Design of Double Containment Canister Cask Storage System

M.Asami[1], T.Oohama[2], K.Kuriyama[3], K.Kawakami[4], T.Matsumoto[1]

1) Design Division, OCL Corporation Osaka Branch Office, Nakanoshima Intes, 6-2-40, Nakanoshima, Kita-ku, Osaka 530-0005, Japan
2) Plant Engineering Group, Nuclear Power Division, The Kansai Electric Power Co., Inc., 3-3-22, Nakanoshima, Kita-ku, Osaka 530-8270, Japan
3) Engineering Department, Nuclear Fuel Transport Co., Ltd., 1-1-3, Shiba Daimon, Minato-ku, Tokyo 105-0012, Japan
4) Design Division, OCL Corporation, New Nishishinbashi Building, 2-11-6, Nishishinbashi, Minato-ku, Tokyo 105-0003, Japan

SUMMARY

Spent fuels discharged from Japanese LWR will be stored as recycled-fuel-resources in interim storage facilities.
The concrete cask storage system is one of important forms for the spent fuel interim storage. In Japan, the interim storage facility will be located near the coast, therefore it is important to prevent SCC (Stress Corrosion Cracking) caused by sea salt particles and to assure the containment integrity of the canister which contains spent fuels.
KEPCO, NFT and OCL have designed the double containment canister cask storage system that can assure the long-term containment integrity and monitor the containment performance without storage capacity decrease. Major features of the combined canister cask system are shown as follows:

- This system can survey containment integrity of dual canisters by monitoring the pressure of the gap between canisters.
- The primary canister has dual lids sealed by welding. The secondary canister has single lid tightened by bolts and sealed by metallic gaskets.
- The primary canister is contained in the transport cask during transportation, and the gap between the primary canister and the transport cask is filled with He gas. Under storage condition in the concrete cask, the primary canister is contained in the secondary canister, and the gap between these canisters is filled with helium gas. Hence this system can prevent the primary canister to contact sea salt particle in the air and from SCC.
- Decrease of cooling performance because of the double canister is compensated by fins fitted on the secondary canister surface. Then, this system can prevent the decrease of storage capacity determined by the fuel temperature limit.
- This system can assure that the primary canister will keep intact for long term storage. Therefore, in the case of pressure down of the gap between canisters, it can be considered that the secondary canister containment is damaged, and the primary canister will be transferred to another secondary canister at the interim storage facility to continue the storage.
- Furthermore, the primary canister will be able to restore in an advanced system such as high capacity vault system adequate for fuels with decreased decay heat and dose rate.

1. Design of the Double Containment Canister Cask Storage System (NEO-CCC)

Main Problems with Spent Fuel Storage Casks

It is under consideration that spent fuels discharged from Japanese LWR are stored two systems; the metallic cask storage system and the concrete cask system.
The problems with these storage systems are as follows:

Metallic Cask Storage System

- Japanese interim storage facility is planned without hot cell. The metallic cask has metallic gaskets at lids for sealing device. Therefore, in case of the loss of sealing function of the primary lid by the aging degradation of metallic gaskets, it is impossible to open the secondary lid. For this reason, the cask with damaged metallic gasket of the primary lid has to be out from the interim storage facility to replace gaskets.

Concrete Cask Storage System

- In the concrete cask storage system, the canister has dual lids sealed by welding. Therefore, the concrete cask system has a high-reliability for the sealing performance. Japanese site location of interim storage facilities, however, will be located near the coast, thus it is necessary to prevent SCC caused by sea salt particles. There are three ways to prevent SCC: the reduction of residual stress caused by welding on the canister, the keeping environmental condition management on the canister surface (e.g. humidity management), the use of super-corrosion-resistant steels. It is difficult to reduce of residual stress of the welded part and to manage humidity on the canister. There are no data to perfectly remove generation of SCC, even if any material is used.

- The canister of the concrete cask in ordinary use doesn't have monitoring system for the sealing performance under storage condition. It is considered that the use of storage system without monitoring system is unacceptable by general public in Japan.

Features of the Double Containment Canister Cask Storage System (NEO-CCC system)

Fig.1 shows the design example of the Double Containment Canister Cask Storage System (NEO-CCC system) solved problems described above.

