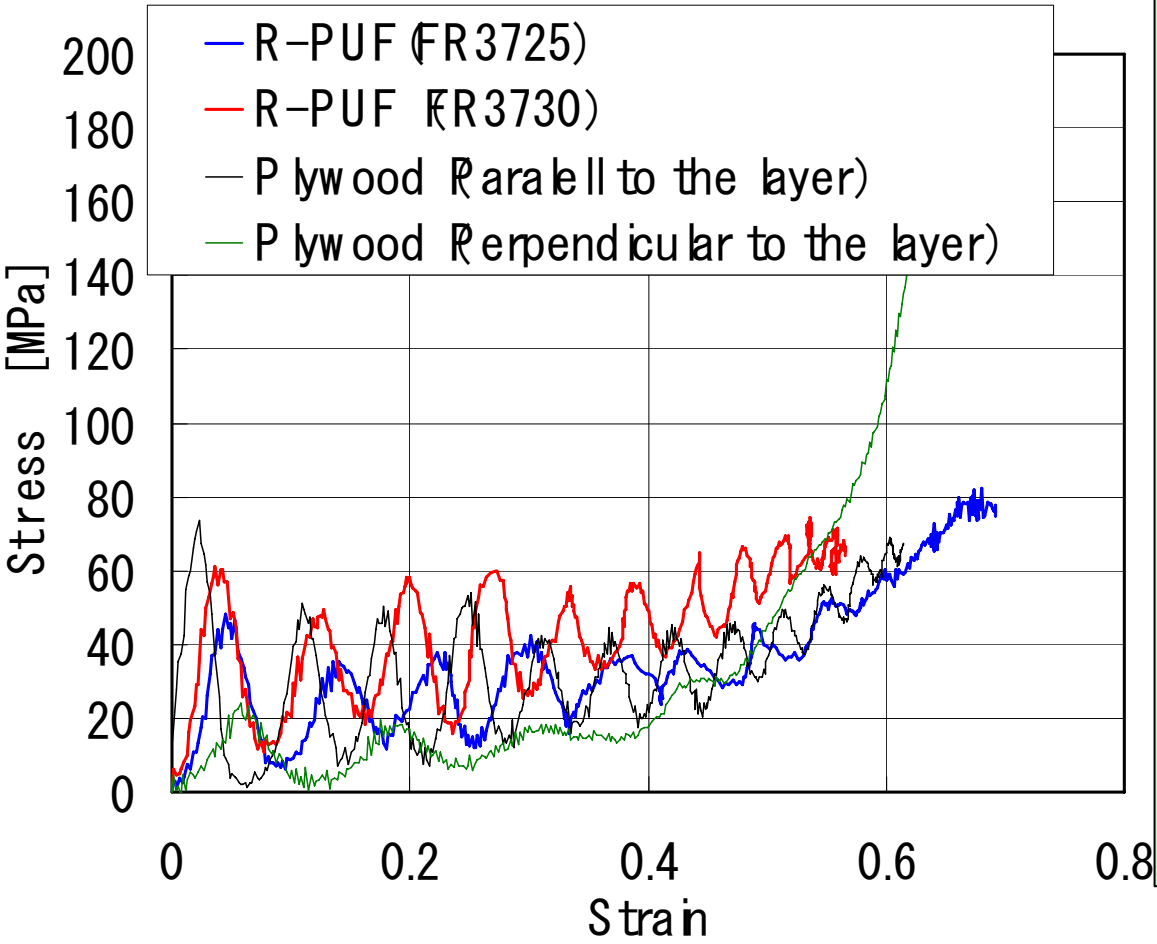
1 point under the target plate.

They were measured with sampling frequency of 50kHz.

