Current Approval Procedures for Type-B Packages in Germany: Selected Topics

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INTRODUCTION

This paper completes the overall view about the current approval activities for Type B packages in Germany during the last 6 years given in a further paper presented at this conference (Zeisler, P. et al. 1995). It discusses topics of special interest from the point of view of the German test authority for Type B packages (BAM).

The first topic concerns the verification (benchmarking) of computer codes which shall be used alternatively for the simulation of mechanical tests. Problems are discussed to be solved in this context from the point of view of BAM. The evaluation of the design criteria by BAM for the CASTOR V/HAWC shipping cask to be used for the transport of high-active waste concentrates (HAWC) from Germany to the reprocessing plant in Mol (Belgium) is the second topic. The last topic deals with the properties of ductile cast iron (DCI), i.e., the material that is preferably used in Germany for large Type B shipping casks.

POLLUX - DROP TESTS AND DROP TEST SIMULATION USING COMPUTER CODES

The POLLUX cask (Figure 1.1) is designed for the transport, interim and final storage of either divided (10 PWR or 30 BWR) or complete fuel elements (4 PWR or 10 BWR). The packaging consists of two casks, the inner containment manufactured from steel and the outer shielding cask manufactured from DCI. The radial gap between the casks amounts to about 1 mm. Two lids are used for the closure of the inner cask, a primary one screwed by 24 bolts and a secondary one with a leaktight weld between the lid rim and the inner cask. The outer cask lid with a thread at its periphery is screwed into the cask.

The papers of Quercetti et al. (1995) and Gogolin et al. (1995) give detailled information about the drop test program and some interesting results of the tests performed with the POLLUX cask. In addition to the certification oriented purpose of that test program, it should also be used for the verification of computer codes applied for analytical test simulations. Further reason for these extensive investigations was the special design of the POLLUX consisting of two casks put into one another.

On one side, the analytical test simulation is allowed alternatively to real tests according to the IAEA Regulations and also the German national regulations (e.g., GGVS 1994); on the other side, the qualification of users as well as the verification (benchmarking) of the codes are necessary prerequisites to get reliable results by analytical test simulations. In order to improve the basis for future analytical test simulations, the BAM and the designer had agreed pre-test computer analyses for all test positions. As the last step, post-test calculations are necessary which require a detailed comparison of test and analytical results with the aim to find out and to explain the reasons for differences. This step of verification requires parametric studies in order to modify modelling assumptions (options as nodalization, modelling of coupling of package components by bolts, shock absorbing elements or other devices, modelling of material behaviour, shock absorber modelling, etc.).

The kind of problems arising in that verification process can be illustrated by two examples for the POLLUX cask:

o Figure 2 shows the comparison between experimental and the analytically estimated axial strains for the test condition "horizontal 9 m drop of the package equipped with shock absorbers, contact of the trunnions with the target in the second phase of the drop" at the location: shielding (i.e., the outer) cask, center, outer surface. Though there exist differences in the duration of the deceleration phase (test: about 20 ms, calculation: about 40 ms), the differences between the maximum strains (about 30%) are in an order which should still be acceptable. The differences in the duration of the drop may be primarily caused by the used shock absorber models. Moreover, some deviations between the experimental and analytically estimated strain functions are explainable by a nonrealistic simulation of the trunnions: Both curves deviate above all after about 7 ms drop duration (the trunnions got contact with the target at that moment). So far, the influence of other (i.e. more realistic shock absorber and trunnion) models on the analytical results must be clarified by systematic post-test analyses.

  Because of the large number of parameters which can influence the results of calculations, it should also be useful to perform probabilistic sensivity analyses using methods recommended (e.g., by Glaeser et al. 1995). That method takes into account probability distributions of all important input parameters and input functions. By different computing runs with random combinations of the inputs taken from these distributions it is possible to get results that have increasing probabilities with an increasing number of runs.

o Figure 3 shows an example with extremely large differences between test and analytical results for the location: secondary (welded) lid of the inner cask, welding seam. Test condition is the "9 m drop of the package onto the outer edge of the lid shock absorber" (deviation from the vertical position: about 16 degrees). The parameter compared is the radial strain. The deviation between the calculated (38 ms) and measured drop duration (55 ms) is smaller in this case and could be explained also by the used shock absorber model. However, the calculated strains are obviously incorrect at all four peripheral locations. (The measured time functions are nearly identical for these positions.) The reason for the differences is probably the modelling of the inner dam-pening elements between the lid of the outer cask and the secondary lid of the inner cask. The model seems to assume a rather regular distributed load of the secondary lid by the forces transmitted by the aluminium bars of the damper. Contrary to it, the test showed stronger deformations of the bars at the rims of the lids. These deformations are distributed in the center on both the aluminium bars and the rather flexible secondary lid of the inner cask. That causes greater lid deflections in the center and consequently at the fixed lid rim with the welding seam. Though the post-test analyses should generally take into consideration the aforesaid recommendations, calculations should primarily be performed with modified models of the dampening elements.

