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SPENT FUEL TRANSPORT USING A CASK LOADED OUTSIDE THE POOL

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1. ABSTRACT

During the last year, SOGIN (the Italian company in charge for decommissioning of Italian NPPs) had to predispose an accelerated decommissioning plan of EUREX pool due to the finding of a water leakage toward environment from the pool. EUREX is a no more operating pilot reprocessing plant passed some years ago under the responsibility of Sogin. There were 52 spent FAs from Trino Vercellese PWR nuclear power plant, 48 irradiated pins from a Garigliano BWR FA, and 10 plates from an irradiated MTR FA stored in the EUREX pool, so the first steep of such accelerated decommissioning plan consisted in the evacuation of this spent fuel.
Considering the necessity to start the evacuation as soon as possible, Sogin decided to use an already existing cask (AGN-1) used in the past for the transport of Trino and Garigliano FA.
This cask has been requalified in order to obtain transport licence for the FAs stored in EUREX pool according to ADR 2005 regulation. Transport license for AGN-1 cask loaded with EUREX FAs was released by APAT (Italian Safety Authority) in the spring of 2007.
Due to limited capacity of EUREX pool crane (27 t for nuclear loads) and limited dimensions of pool operational area, it was not possible to transfer the AGN-1 cask (50 t) inside the pool for FAs charging.
The solution implemented to overcome this problem has been the loading of cask outside the pool. A special shielding shuttle was developed and used to allow safe spent fuel transfer between the pool and cask. This procedure avoided also problem of excessive contamination of cask surface that should had been arisen in case of cask immersion in the pool due to very high level of contamination of EUREX pool water.
Some other shielding devices were developed and used to reduce dose rate during cask loading operations.
Nevertheless the evacuation of spent fuel assemblies from EUREX pool was a very challenging activity due to short time available, unfavourable space conditions inside pool building and handling tools limitations, all loading and transport operations were performed successfully and without particular problems.
10 transports were carried out to evacuate all spent fuel stored in EUREX pool. Spent fuel was transferred to Avogadro Deposit pool. First loading sequence start the 2nd of May 2007 and the first transport was performed the 6th of may 2007. The 10th and last transport was performed the 21st of July 2007.
A dose less than 50 μSv (neutron + gamma) has been measured for the most exposed operator during a complete cask loading sequence.

2. INTRODUCTION

Starting from summer 2006, SOGIN (the Italian company in charge for decommissioning of Italian NPPs) had to predispose an accelerated decommissioning plan of EUREX pool due to the finding of a water leakage toward environment from the pool.
EUREX is a no more operating reprocessing plant sited in North-West of Italy (Saluggia – Piemonte), passed some years ago under the responsibility of Sogin.
In the past, various types of irradiated FAs were transferred in the pool of the plant for studying reprocessing methodologies. Due to the stop of the reprocessing development program, some of those spent FAs remained stored in the pool.

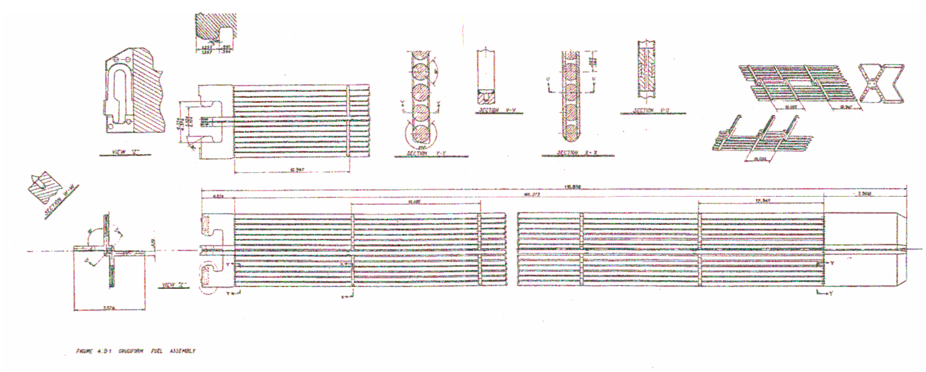
At summer 2006 there were 52 spent FAs from Trino Vercellese PWR nuclear power plant, 48 irradiated pins from a Garigliano BWR FA, and 10 plates from an irradiated MTR FA stored in the EUREX pool.
The first steep of the accelerated decommissioning plan of the EUREX pool consisted in the evacuation of all spent fuel stored inside the pool.
Considering the necessity to start the evacuation as soon as possible, Sogin decided to use an already existing cask (AGN-1) used in the past for transportation of Trino and Garigliano FAs.
Due to limited capacity of EUREX pool crane (27 t for nuclear loads) and limited dimensions of pool operational area, it was not possible to transfer the AGN-1 cask (50 t) inside the pool for FAs loading.
The solution implemented to overcome this problem has been the loading of cask outside the pool.