Restraint condition of test specimen



Test result of drop weight test



Define

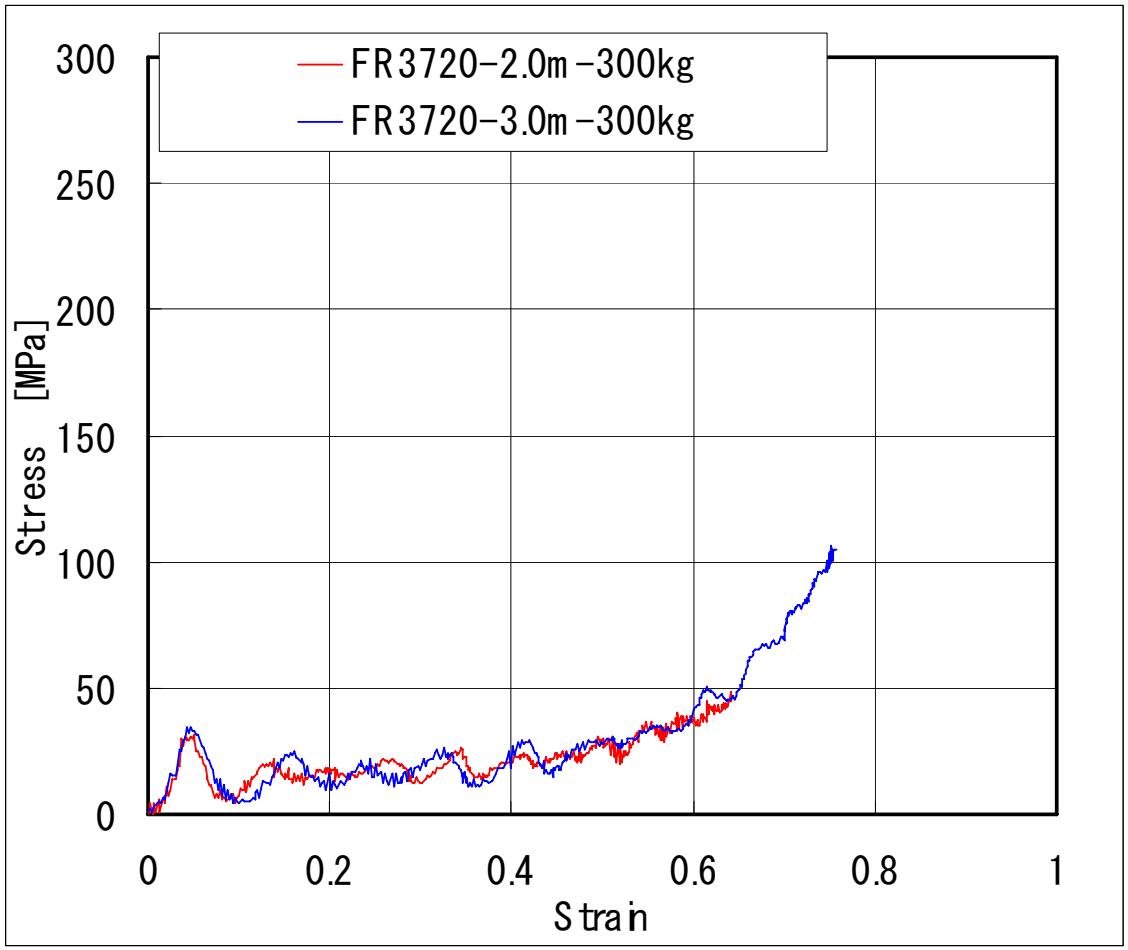
Strain $= (D_W - D_T)/L_T$

- D_W : weight displacement
- D_T : target plate displacement
- L_T : initial height of the test specimen.

Stress $= P/A_T$

- P : impact load
- A_T : initial cross sectional area of the test specimen.