The results of this and further comparisons offer some problems of code benchmarking (and consequently of the use of computer codes alternatively to tests) which arise primarily from the modelling or other optional assumptions: A good agreement between experimental and analytical results at any reference location does not allow the conclusion that this is true at each other location. Furthermore, it means that the agreement between the experimental and analytical results for one test condition does not allow the conclusion that this is true for other test conditions, and that the agreement between the experimental and analytical results for one package design does not allow the conclusion that this is true for other package designs. However, the really necessary restrictions depend on the degree of verification (benchmarking) on one hand and on the experience of the user of the code on the other hand: the proper setting of the modelling and other options included in the code (see above) requires an extensive experience and qualification of the user.

Real tests performed with package prototypes or scaled package models had priority in Germany up to several years ago. Nowadays, the situation has been changed so far as efficient computer codes are available and the designers prefer computer code simulations alternatively. This requires unambiguous procedures for the computer code verification by pre-test calculations, tests, and post-test calculations for defined package geometries. So far, the POLLUX tests are part of this process.

CASTOR V/HAWC - CONCEPTION OF CONTAINMENT AND MATERIALS SELECTION

The CASTOR V/HAWC cask (Figure 1.2) is a specific design for the transport of high-active waste concentrates (HAWC) in form of 3.5-6.0 molar nitric acid loaded with radionuclides with a maximum specific activity of about 18.5 TBq/liter. The total contents of the package amounts to 3,500 liter HAWC and additional 200 liter flushing liquid.

The design of the cask had to consider the possibility of a release of large parts of the activity from a containment of usual design which is much higher for liquids then for packages containing, e.g., spent fuel elements. The barriers of fuel elements (cladding, fuel matrix) limit substantially the part of activity to be released if the containment of the package fails in consequence of an accident. This higher risk of HAWC transports led to requirements to the CASTOR V/HAWC shipping cask which are more stringent then those necessary according to the IAEA Regulations. The most important safety characteristics of the cask, which are the result of many discussions (with participation of the German authorities including BAM), are as follows:

o The primary containment (i.e., the containment in the proper sense of the IAEA Regulations) is, with exception of the primary lid, enclosed by a secondary containment, i.e., a steel liner. The gap between the containment and the liner is accessible and allows the control of pressure and activity concentration in it. Because of the corrosion resistence of the liner material, countermeasures (evacuation of the package) are possible before dangerous situations with activity releases into the environment arise after a primary containment leakage.

o Both containments are manufactured from stainless steel (X2 CrNi 19 11) with a Molybdenum percentage < 0.3%. This material has been already used for the HAWC storage tanks which are in operation for many years without any corrosion problems.

o The seals used for the small closure lids of the containment (primary lid) are gold plated metal seals additionally protected against a direct contact with HAWC by double elastomer seals which are also resistent against nitric acid for periods in the order of the duration of transports.

o Protection of the closure lids of the primary containment by a secondary lid that provides a compartment between the primary and secondary lid. It would act as a useful buffer if activity should be released through the closure lid seals.

o Additional measures in order to compensate the lack of an impossible periodic inspection of the outer wall of the (inner) containment covered by the liner: periodic video inspection of the inner walls of the containment and continuous control of the gap between containment and liner (see above).

Though results of drop tests with CASTOR casks of similar design (e.g., CASTOR Ia, Ic, IIa) were available, it was necessary to prove that the (inner) containment does not fail if the package would be subject to the mechanical tests. With the aim to guarantee a minimum failure probability of the containment, BAM asked for particular safety proofs for these accident conditions and made high demands on the outer cask that has, in addition to its shieldung function, a protective function for the inner containment:

o Proof of permissible strains at the junction (i.e., the welding seam) between the primary lid and the cylindrical shell of the (inner) containment under IAEA test conditions, especially at the horizontal 9 m drop test and the 9 m drop test flat onto the bottom shock absorber, and ensuring by measures of quality assurance during manufacture and assembling of the containment that the gap between containment and liner does not exceed the tolerable measure (0.25 mm) and that the gap between the liner and the outer (shielding) cask is fully filled up by the specified material.

o Stipulation of very stringent material properties (compared with those for other Type B packages) for the outer cask that is manufactured from DCI.

