DOSE RATE MEASUREMENTS AT SEVERAL CASKS FOR TRANSPORT AND INTERIM STORAGE

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SUMMARY

Several types of dual purpose casks for transport and interim storage of spent fuel elements (SFE) and vitrified high-active waste (HAW) from reprocessing were approved in Germany in the past years. That are e.g. the following cask types:

- CASTOR IIa and CASTOR V/19 for spent fuel elements of pressurised water reactors, and
- CASTOR HAW-20/28-CG and TS 28 V for vitrified HAW from reprocessing

With the beginning of interim storage at the Gorleben site in April 1995 there was the possibility to carry out comprehensive dose rate measurements around loaded casks with different contents and different arrangement of neutron shielding.

The paper summarises the differences between the dose rates derived from commercial rem-counters and those reference values derived from neutron spectra at locations which are important for radiation protection and for the compliance with limits for the transport of radioactive material. Furthermore, several horizontal and vertical distributions will be shown. It is referred especially to points which are important for radiation protection during dispatch.

BRIEF DESCRIPTION OF THE CASK DESIGN AND CONTENTS

Dual purpose casks for transport and interim storage of the „CASTOR family" presented in this paper consist of a thick-walled finned cylindrical cask body made of ductile cast iron which is closed with a primary and secondary lid each made of forged or stainless steel and respective screws and seals (double-lid system). Polyethylene rods are built in into the cask body concentrically and polyethylene plates are placed at the bottom area and at the lower side of the secondary lid to make the neutron shielding more effective.

In contrast with the CASTOR-type casks the body and the lids of the TS 28 V cask are made of forged steel. The neutron shielding, borated resin, is fixed to the outer side of the cask body and manteled by a thin steel layer.

The outer dimensions of these four cask types (Fig. 1a to 1d) are about 2500 mm in diameter and 6000 mm in height. The loaded casks in the storage configuration weight 110 tons to 130 tons.

The gamma radiation around these casks mainly results from the fission products ^{137}Cs/^{137m}Ba, ^{134}Cs, ^{106}Ru/^{106}Rh, ^{144}Ce/^{144}Pr and ^{154}Eu. At casks for SFE also ^{60}Co contributes to the radiation field, due to steel activation of the fuel element carriers and the top fittings.

Neutron radiation is mainly caused by spontaneous fission of ^{244}Cm and (α,n)-reactions of ^{244}Cm and ^{241}Am with oxygen or boron. According to the Safety Reports the neutron emission due to (α,n)-processes is almost negligible for SFE (5 % ... 10 %) with a high burnup */Börst et al 1992/* while it has a share of about 50 % for vitrified HAW.

OBJECTIVES OF THE MEASUREMENTS

Measurements of neutron and gamma dose rates were performed at various positions that are relevant for radiation protection and for the compliance with the limits for transport as well as for the storage facility. The measuring points used at every cask are shown in Fig. 2. Some of these points must be explained in detail, that are

- MP3 - That is the point with the highest expected dose rate and with the „hardest" spectrum, especially for casks with SFE due to the burnup distributions of SFE.
- MP2 - At this point the „weakest" spectrum is expected when the cask is loaded with SFE.
- MP1 - Close to this point the workers spend most of the time while preparing the cask for the interim storage.

The objectives of the measurements were

- to determine accurately neutron and gamma dose rates and neutron spectra at various positions, inclusively their horizontal and vertical distributions,
- to estimate systematic measuring uncertainties of commonly used neutron monitors and to give regards for correction factors for routine surveys,
- to recognise weak points of the shielding due to the design of the casks, e.g. areas with reduced neutron absorbers.

MEASURING INSTRUMENTS

The gamma dose rates were determined with following area dosemeters:
- **FH 40 F2** (GM-counter) - FAG Kugelfischer, FRG
- **AD 5** (GM-counter), Automess, FRG
- **Szintomat 6134 A**, Automess, FRG

The total uncertainty of the gamma dose rates is assessed to about ± 25 %.