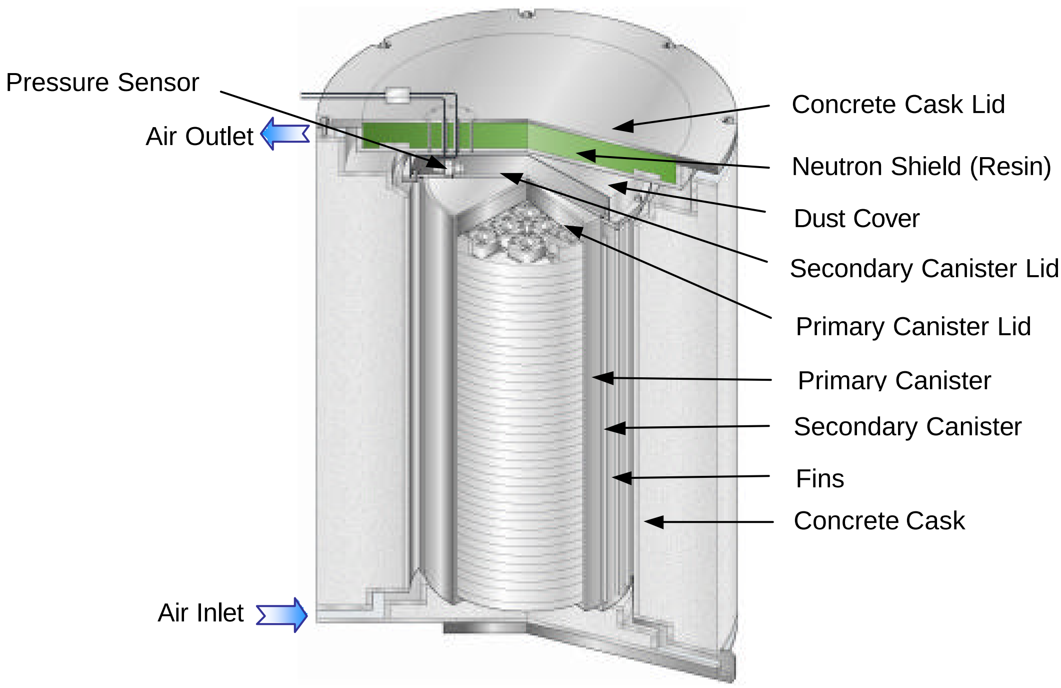
The primary canister used in the NEO-CCC system is ordinary canister, which is made of stainless steel welded structure with dual welded lids. The primary canister containing fuel assemblies is stored into the secondary canister in the concrete cask. The safety features of the NEO-CCC system are as follows:

Securing and assurance of sealing performance

Fig.2 shows upper part of the concrete cask under storage condition. The NEO-CCC system has dual canisters: the primary canister and the secondary canister. The gap between the primary canister and the secondary canister is filled with helium gas, and the primary canister is not directly exposed to surrounding atmosphere. The primary canister is, therefore, able to avoid SCC caused by sea salt particles. Besides, the pressure of the gap is monitored continuously, so that the containment integrity or non-integrity of the secondary canister is obtained. The pressure decreasing will be occurred by the loss of sealing performance of the secondary canister because the secondary canister will be kept inlet in helium gas. Therefore, the primary canister will be transferred to another secondary canister at the interim storage facility without hot cell to continue the storage.

Enhancement of the Heat Removal Performance

Fig.2 also shows heat flow at the gap between the secondary canister and the concrete cask. Double containment system causes arising temperature of fuels and basket in the primary canister, compared with ordinary canister systems. In this system, heat radiation fins are fitted the surface of the secondary canister to increase heat removal performance.