According to the results of the expertise of BAM, the integrity of the inner containment is guaranteed under all conditions to be taken into consideration. Besides the limitation of the stresses on the permissible level (0.9 $R_{p0.2}$), the material of the inner containment is a very tough steel excluding a brittle fracture, on one hand. On the other hand, the radial and axial gaps between the the components of the packages ensure that the possible strains can not nearly reach the very high value of the ultimate elongation (40%) of the inner cask material.

A hypothetical failure of the outer cask will not generally influence the leaktightness of the inner cask. Moreover, the experience of the BAM with DCI cask tests and the results of calculations show that a brittle fracture can be excluded under IAEA test conditions. The remaining risk resulting from a hypothetical failure of the cask at conditions beyond those defined in the IAEA Regulations (IAEA 1990) is reduced by fracture toughness values of 2,250 $Nmm^{-3/2}$ and ultimate elongations of >12% even for specimens taken from the centre of the walls.

QUALITY LEVEL OF GERMAN DCI CASKS

DCI has been used in Germany for about 15 years as a basic material for Type B shipping casks. Since that time, BAM has analyzed the material properties of about one thousand DCI casks. The results of the BAM examinations are summarized in Figures 4 and 5, here illustrated by the ultimate elongation values. The Figures show clearly the high-quality level that has been reached already at the beginning of the 15 years period for cask wall thicknesses lower than about 350 mm. On the other hand, an evident increase of the ultimate elongation has been achieved for wall thicknesses greater than 350 mm. The latter is a result of improved casting technologies and carefully planned casting procedures, especially with respect to the chemical composition of the original (raw) material, the design of casting moulds, and the casting process itself. The results for the CASTOR designs examined by BAM last year underlines that fact: All elongation values measured with specimens of CASTOR X/28F (wall thickness 393 mm), CASTOR 440/84 (465 mm), CASTOR HAW 20/28 CG (515 mm), and CASTOR V/19 (515 mm) are higher then 10 %. The ultimate elongation stands here for other important properties of DCI (e.g., the fracture toughness) which show qualitatively a similar behaviour.

SUMMARY AND CONCLUSIONS

The paper gives an overall view about Type B cask-related certification activities in Germany during the last years. Some more detailed deliberations concerned the problem of the IAEA drop-test simulation by using computer codes and the requirements for HAWC shipping casks. Moreover BAM results of DCI material testing are presented. The conclusions can be summarized as follows:

- o The use of computer codes for the IAEA drop test simulation which is generally accepted according to the IAEA Regulations requires a reliable proof that the codes are verified for adequate cask designs and load conditions. The verification of codes is a complicated and obviously very expensive process. Cooperation between interested users would be advantageous for that reason.

- o HAWC transports require specified cask designs because of the higher risk of accidents in case of cask failure. From the point of view of the German authorities, specified requirements have to be fulfilled by such casks in addition to the requirements of the IAEA Transport Regulations.

- o DCI is a well-established material for Type B packages. The safety level of these packages has been proved by tests according to the reqirements of the IAEA Regulations as well as by tests beyond these conditions. Moreover, the properties of DCI have been continuously improved during the last years especially for thick-walled casks by more appropriate casting technologies.

REFERENCES

Gogolin,B., Droste, B., Quercetty, T., *Drop Test Program with the German POLLUX Cask for Final Disposal of Spent Fuel*, conference paper PATRAM '95, Las Vegas NV, USA (1995)

Glaeser, u.a., *Quantifizierung der Unsicherheiten von thermohydraulischen Störfallrechnungen*, 19. GRS-Fachgespräch, Berlin, 25./26. 10. 1995

Quercetty, T., Droste, B., Gogolin, B., *Integrity of the German POLLUX Cask for Final Disposal: Experimantel Results of the Mechnical Tests*, conference paper PATRAM '95, Las Vegas NV, USA (1995)

International Atomic Energy Agency, *Regulations for the Safe Transport of Radioactive Material, 1995 Edition (As Amended 1990)*, Vienna, 1990

Jones, J. W. *Pre-Drop Analysis of POLLUX Cask, Part I, 9 m Side Drop, BAM No. 9.3/782, and 9 m End Drop*, BAM No. 9.3/783, Swanson Service Corporation, 1994;3 (unpublished report)

Jones, J. W. *Pre-Drop Analysis of POLLUX Cask, Part II, 9 m Corner Drop*, BAM No. 9.3/784 Swanson Service Corporation, 1994;6 (unpublished report)