The neutron dose rates were measured with various survey instruments, so called 'rem-counters':

***Andersson-Braun* type** (cylindrical moderator with BF_3 counter):
- **NG 2** ('Snoopy') - Nuclear Technology Inc., USA
- **NM 2** - Nuclear Enterprises Ltd., UK,
- **2202D** - Alnor, SF
- **FHT 750** ('Biorem') - Eberline Instruments, FRG

***Leake* type** (spherical moderator with ^{3}He counter):
- **N 91** - Harwell Instruments, UK
- **0949** - Harwell Instruments, UK

***Berthold* type** (spherical moderator with He^3/Methane counter):
- **LB 6411** - EG&G/Berthold, FRG

Andersson-Braun and *Leake* type monitors have already been used for routine survey for more than 20 years. Except the LB 6411 and the FHT 750, the counters are calibrated by the manufacturer for the operational quantity 'maximum dose equivalent' H_{made} according to the ICRP 21 recommendation for ^{241}Am-Be neutrons (mean energy 4.5 MeV). The LB 6411 and FHT 750 are calibrated for the new quantity 'ambient dose equivalent' H*(10) according to the ICRP 60 recommendation for ^{241}Am-Be or ^{252}Cf neutrons (mean energy 2.1 MeV). In addition, the instruments of the Federal Office For Radiation Protection (BfS) were recently calibrated at a Am-Be standard field of the Physikalisch Technische Bundesanstalt (PTB). As a result of this calibration, deviations to the manufacturers data of less than 3 % for the LB 6411 and NG 2 rem-counters, but 23 % for the Harwell N 91 and 53 % for the Harwell 0949 were found.

It is a major disadvantage of all neutron survey meters that their dose equivalent response depends relatively strong on the neutron energy or the spectrum. (see Fig. 3). This unavoidable characteristic results in differences between real dose rates and measured ones, if the real spectra differ from those used for calibration. To quantify these differences, the dose rates measured with the individual dosemeters were compared with reference values. These reference dose rates were derived from neutron spectra measured by means of a *Bonner* multisphere spectrometer */Rimpler 1998/* with a total uncertainty of ± 15 % at maximum.

RESULTS

Table 1 shows the ratio of the measured neutron dose rates (H_m) to the reference neutron dose rate derived from a *Bonner* multisphere spectrometer, i.e. the average of H_m/H_{made} for the *Leake* and *Andersson-Braun* type monitors and H_m/H*(10) for the LB 6411 and the FHT 750, respectively, for the individual casks.

It is obvious that the LB 6411 monitors underestimate the dose rate for all spectra systematically by only about 10 % on average, with the smallest divergences for individual casks as well as for the overall response. The underestimation is not primarily attributed to the energy response of the counter but to the fact that the reference dose rates for H*(10) are about 50 % higher than those for H_{made} */Rimpler 1998/*.

The NG 2 and the NM 2 also provide sufficient results. Both rem-counters overestimate the „real" dose rate, the NG 2 by about 40 % and the NM 2 by 20 % on average.

The *Leake* type monitors considerably overread the dose rate - the Harwell N 91 by 100 % and the Harwell 0949 by 140 % on average - and show the highest variation of the relative response for the individual fields. The other rem-counters (FHT 750, Alnor 2202D) are listed in Tab. 1 for completion only.

It is intended to recommend the mean values for the relative dose equivalent response of the individual neutron monitors (last column in Tab. 1) as correction factors for routine surveys. This may help to improve the accuracy of dose rate measurements at transport and storage of CASTOR type casks.

Fig. 4 shows the distributions of the dose rates versus the cask height, measured at a distance of 30 cm from the outer surface. Some comments should be given to these illustrations:

- CASTOR IIa: The illustration indicates an increased gamma dose rate at about 1 m height, which is caused by the activated fuel element carriers.
- CASTOR V/19: The enlarged gamma dose rate at a height of 5 m could only be found for a very small area close to the trunnions It drops down to the expected level already a few centimetres outside this region.

- CASTOR HAW-20/28-CG: The higher gamma dose rate at the cask bottom is due to the reduced shielding in this area.

All gamma and neutron dose rates are below the limits for transportation and interim storage.