Difference of falling height

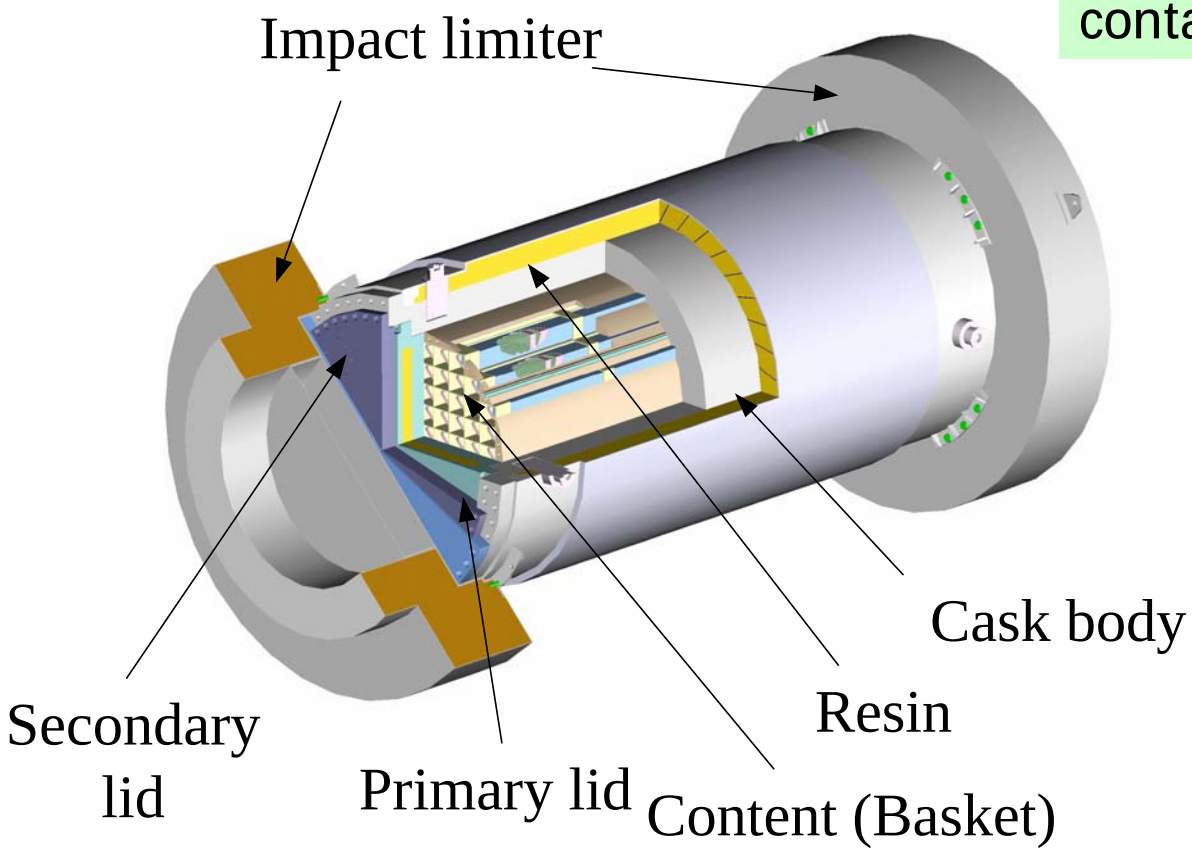


Height 2m:
Impact velocity :6.3m/s

Height 3m:
Impact velocity :7.7m/s

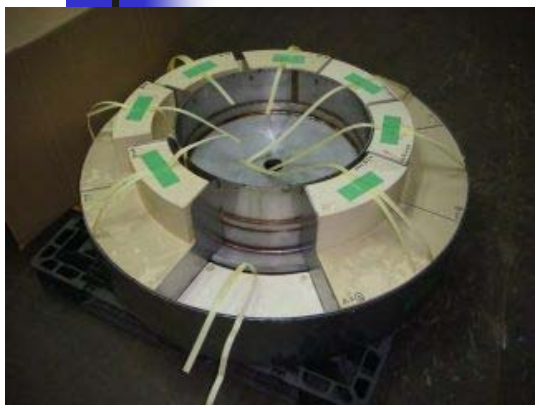
Hitz-B69 cask

Transport and storage cask containing BWR 69 spent fuel



(Length: 6.8m, Diameter: 3.5m, Mass: 132ton)

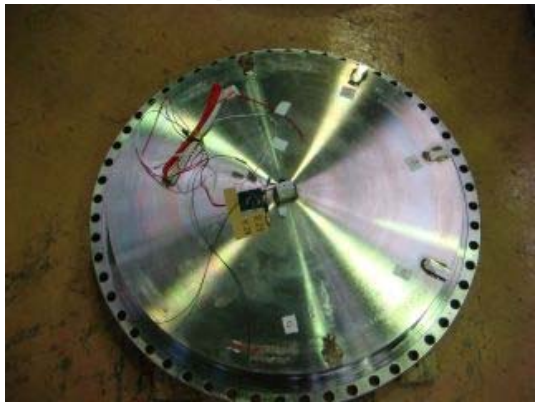
Parts of 1/3 scale cask model



Impact limiter

Impact limiter and cover plate

Content (Basket)