Size	External Diameter	3.6 m
	Overall Height	5.9 m
Main Material	Primary Canister	Stainless Steel
	Secondary Canister	Carbon Steel
	Concrete Cask	Carbon Steel+Concrete+Resin

Fig.1 Double Containment Canister Cask Storage System (NEO-CCC System, example)

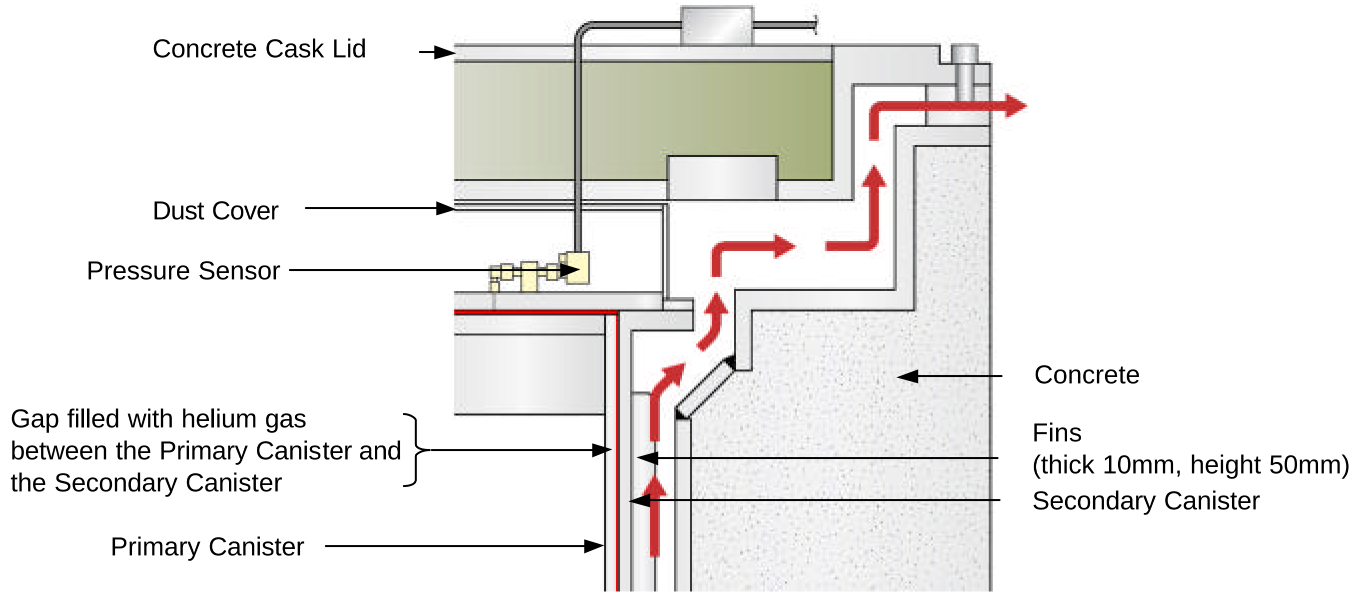


Fig.2 Upper Part of the NEO-CCC System

2. SAFETY EVALUATION OF THE DOUBLE CONTAINMENT CANISTER CASK STORAGE SYSTEM

Loading conditions of Storage System

Table.1 shows loading conditions of storage system used in safety evaluation:

Table.1 Loading Conditions of Storage System Used in Safety Evaluation

	Unit	Value
Heat Load	kW/Cask	21
No. of Fuel Assemblies	No./Cask	PWR fuel: 24
Initial Enrichment	wt% U-235	4.2
Max. Burnup	MWd/MTU	48000
Cooling Time	year	10

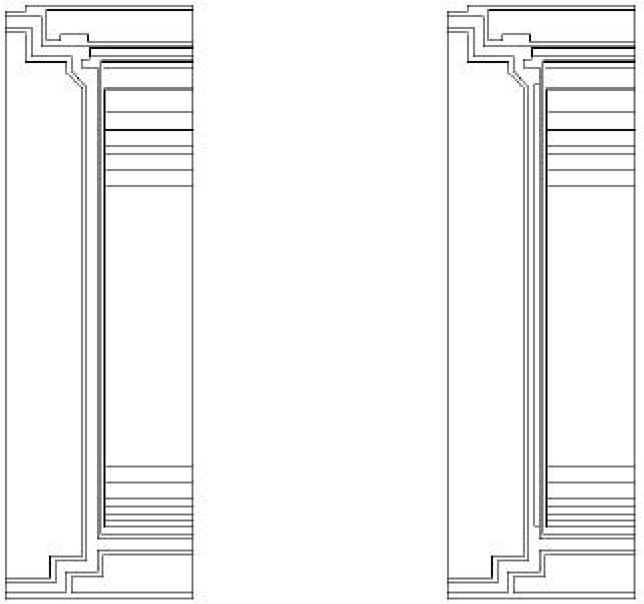
Thermal Evaluation

Heat flow analysis for NEO-CCC system cask has been performed to evaluate thermal performance of the system under storage condition by using FLUENT analysis code. **Table.2** shows the principal input parameters of heat flow analysis. **Fig.3** shows the analytical model. **Fig.4** shows temperature distribution, and **fig.5** shows the vector diagram of air flow velocity.