Fig. 5 shows horizontal dose rate distributions for three casks at different distances. These distributions confirm the expected course that is nearly proportional to the inverse of the distance.

Further extensive measurements, which can not be presented in detail within this work, were carried out to localise weak points of the shielding. The results can be summarised as follows:
At casks loaded with vitrified HAW, dose rates at the lid are higher than those on the middle of the cask side. While the neutron dose rate raised only by a factor of 1.3 at MP1 compared to MP3 for the CASTOR HAW-20/28-CG, an increase by a factor of about 25was found at the same points for the TS 28 V. The reason for that is the arrangement of the shielding in this area. Moreover, dose rate enlargements up to a factor of about 4 were observed at the trunnions of the TS 28 V, compared to MP3.
At the CASTOR V/19, increased gamma dose rates were detected only for very small regions, which are necessary in particular for the fixing of the cask during transport. In the meantime an improvement was achieved by additional technical measures, so that the dose rates reach the same level as in the area beside them. Finally, it is to be stated that even at these positions the dose rates did not exceed the permissible limits.

REFERENCES

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paper presented at this conference

Table 1: Relative Dose Equivalent Response of Neutron Monitors

Monitor Type		Operational Quantity	Calibration Source	Castor IIa (7 MP)	Castor V19 (3 MP)	TS 28V (3-4 MP)	HAW 20/28 (5 MP)	Overall Mean Response
				Mean Relative Response ± max. Deviation				
Berthold	**LB 6411**, BfS [1]	H*(10)	^{241}Am-Be	**0,88** - 5 % + 11 %	**0,94** - 5 % + 7 %	**0,95** - 1 % + 1 %	**0,90** - 6 % + 5 %	**0,92**
	LB 6411, BLG [2]	H*(10)	^{252}Cf			**0,95** - 14 % + 9 %	**0,87** - 1 % + 1 %	**0,91**
Andersson-Braun	**FHT 750** [2]	H*(10)	^{252}Cf		**1,07** - 13 % + 20 %		**0,90** - 18 % + 7 %	**0,99**
	NG 2, BfS [1]	H_{made}	^{241}Am-Be	**1,37** - 11 % + 16 %	**1,43** - 9 % + 9 %	**1,41** - 12 % + 20 %	**1,26** - 5 % +13 %	**1,37**
	NM 2, BLG [2]	H_{made}	^{241}Am-Be	**1,14** - 10 % + 18 %		**1,27** - 15 % +27 %	**1,23** - 3 % + 7 %	**1,21**
	Alnor 2202D-1, GKN [2]	H_{made}	^{241}Am-Be		**1,23** - 9 % + 16 %			
	Alnor 2202D-2, GKN [2]	H_{made}	^{241}Am-Be		**1,31** - 15 % + 23 %			
Leake	**Harwell N91, BfS** [1]	H_{made}	^{241}Am-Be	**2,21** - 12 % + 23 %	**2,05** - 10 % + 8 %	**1,84** - 5 % + 4 %	**1,84** - 3 % + 11 %	**1,99**
	Harwell 0949, BfS [1]	H_{made}	^{241}Am-Be	**2,58** - 13 % + 17 %		**2,32** - 17 % + 27 %	**2,31** - 6 % + 6 %	**2,41**

[1] Calibration factor according to the PTB calibration

[2] Calibration factor according to the manufacturer

BfS -	Federal Office For Radiation Protection
BLG -	Interim Storage Facility at Gorleben
GKN -	Nuclear Power Plant Neckarwestheim
PTB-	Physikalisch Technische Bundesanstalt