Zeisler, P., Droste, B., Rödel, R., Rehmer, B., *Current Approval Procedures for Type B Packages in Germany - Overview*, conference paper PATRAM '95, Las Vegas NV, USA (1995)

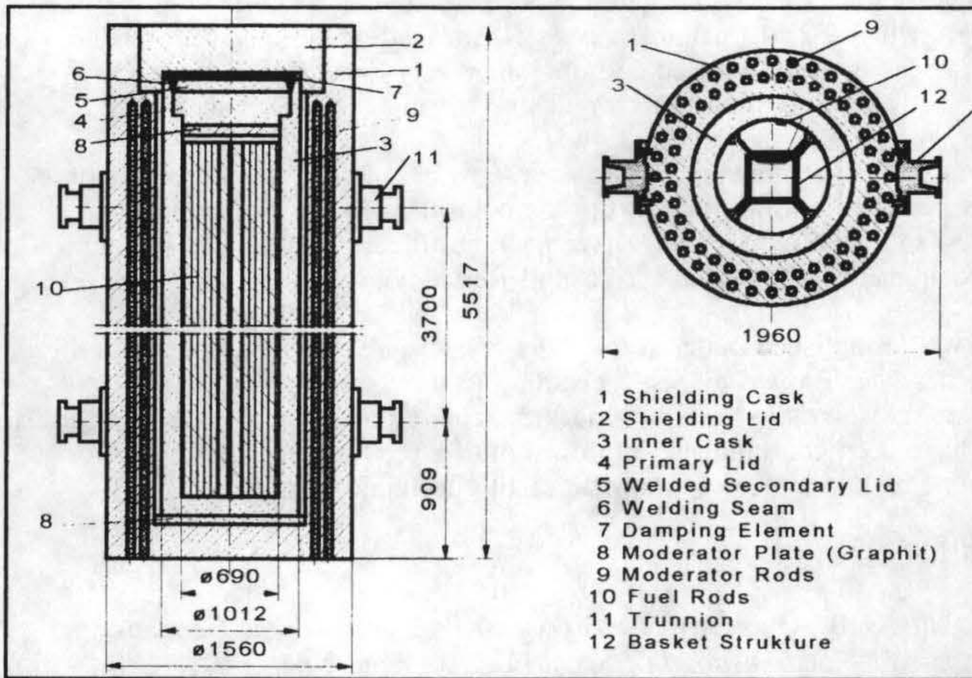

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Fig. 1.1: POLLUX Final Disposal Cask

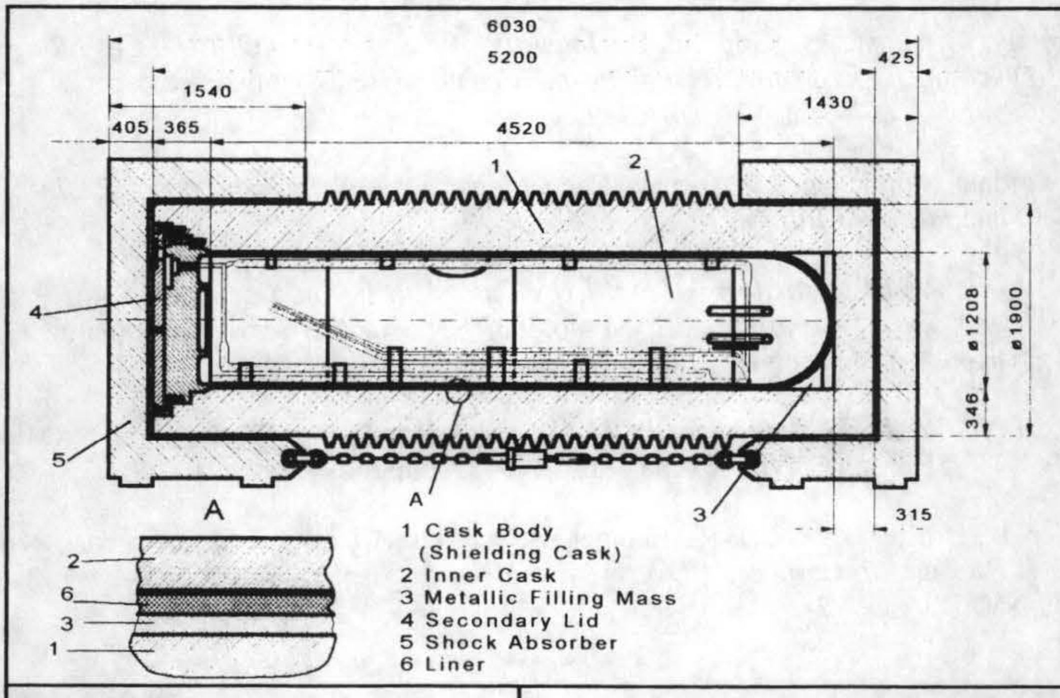

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Fig. 1.2: Transport Cask CASTOR V/HAWC Longitudinal Cut