Primary lid

Secondary lid

Cask body

Hitz
Hitachi Zosen

Maximum acceleration (1/10 scale model)

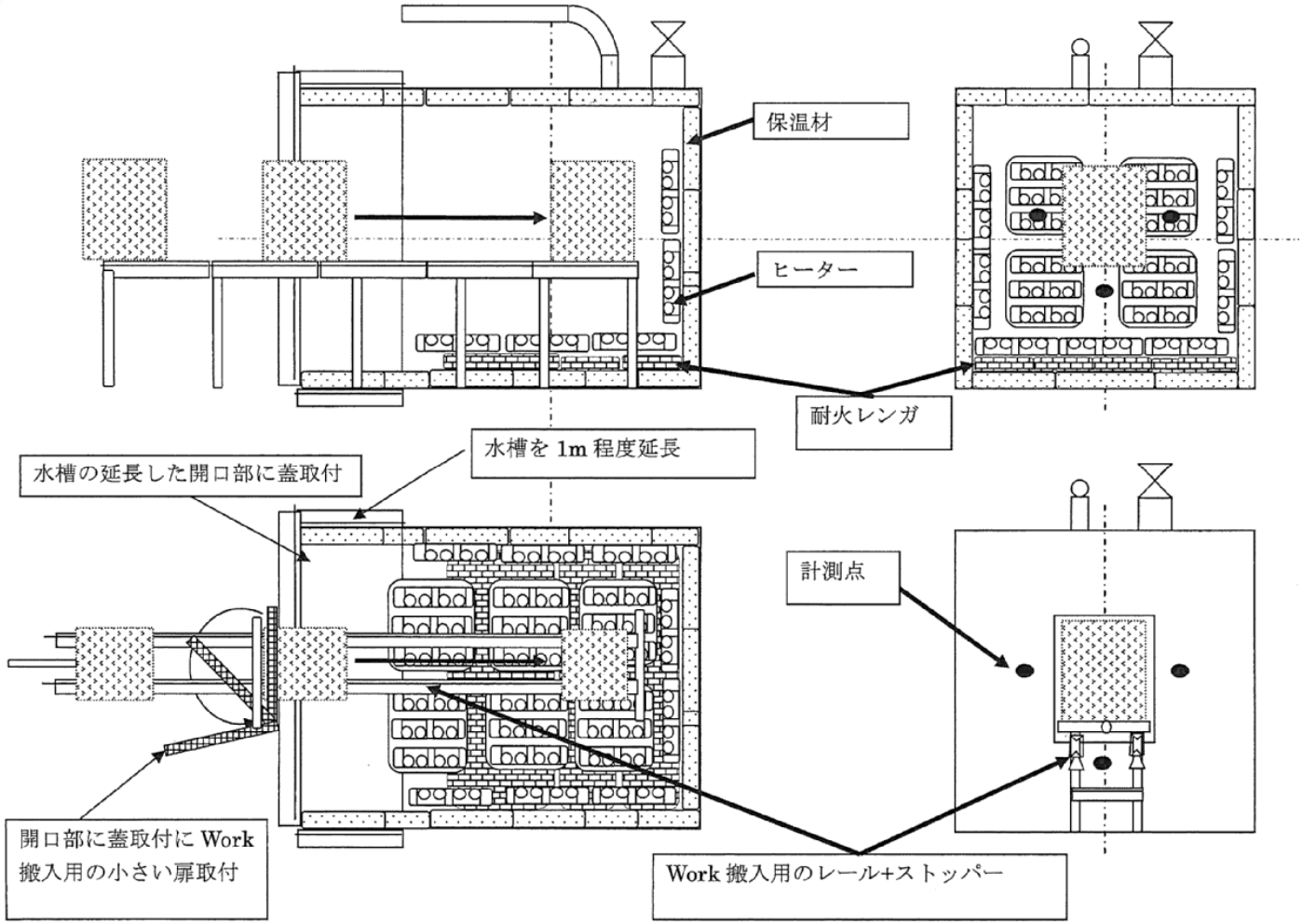
Material of impact limiter	Scale	Drop orientation	Maximum acceleration*	
			Lid (m/s^2)	Cask body (m/s^2)
R-PUF (FR3730)	1/10	Side Drop	579.0	532.1
Plywood**	1/3	Side Drop	623.3	545.6