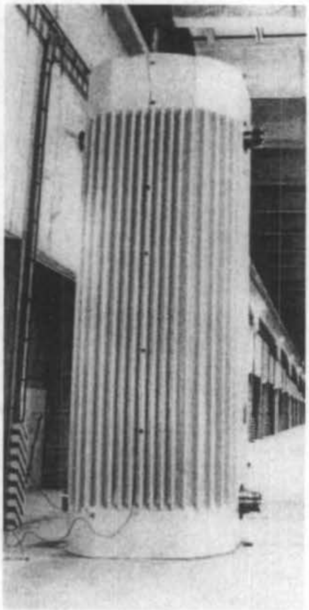


Fig. 1a: CASTOR IIa

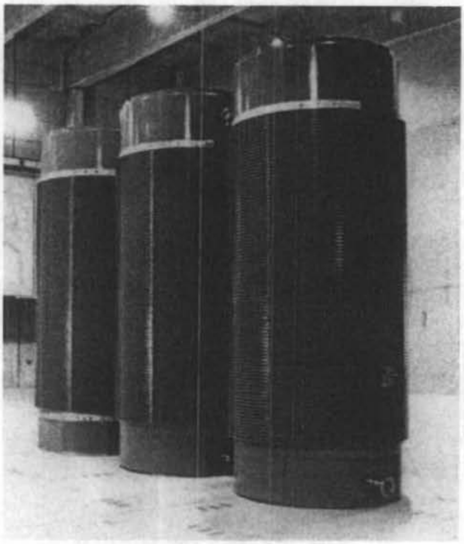


Fig. 1b: CASTOR V/19

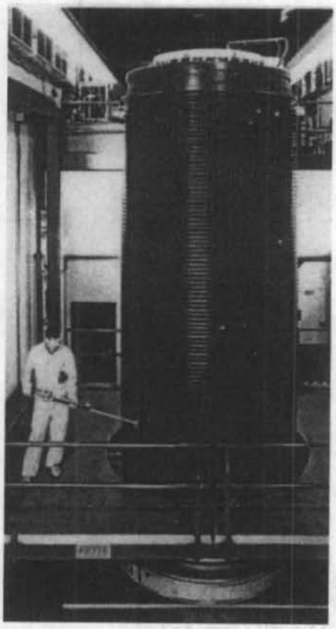


Fig. 1c: CASTOR HAW-20/28-CG