Table.3 shows maximum temperatures of main parts of NEO-CCC system cask. The temperature difference between canisters is about 21°C (The case of without Fin). It means that the inner temperature goes up 21°C by the dual canister structure. On the other hand, the inner temperature of the primary canister goes down 11°C by the attachment of fins. In this design, fin height is 50mm and number is only 36. Therefore, it is verified that the inner temperature could be reduced effectively by attaching suitable number of fins.

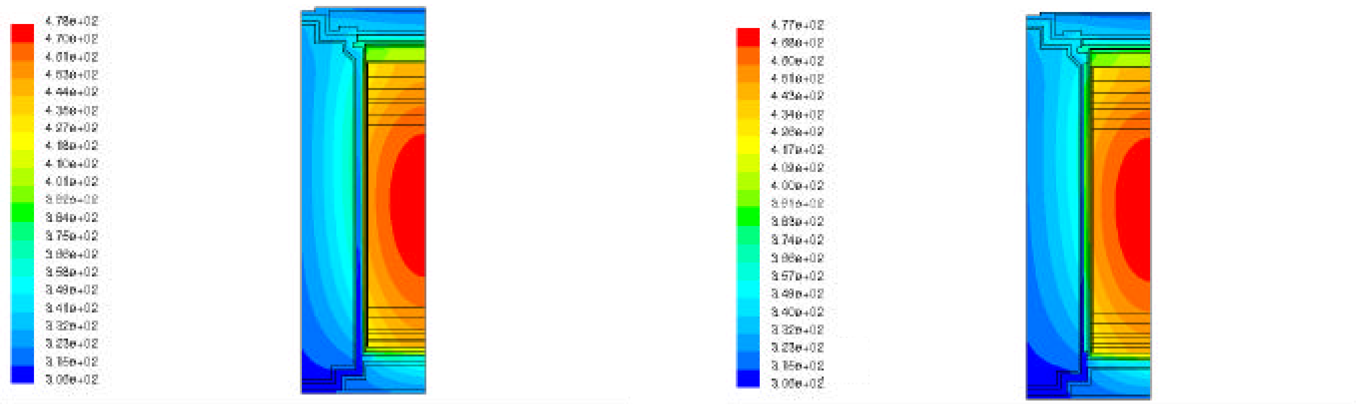
Table.2 Main Parameters of Heat Flow Analysis

Item	
Analysis Code	FLUENT
Air Temperature (Inlet Air)	33°C
Air Temperature (Average)	45°C
Max. Heat Generation	21kW
Turbulence Model	Realizable k-e model
Fins on the Secondary Canister	with Fin (36-pieces) or without Fin



(a) without fin (b)with fin

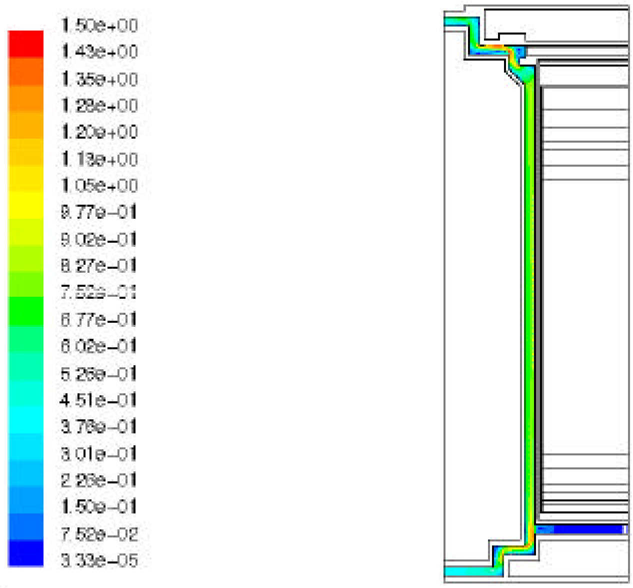
Fig.3 Analytical Model



(Unit:K) (Unit:K)