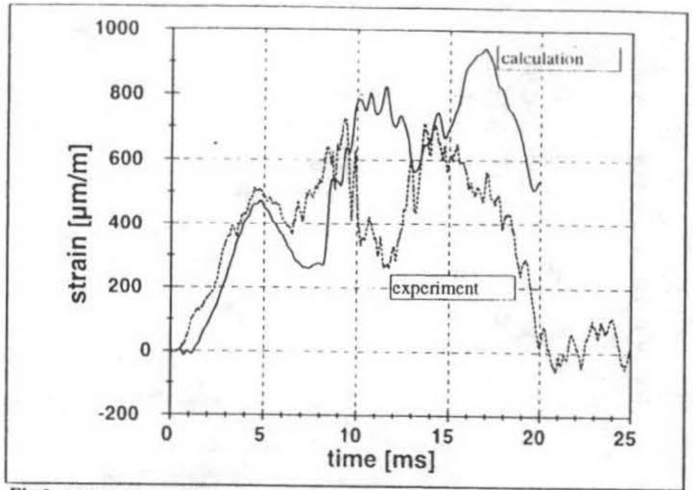

Fig.2: POLLUX; 9 m Side Drop; Maximum Axial Strains in the Outer Cask Wall
Calculation: ANSYS (Jones, J.W. 1994,3)

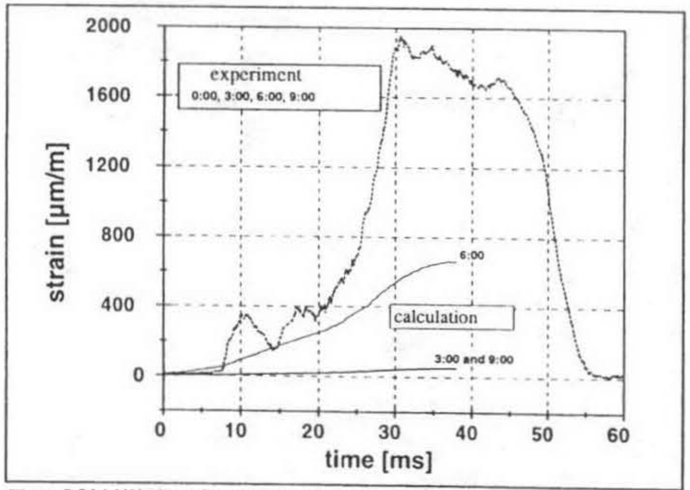

Fig.3: POLLUX; 9 m Corner Drop (Lid Shock Absorber);
Radial Strains in the Weld of the Secondary Lid (Inner Cask);
Calculation: ANSYS (Jones, J.W. 1994,6)

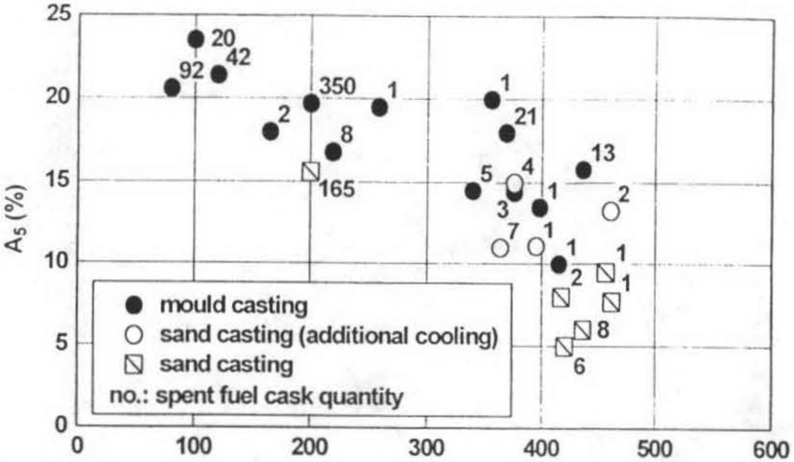

Fig.4: Period from 1980 to 1989
Quality Level of DCI Spent Fuel Casks
Ultimate Elongation vs. Wall Thickness
Fig.5: Period from 1990 to 1995