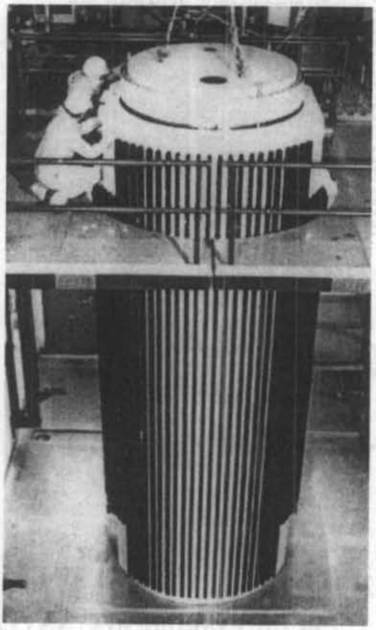


Fig. 1d: TS 28 V

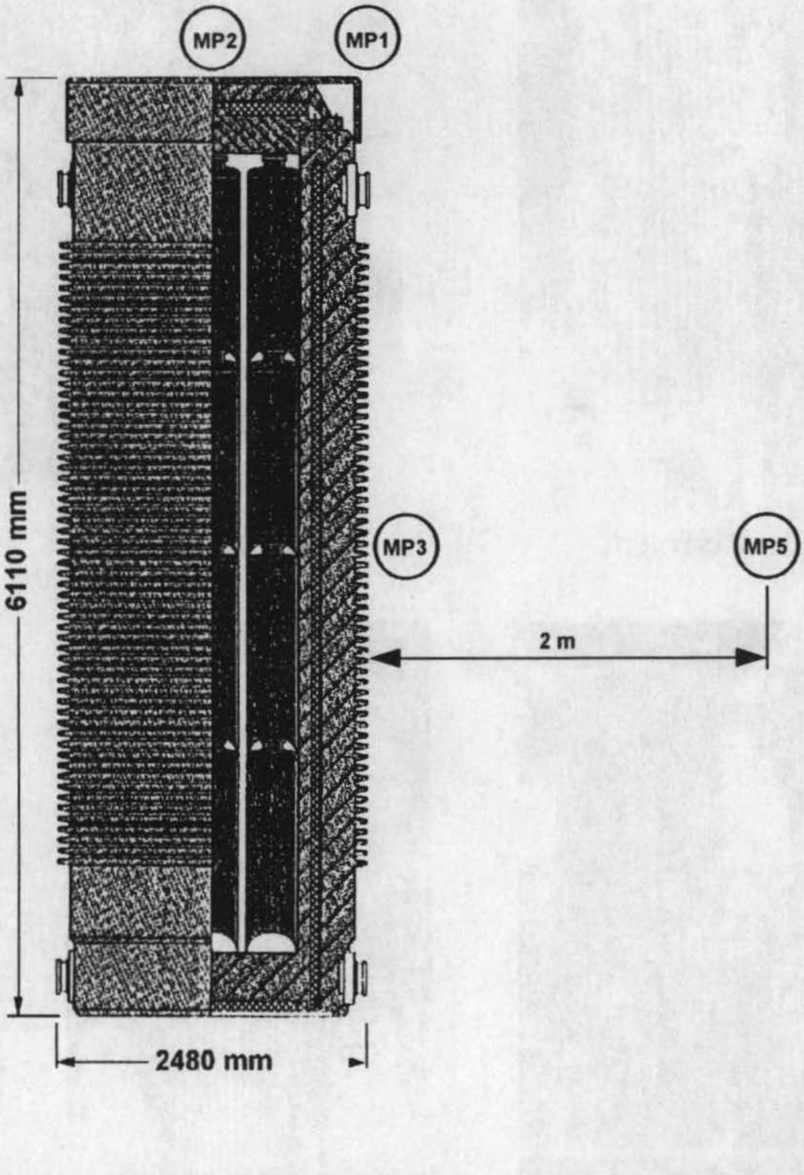


**Fig. 2: Important Measuring Points
(on the example of CASTOR HAW-20/28-CG)**

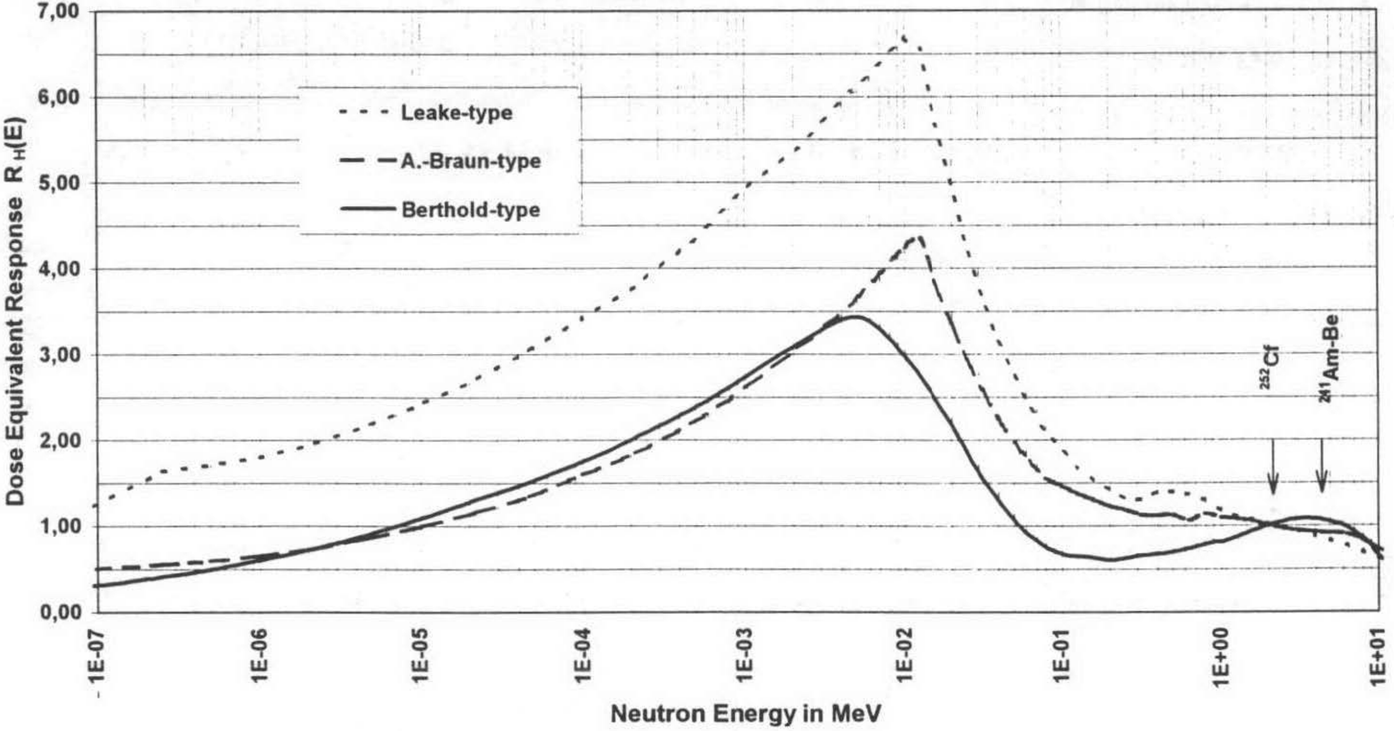