3. DESCRIPTION OF SPENT FUEL TRANSFERRED FROM EUREX POOL

<u>Trino Vercellese cruciform FAs</u>

52 FAs irradiated in Trino Vercellese PWR NPP were transported in 1977 at EUREX plant in view of a reprocessing program, and have been stored at EUREX pool for about 30 years.
Trino Vercellese NPP was one of the first PWR NPP model developed by Westinghouse, with particular core geometry.
The 52 FAs stored in EUREX pool have a peculiar cruciform shape (see figure 1) and inside the core they were placed among 4 standard FAs (24 in a fixed position, and 28 attached to cruciform shaped control rod).

Figure 1. Drawing of a cruciform Trino FA



All cruciform FAs were irradiated during the fist 4 cycles of Trino NPP (fist BOC 10/22/ 1964, last EOC 08/16/1974) and their burnup is in the range from 25674 MWd/tHM to 35635 MWd/tHM. The main nuclear and dimensional characteristics of those FAs are summarized in table 1.

Table 1. Trino cruciform FAs nuclear and dimensional characteristics

N° of Trino cruciform FAs	--	52
Fuel type	--	UO2
Total FA length	mm	2945.84
Active length	mm	2387
Max dimension of FA cross section	mm	191.82
Initial enrichment in ^{235}U	%	2.72
Max U tot in a FA	kg	38.955
Total nominal mass of FA	kg	72.64
N° of pins per FA	--	28
N° of fuel pins per FA	--	26
Cladding thickness	mm	0.7315
Pins external diameter	mm	10.922
Cladding Material	--	AISI 304
Top and bottom plate material	--	AISI 304

For the cruciform FA with the maximum burnup was performed an isotopic depletion evaluation with SAS2H sequence from SCALE 4.4 code package in order to evaluate isotopic inventory and neutron and gamma source spectra used for the design of shielding devises.
Total gamma and neutron source for the active zone of maximum burnup cruciform FA are respectively 1.18 E+14 photon/s and 1.55 E+07 neutron/s at reference date of 12/31/2003.

Fuel Pins from Garigliano NPP

48 half pins coming from a BWR FA irradiated at Garigliano NPP have been stored in EUREX pool since 1968. The original FA belong to the fist core of Garigliano NPP and it was irradiated during the two sub cycles of first reactor cycle (BOC 11/23/1963, EOC 05/07/1967) reaching a burnup of 9500 MWd/tHM. There are 4 different type of half pins, and their main nuclear and dimensional characteristic are summarized in table 2.

Table 2. Garigliano half pins nuclear an dimensional characteristics

N° of half pins	--	48
Fuel type	--	UO_2
Max half pins length	mm	1536
Max Initial enrichment in ^{235}U	%	2.1
Total U tot mass in the 48 half pins	kg	66.416
Max total weight of an half pin	kg	1.5
Cladding thickness	mm	0.762
Half pins external diameter	mm	13.56
Cladding Material	--	Zircalloy 2

Total gamma and neutron source for the 48 half pins, evaluated with SAS2H sequence, are respectively 5.08 E+13 photon/s and 4.79 E+05 neutron/s at reference date of 12/31/2003.

MTR irradiated plates

Various MTR reprocessing campaigns were performed at EUREX plant. After interruption of reprocessing activities, 10 irradiated plates coming from a MTR FA irradiated at Petten research reactor remained stored inside the pool. Each plate have dimensions of 62.5 x 7.11 x 0.127 cm and an initial total U mass of 9.36 g (initial U-235 enrichment of 89.65%).
The 10 plates have an average burnup of 247000 MWd/tHM and a decay time of about 42 years.

4. AGN-1 CASK

The AGN-1 was designed, manufactured and licensed (AgipNucleare) in the eighties for the transport of Trino and Garigliano spent fuel. More than 300 irradiated FAs were transported in the past from Trino and Garigliano NPPs to Avogadro deposit with AGN-1 cask.
A drawing of AGN-1 in transport configuration is reported in figure 2. A summary of main cask dimension and characteristic is reported in table 3.
The internal basket of AGN-1 has seven channels available for FAs loading.