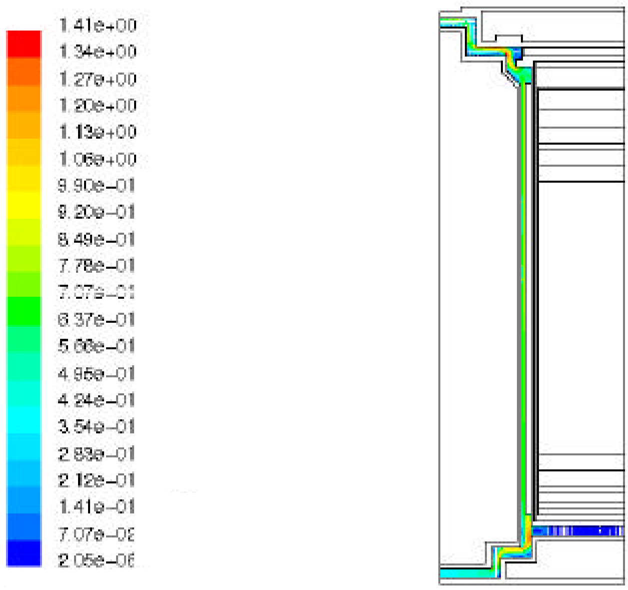
(a) without fin (b)with fin

Fig.4 Temperature distribution



(Unit:m/s)