*: Max acceleration was converted to the value of actual size cask according to the similarity law
**: Result of the plywood as material of the impact limiter refers to [1]

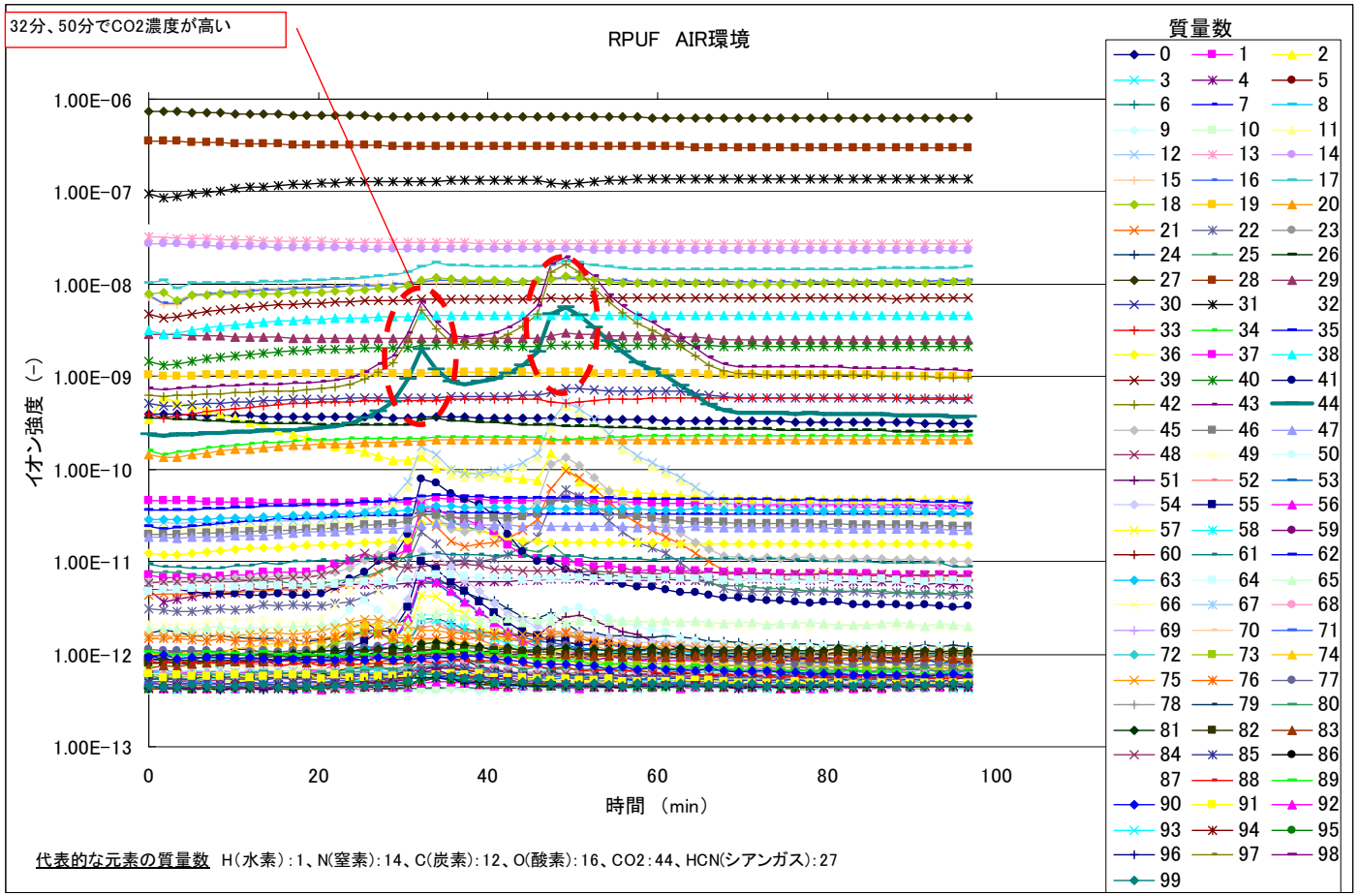
The R-PUF model showed a decrease by 2-7% in the maximum acceleration compared to the plywood model. Thus, the impact limiter composed of R-PUF indicated superior shock absorbing capability to that composed of plywood.