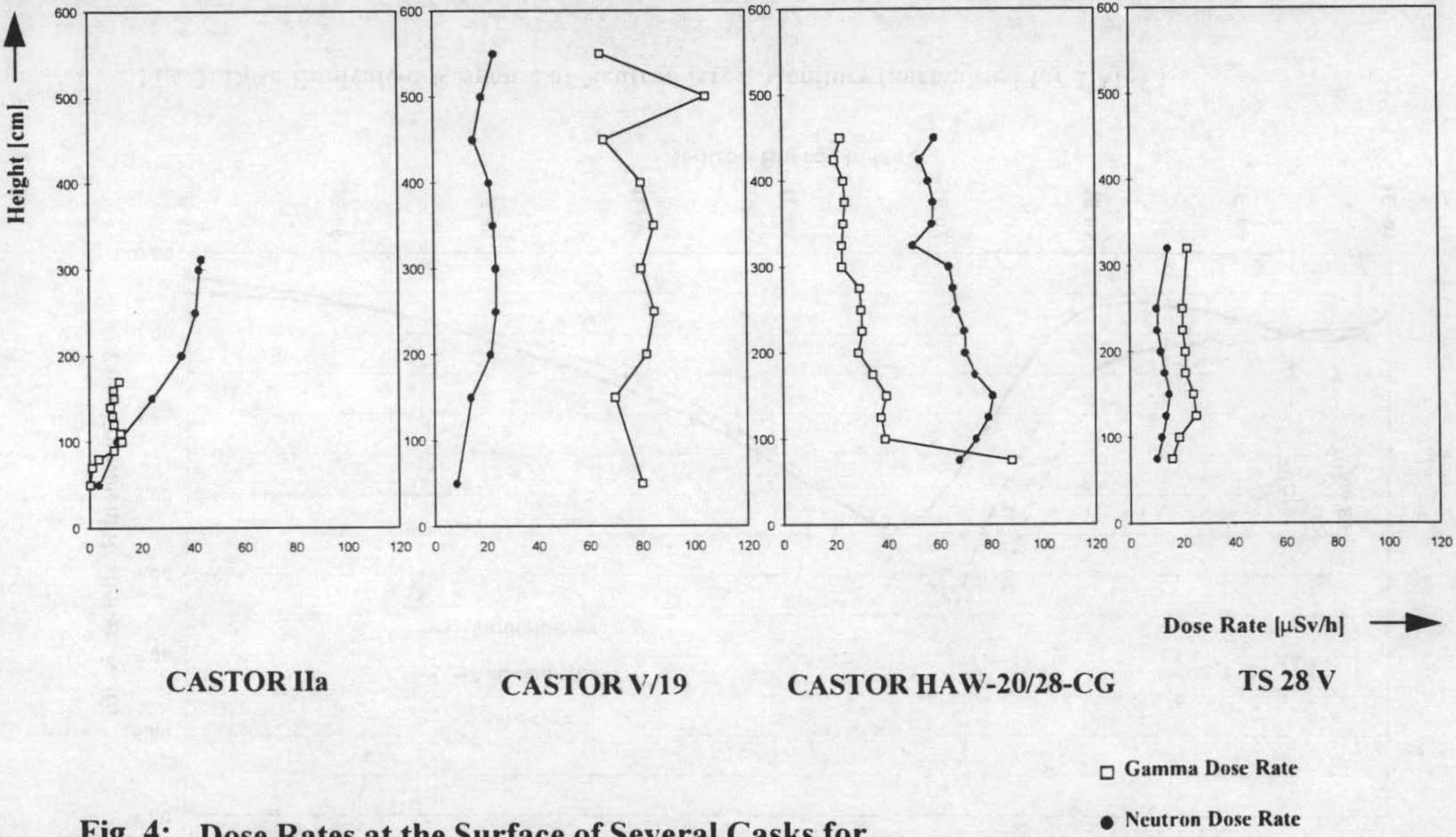
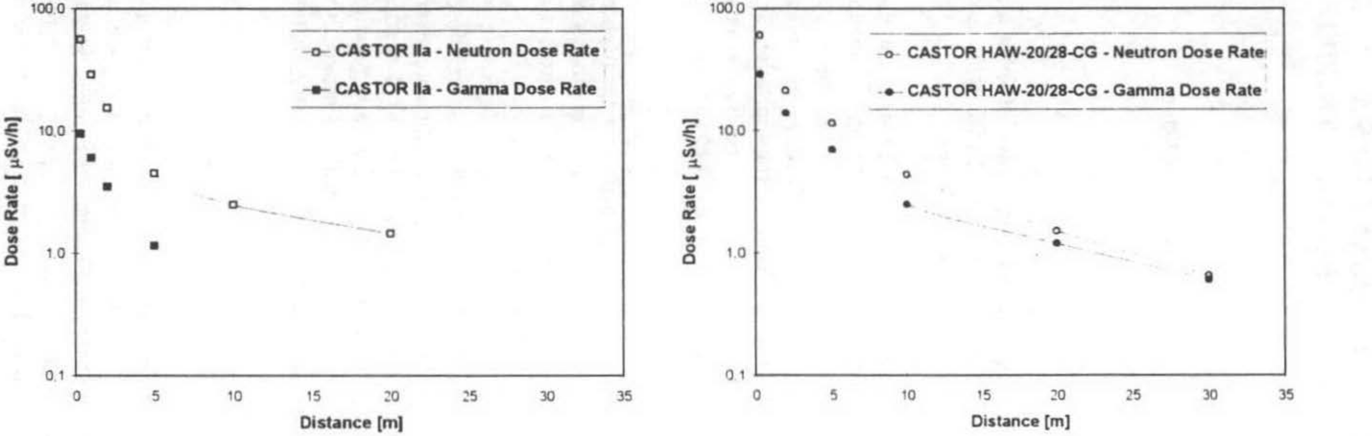


Fig. 3: Dose Equivalent Response of Neutron Area Monitors (normalised for 2 MeV)



CASTOR IIa **CASTOR V/19** **CASTOR HAW-20/28-CG** **TS 28 V**

Fig. 4: Dose Rates at the Surface of Several Casks for Transport and Interim Storage



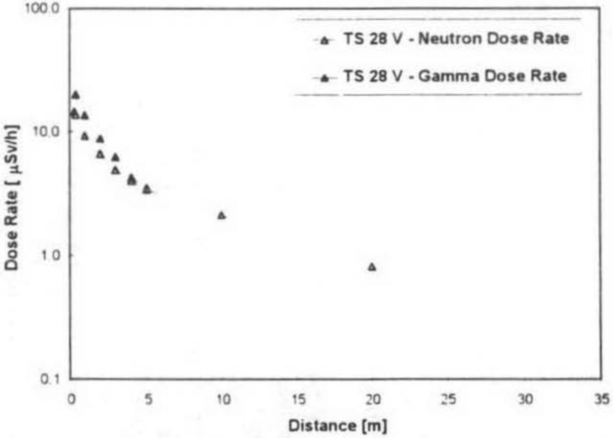


Fig 5: Dependence of Dose Rate on Distance