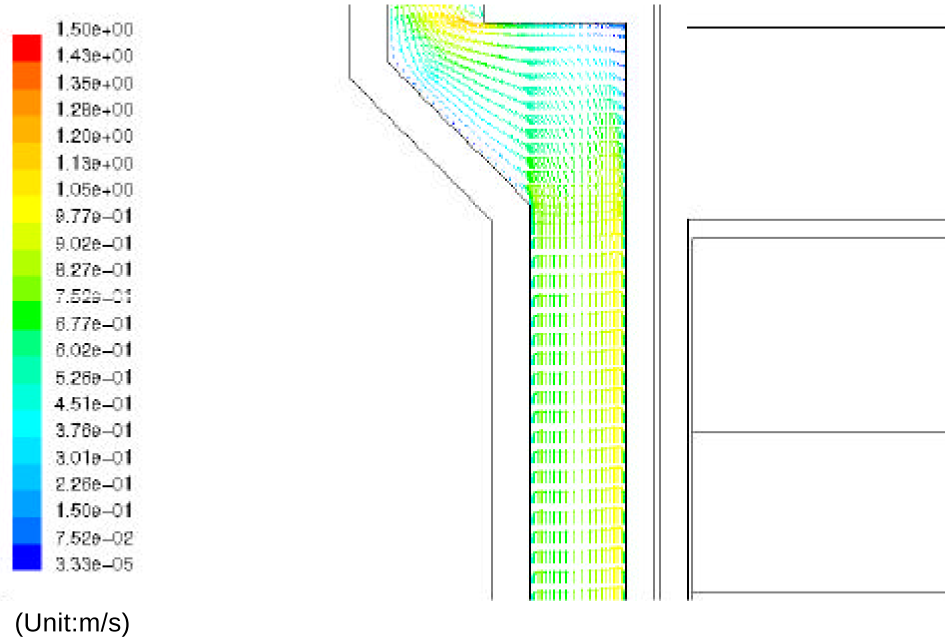
(a) without fin



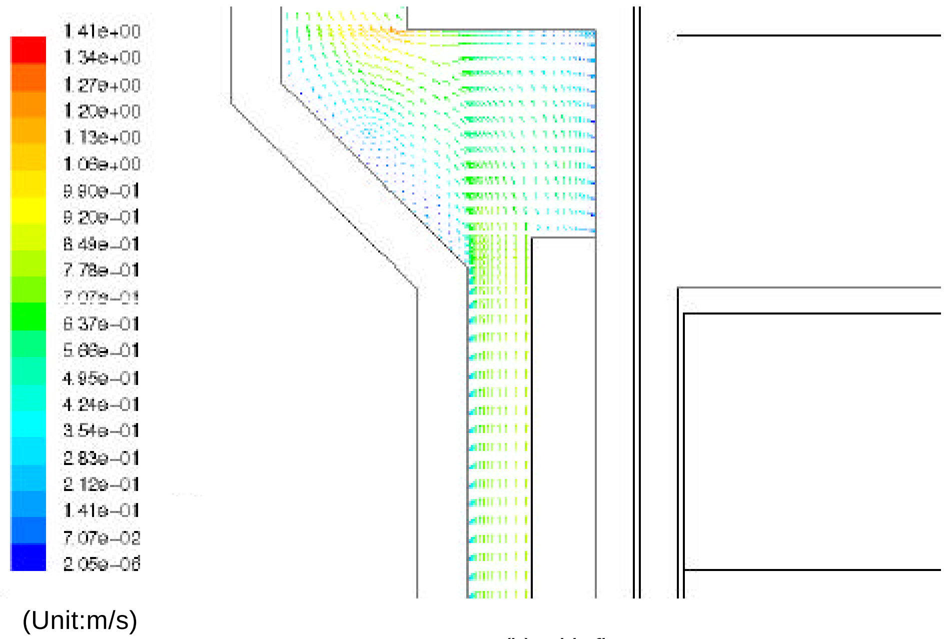
(Unit:m/s)

(b) with fin

Fig.5-1 Vector Diagram of Air Flow Velocity



(a) without fin



(b) with fin

Fig. 5-2 Vector Diagram of Air Flow Velocity (Upper Part)

Table.3 Summary of the heat flow analysis results

Location	Unit	Analytical Result(Max.)		Temperature Difference
		Without Fin(1)	With Fin(2)	ΔT:(1)-(2)
Internal Surface of Primary Canister Shell	°C	162	151	11
Internal Surface of Secondary Canister		141	125	16
Metallic Gasket of Secondary Canister		101	98	3
Exhaust Air		66	68	-2
Concrete		97	89	8

Shielding Evaluation around the NEO-CCC System Cask

In this design, the target of dose limit at 1-meter from the concrete cask surface is supposed about 40 m Sv/h in consideration of dose limit per year and working time.

The shielding analysis was performed by DOT3.5 computer code with DLC-23F cross section library.

Table.4 shows the shielding performance of the NEO-CCC system cask. It is found that the maximum dose rate is 89 m Sv/h at the concrete cask surface and 46 m Sv/h at 1-meter distance from the concrete cask surface. **Table.4** also shows dose rates near the upper/bottom duct (the air outlet/inlet) of the cask. Dose rates near ducts are not over the value of the side position. Hence, it has proven that the streaming-effect of ducts has little influence.

Table.4 Shielding Performance of the NEO-CCC System

Location		Dose Rate (m Sv/h)				
		Neutrons	Fuel Gammas	Gammas from Fuel Hardware Activation	Secondary Gammas Generated by Neutron Capture	Totals
Side	External Surface	9	47	20	13	89
	at 1-Meter from External Surface	4	25	11	6	46
Upper Duct	External Surface	30	1	17	1	49
Bottom Duct	External Surface	43	1	2	1	47

3. CONCLUSION

The double containment canister cask storage system (NEO-CCC system) has been developed, which solves problems for present storage casks. Safety evaluation for this system was performed as follows:

- Because of temperature difference occurred between the primary canister and the secondary canister, the temperature of the primary canister is probably greater than that of representative concrete cask system. By attaching suitable number of fins on the secondary canister, the inner temperature could be reduced effectively.
- The dose rate was evaluated for the NEO-CCC system. As a result, dose rates near ducts are not over the value of the side position. Hence, it has proven that the streaming-effect of ducts has little influence.

REFERENCES

Kawakami, K. et al., *Design of Spent Fuel Transportable Storage Cask*, PATRAM 2001 - Session 3.13 P-3 (2001).

Nakatani, T. et al., *Heat Removal Design for the Modular Shielding House for Keeping Spent Fuel Transportable Storage Casks in an Interim Storage*, PATRAM 2001 - Session 3.13 F-1 (2001).

Ueki, K. et al., *Shielding Ability of a Modular Shielding House for Keeping Spent Fuel Transportable Storage Casks in an Interim Storage Facility*, PATRAM 2001 - Session 3.13 F-2 (2001).