Figure 2. Drawing of AGN-1 cask in transport configuration

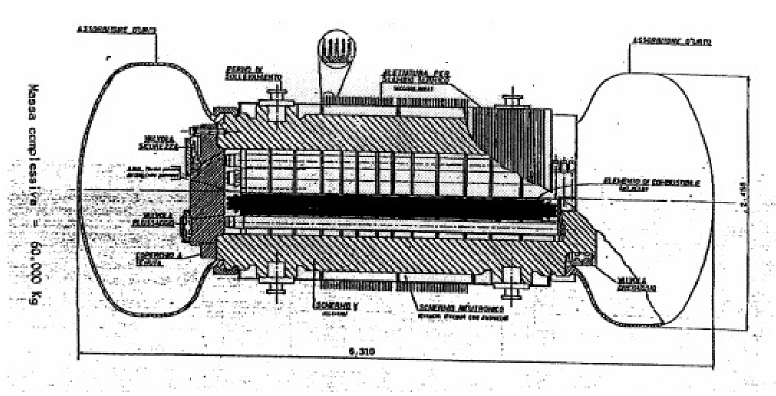


Table 3. Main dimensional data of AGN-1 cask

Cask high (without impact limiter)	cm	4120
Cask diameter	cm	1880
Internal cavity high	cm	3370
Internal cavity diameter	cm	840
Cask weight	tons	50

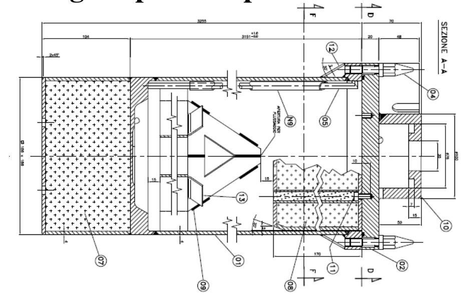
5. TOOLS AND EQUIPMENTS DEVELOPED FOR CASK LOADING OUTSIDE THE POOL

Considering the necessity to start the evacuation of EUREX pool as soon as possible, Sogin decided to use the AGN-1, an already existing cask, for transportation of spent fuel stored inside the pool.
However, for its dimensions and weight, there was no possible to transfer the AGN-1 inside EUREX pool. The solution implemented to overcome this problem has been the loading of cask outside the pool using additional equipments and tools developed and manufactured (in collaboration with AnsaldoNucleare) specifically to this scope.

Special capsule for FAs

A special capsule was developed to take in each Trino cruciform FA. This capsule, made in stainless steel, has a top lid with a shielding lead thickness (17 cm) and bottom lead shield (10 cm). Lid is provided with a seal in order to assure tightness when fixed on capsule. Capsule is equipped with two valves to allow water draining from capsule once it was closed. Figure 3 reports a drawing of the capsule.
For Garigliano half pins and Petten MTR plates, two specific transport quivers were developed in which those fuel were putted. The quivers were, in their turn, putted inside specific capsules similar to the capsule for Trino cruciform FA.

Figure 3. Drawing of special capsule for Trino cruciform FA



Shielding shuttle

A special shielding shuttle was developed and used to allow the safe spent fuel transfer between the pool and cask assuring the required shielding of the FA. Shielding shuttle is, basically, a lead cylinder with an internal cavity to host the FA or the capsule with FA inside. Shielding shuttle is 418 cm high and has an external diameter of 76 cm. The minimum shielding thickness of lead in radial direction is 12 cm. The upper part of shuttle provides a shielding thickness of 12 cm of lead. The shuttle cavity is open at the bottom. FA shielding in bottom direction, when shuttle is completely extracted from the pool, is provided by the bottom shield of the capsule.
The shuttle is equipped with a lifting devise designed in compliance with NUREG 0554 criteria that allows the safety hanging and lifting of Trino cruciform FA or of special capsule inside the shuttle cavity. Hanging is performed by a “twist lock” mechanism operated by a lever placed outside the shuttle. Lifting devise is driven by two (redundant) electrical engines. The total weight of shielding shuttle is 20 tons, so it can be handled without problem with EUREX pool crane for which the maximum critical load is 27 tons. A drawing of shielding shuttle is reported in figure 4.