[1] H. Tobita and K. Araki: Containment Performance of Transportable Storage Casks at 9m Drop Test. PATRAM2004, Berlin, Germany, 2004.

Overviw of furnace



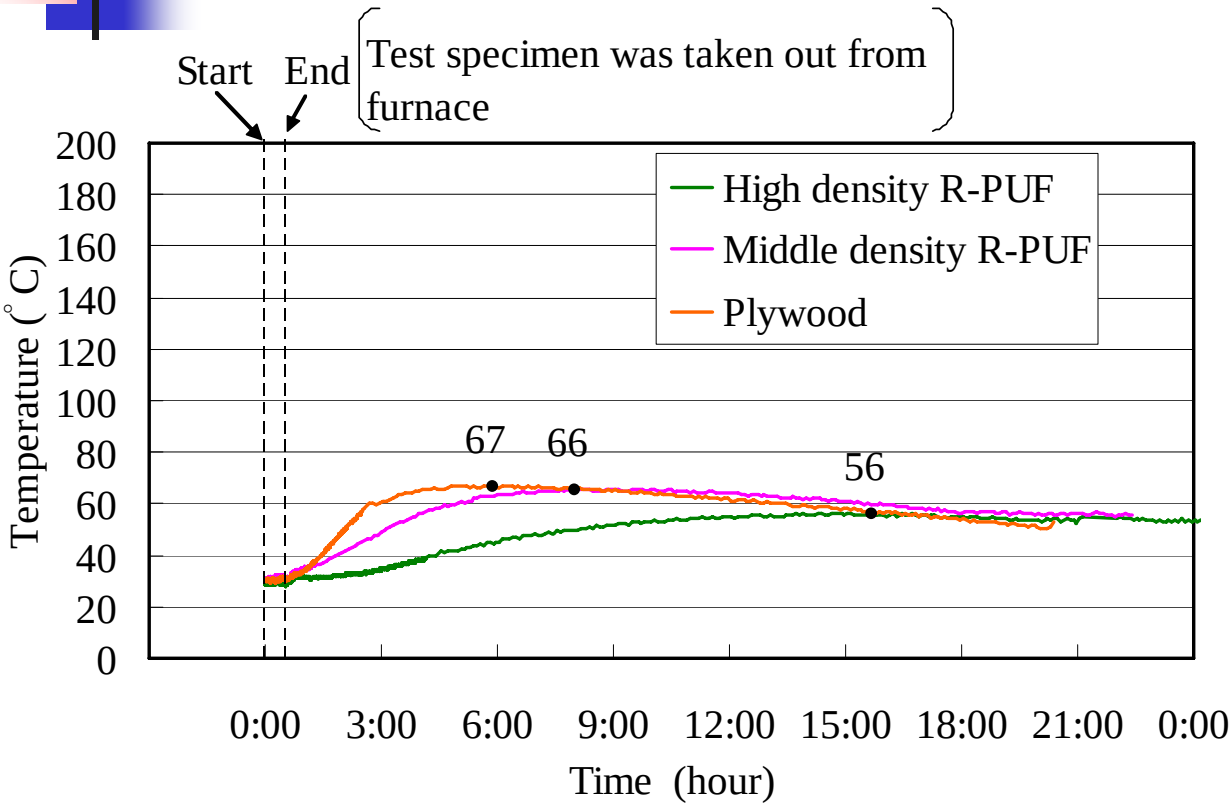
Differential thermal analysis of R-PUF



TG/DTA：

Seiko Instruments
TG/DTA220

Inside temperature of test specimen



These results indicate that R-PUF showed almost the same fire resistant capability as plywood.