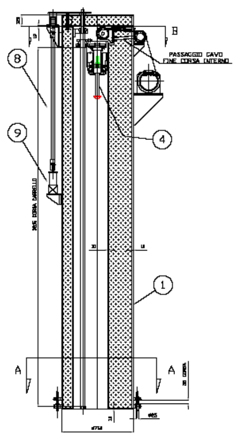
Additional shielding plate inside the cask

An additional shielding plate is placed above internal basket of cask. The plate, made in lead has a thickness of 11.7 cm. The plate has six holes in correspondence of the basket channels where capsule with FA have to be loaded. When capsule are lowered down in the basket, the upper shielding plug of capsule are placed at same level of shielding plate, so that a continuous shielding thickness above the FAs is assured.

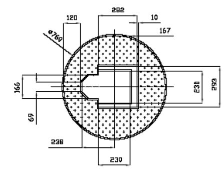
Special Cask lid for the loading with mobile shield

A special cask lid with 6 independent (one for each basket channel) mobile shields was developed to be use during cask loading in order to assure shielding during the lowering of the capsule with FA inside the channel of the basket. Shielding shuttle can be placed on the special cask lid, and opening one of its mobile shields, the capsule with FA can be lowered inside the channel below the opened mobile shield. Each mobile shield is driven by an electrical engine. A drawing of special cask lid is reported in figure 5.

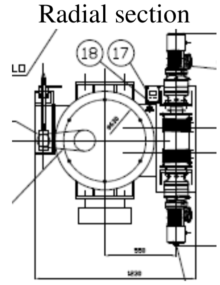
Figure 4. Drawing of shielding shuttle



Axial section

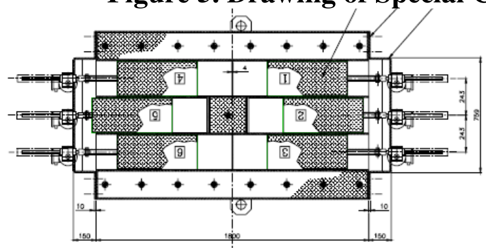


Radial section

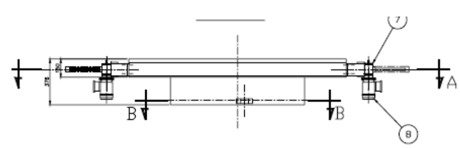


View from the top

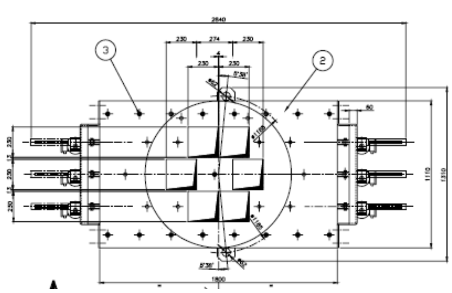
Figure 5. Drawing of Special Cask lid for the loading with mobile shield



Radial section



Axial section



View from the top

6. CASK LOADING SEQUENCE

As said above, AGN-1 internal basket has seven channels. However only six were used for the transport of spent fuel stored in EUREX pool, because there was no possible to predispose a mobile shield of special cask lid for the central channel of the basket.

The 52 Trino cruciform FAs were transferred with 9 transports (8 with cask loaded with 6 FAs and the last one with cask loaded with 4 FAs).

The Garigliano half pins and the Petten MTR plate were transferred with one transport using two basket channels, one loaded with the capsule containing the transport quiver with the 48 Garigliano half pins and the other one loaded with the capsule containing the transport quiver with the 10 MTR plates.
Loading sequence for the Trino cruciform FAs can be summarized in the following steps:

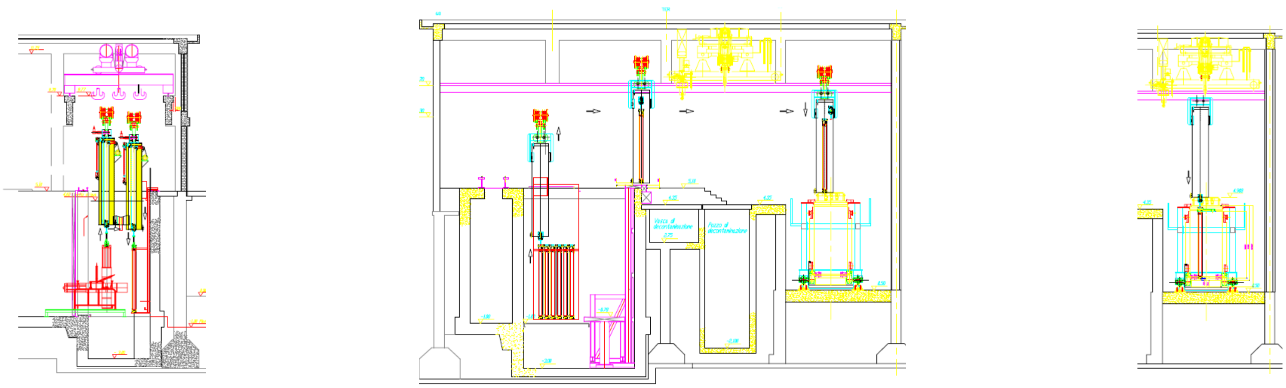
1. In the pool, the cruciform FA is transferred from the rack where it is stored into the special capsule. Due to inadequate pool deep, shielding shuttle is needed for this transfer to assure adequate shielding. In fact during this operation FA is partially outside the water (about 1.5 m). So FA is hooked by shielding shuttle lifting devise, lifted inside the shuttle cavity and then lowered into the special capsule. Capsule shielding lid is then placed and fixed. Water is left inside the capsule to improve neutron shielding during FA transfer in the cask, so capsule is only partially drained using capsule connecting valves.
2. The capsule with a FA inside is hooked by shielding shuttle lifting devise and lifted inside the shuttle cavity.
3. The capsule with FA inside is transferred by shielding shuttle from the pool to the cask positioned in the entrance area of pool building.
4. Shielding shuttle is coupled with special cask lid, above one of the basket channels for FAs.
5. The mobile shield of special lid that close the channel is moved in open position and the capsule inside the shuttle is left down inside the basket channel.
6. Mobile shield of special cask lid is moved back in closing position.

Step from 1 to 6 is repeated for 6 FAs to fill all the available cask basket channels.

7. The special lid with mobile shields is removed
8. The cask original lid is positioned and fixed.
9. Radiological controls on cask surface are performed.

Once loading procedure is completed and leak test performed, cask is transferred outside the pool building, placed on the road vehicle and impact limiters are mounted. Then cask is ready to be transported.
A drawing reporting the loading sequence is presented in figure 6.
Garigliano half pins and MTR plate are loaded inside specific transport quivers (one for the 48 half pins and one for the 10 plates). Then each quiver is inserted in a special capsule. Once in the capsules, loading sequence is the same used for Trino cruciform FA, starting from step n° 2.

Figure 6. Drawing of loading sequence inside the EUREX pool building



FA is extracted from rack and inserted in the capsule using the shielding shuttle

Capsule with FA inside is transferred from the pool to the cask using the shielding shuttle

Capsule with FA inside is lowered down in to the cask

7. RADIOPROTECTION CONSIDERATIONS

One of the most important aspects that have been carefully analyzed for the solution of loading the cask outside the pool is the dose to the operators involved in the loading operations.
Considering the Trino cruciform FA with maximum burnup, to which correspond the maximum neutron and gamma source term, shields have been designed in order to reduce dose rate to an acceptable level for all the phases of loading sequence in the areas where operators are present.
Beside shielding equipments described in chapter 5, to improve shielding (in particular for neutrons) during loading sequence, water is left inside capsule and inside the cask cavity. The quantity of water inside the cask cavity is so that, once all the six capsules are inserted inside basket channels, water level reach the top of cavity, covering all the capsules with FAs.
Considering the geometry complexity of the problem, in the design phase, shielding evaluations have been performed using three dimensional codes. For neutrons and for all the situations in which gamma flux streaming or reflections can give rise to a non negligible contribution to dose rate, Monte Carlo code MCNP has been used for calculations. For gamma, in the situations in which only the attenuated flux through the shield contribute to the dose rate outside the shield, point kernel code QADS from SCALE 4.4 is used for calculations.
In table 4 for each loading phase (see chapter 6) is reported the estimated time duration, the involved operator number and the corresponding dose foreseen in design phase.

Table 4. Estimated individual dose and collective dose for loading sequences in design phase

Loading phase	Loading phase duration	Dose/loading phase	N° of loading phase/loading sequence	Individual dose/loading sequence	N° of operator	Collective Dose/loading sequence	N° of loading sequences	Collective dose for 10 loading sequences
	min	(µSv)		(µSv)		(man.µS)		(man.µS)
1	15	10.3	6	61.8	3	185.4	10	1854
2	8	5.5	6	33	3	99	10	990
3	30	22	6	132	2	264	10	2640
4	2	1.8	6	10.8	2	21.6	10	216
5	15	3.8	6	22.8	2	45.6	10	456
6	5	0	6	0	1	0	10	0
7	7	12.5	1	12.5	3	37.5	10	375
8	75	46.7	1	46.7	3	140.1	10	1401
9	15	3.3	1	3.3	2	6.6	10	66
TOT				**323**		**800**		**8000**

Due to conservative assumptions intentionally used during the design phase for dose rates calculation, and regarding distances of operators from source and time duration of loading phases, the dose actually measured for the most exposed operator during a complete loading sequence was less then 50 µSv, about 1/6 of estimated dose.
The collective dose for all the 10 loading sequences was less than 1.5 man.mSv
Those very good results in term of operational exposure for a not conventional operations has been reached by means of a careful design of activity and shielding device, carrying out of adequate radioprotection procedures and a thorough training of operators.
Moreover the loading outside the pool avoided problem of excessive contamination of cask surface that should had been arisen in case of cask immersion in the pool due to very high level of contamination of EUREX pool water, avoiding dose to the operators during cask surface decontamination.

8. AGN-1 CASK LICENSING FOR TRASPORT OF SPENT FUEL STORED IN EUREX POOL

In the summer of 2006, when Sogin decided to use AGN-1 cask for transport of spent fuel stored in EUREX pool, AGN-1 has not been used for a long time, and cask license for transport was expired in 2001. Furthermore transport license was related to standard Trino FAs and to Garigliano FAs, and not to cruciform FAs, as the ones stored in EUREX pool, nor to Garigliano half pins and MTR plates.

So, in parallel to design of loading sequence and devices, Sogin started a licensing iter with APAT, the Italian safety authority, in order to obtain license for the transport of spent fuel stored in EUREX pool with AGN-1 cask.

All the needed analyses (mechanical, thermal, shielding, criticality, release) were performed, in collaboration with University of Pisa DIMNP, to demonstrate the compliance of cask, loaded with Trino cruciform FAs, Garigliano half pins and MTR plates, with the requirements of radioactive material transport regulation (ADR 2005).

In particular, an accurate impact analyses has been performed by University of Pisa DIMNP to demonstrate that Trino cruciform FAs and Garigliano half pins do not undergo to cladding breaking following to the worst type of impact to be considered for the accidental condition according to ADR 2005 (9 m cask drop on unyielding surface)

Transport license for AGN-1 cask loaded with EUREX spent fuel was released by APAT in the spring of 2007. The package has been classified as B(M)F type according to ADR 2005.

9. CONCLUSIONS

Nevertheless the evacuation of spent fuel assemblies from EUREX pool was a very challenging activity due to short time available, unfavourable space conditions inside pool building and handling tools limitations, all loading and transport operations were performed successfully and without particular problems.

Ten transports were carried out to evacuate all spent fuel stored in EUREX pool. Spent fuel were transferred to Avogadro deposit pool.

First loading sequence started the 2nd of May 2007 and the first transport was performed the 6th of may 2007. The 10th and last transport was performed the 21st of July 2007.

A dose less than 50 μSv (neutron + gamma) has been measured for the most exposed operator during a complete cask loading sequence.

10. ACKNOWLEDGMENTS

We would like to thank very much all the people who worked to the project of evacuation of spent fuel from EUREX pool, that with their relevant efforts make possible to successfully complete the fuel transfer in a so short time. A special thanks to EUREX plant personnel for their professionalism and availability. Our gratefulness goes also to AnsaldoNucleare which designed and realized the equipments for loading sequence and to University of Pisa DIMNP for its relevant work for supporting the cask transport licensing.

We would like to express, finally, our appreciation for APAT for its availability in processing quickly Sogin application for the EUREX spent fuel transfer project and for its indications and surveillance aimed to improve the safety in the transfer activities.

11. REFERENCES

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[2] NUREG 0554 “Single failure cranes for nuclear power plant”

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[4] MCNP4C: Monte Carlo N-Particle Transport Code System. RSICC-CCC-700