Technique of Stowing Packages Containing Radioactive Materials During Maritime Transportation

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INTRODUCTION

The Mont Louis accident (August 25, 1984 - North Sea), in which uraniumhexafluoride packages were involved, alarmed a large number of European competent authorities, including the Commission of European Communities. The latter sponsored in 1986-1987 a bibliographic data collection to obtain a first view on the problem.
(C.E.C. contracts n° 86-B-7015-11-004-17 and 86-B-7015-11-005-17)
The collected data supply the necessary basis for further work, aiming to increase the safety of transporting radioactive material by ship.

I. AIM OF THE STUDY

The study collected the different deceleration values, used by the transport companies and defined the accident conditions to be considered. This work can serve as a basis for later research to end with the proposal of a code of good practice for stowing.

II. PERFORMERS OF THE STUDY

The research-work has been carried out jointly by C.E.A.-France, I.P.S.N. at Fontenay-aux-Roses and by Transnubel S.A.. Brussels Belgium.

III. TASKS INCLUDED IN THE DATA COLLECTION

The preliminary research included two main tasks :
- a statistical analysis,
- a bibliographic study of ship accidents,

These tasks have been carried out by performing the following inquiries :

- collection of information from British and French ship registrating companies,
- discussions with the French "Compagnie Générale Maritime" and the Belgian "Compagnie Maritime Belge",
- bibliographic study with the help of OMI "Organisation Maritime Internationale",
- analysis of accidents in the open sea and in the harbours,
- investigation of the French standards relating to the stowing of trucks on carferry decks,
- investigation of the sea transportation of packages loaded with irradiated fuel on board of ships especially built for this kind of transportation,
- attempt to define the number of decelerations (g) generated during storms and in chocs.

IV. COLLECTED DATA

Nearly 50 documents have been consulted to obtain information concerning, on the one hand the accelerations to be considered during normal transport conditions and in contact conditions, besides the ship area, to be reserved for the storage of packages containing radioactive products and on the other hand the accident statistics.

IV.1. Collected data concerning the accelerations to be considered during normal transportation conditions and in contact conditions

The following values have been found :

1. longitudinal accelerations : between 0,29 and 2 g
2. transversal accelerations : between 0,75 and 2 g
3. vertical accelerations : between 0,15 and 3,5 g
4. roll with a max. angle of 30° and a period varying between 10 and 50 s
5. pitch with a max. angle of 10° and a period varying between 5 and 15 s

The accelerations given especially for collisions nearly differ from the ones mentioned hereabove :

1. longitudinal accelerations : between 0,135 and 1,5 g
2. transversal accelerations : between 0,11 and 3,65 g

Remark : Most of the data found concern the ship itself and not the cargo.

The highest values found are :

1. longitudinal acceleration : 2 g
2. transversal acceleration : 3,65 g
3. vertical acceleration : 3,5 g

IV.2. Collected data concerning the areas on board of a ship to be reserved for the stowage of packages containing radioactive products

The document "American national standard for highway route controlled quantities of radioactive materials - Domestic barge transport - ANSI N° 14.24 - 1985" defines the area on board of barges where such containers can be stowed as follows :

- at a distance of minimum B/5 inboard from the side of the vessel, where B is equal to the beam of the barge,
- at a distance abaft the forward perpendicular and forward of the stern transom of $L^{2/3}/3$ or 14,5 m min. where L is the length of the barge.

V. COLLECTED DATA CONCERNING ACCIDENT STATISTICS

Several documents contain information concerning the probability of a ship having an accident. These collected data are given in table I "Collected date concerning ship accident probabilities".

Furthermore, Lloyd's Register of Shipping has supplied the following information :

- an analysis of the types of accidents near most of the European coasts for 5 different ship size bands (500 to 15.000 dwt.),
- the collection of more detailed information concerning 16 accidents,
- an analysis of ship movements for the English Channel and the assessment of accidents frequencies,
- a selection of reference type accidents to be used in further tasks (theoretical approach and scale tests).

A summary of this study is given in paragraph VI.

VI. SUMMARY OF THE STUDY PERFORMED BY "LLOYD'S REGISTER OF SHIPPING"

VI.1. Study area

The study area involved, includes the Western Mediterranean and its approaches, Eastern Atlantic Waters, the North Sea and the Baltic, as well as the Kiel Canal.
The area is shown on figure 1.

VI.2. Time period considered in the study

The period 1978 to 1986 has been considered.

VI.3. Chosen ship types and deadweight size bands

The chosen ships are all :
- general dry cargo,
- Ro-Ro (cargo and/or passengers),
- container and nuclear fuel carriers,
- combinations of these classes.

The chosen deadweight size bands in tonnes are :
- between 500 and 1.999,
- between 2.000 and 4.999,
- between 5.000 and 9.999,
- between 10.000 and 14.999,
- 15.000 and above.

VI.4. Analysis of the accident types

The following averages per year (over 9 years) have been found :
- 35,2 ships are lost,
- 199,4 ships are heavily damaged,
- 234,6 ships are either lost or heavily damaged.

The study gives as main causes of accidents to ships carrying nuclear materials in European Waters the following percentages :
- collision (16,5 %)
- contact (6,5 %)
- fire/explosion (11,2 %)
- foundered (9,1 %)
- hull/machinery damage (34,5 %)
- wreched/stranded (20,5 %)

Furtheron in the study, the hull/machinery failure has been omitted since no damage to cargo is likely as a direct result and the foundering where cargo damage is due to water ingress.

VI.5. More detailed casualty investigations

16 accidents have been selected in the frame of this more detailed casualty investigations.
High penetrations were found for Ro-Ro ships (3,9 m - 7,0 m - 4 à 5 m - 4 à 5 m).

VI.6. Final selection of suggested reference scenarios

8 suggested reference scenarios have been selected to provide a typical cross-section of "worst case" accidents for the selected ship types. It is considered that collision is likely to provide the most common scenarios incident with respect to acceleration forces on the cargo.

Therefore, the selection of the scenarios reflects this.
Information concerning these 8 accidents is given in table II.

The following penetration depths have been found :

- 1° case	2 à 3 m	
- 2° case	-	
- 3° case	1 à 2 m	
- 4° case	1 à 2 m	average of the max. values : 2,67 m
- 5° case	1,5 m	
- 6° case	3,9 m	
- 7° case	7,0 m	
- 8° case	2,0 m	

VI.7. Movement analysis in the Marsden grids 145 and 216

A total casualty rate of $3,53 \cdot 10^{-7}$ is obtained per ship kilometre sailed in these grids.
This rate implies for a typical 220 km voyage across the North Sea from U.K. to Rotterdam for example a probability of $7,8 \cdot 10^{-5}$ for a serious accident per voyage.
Similarly, the probability of a serious collision would be $1,5 \cdot 10^{-5}$.

VII. CONCLUSIONS

The complete study has given the following results :
- the accelerations to be considered for the ship during normal transport conditions and in collision conditions,
- information concerning the areas on board of ships to be reserved for the stowing of packages containing radioactive products,
- the selection of 8 accident types, providing a typical cross-section of "worst case" accidents for the selected ship types,
- the definition of the probability for a serious accident per voyage and for a serious collision during a typical 220 km voyage in the North Sea.

The collected data supply the necessary basis for further tasks in this field as there are : a theoretical approach of the problem and the necessary tests in order to increase the safety of stowing packages containing radioactive products on board of a ship.

Document title	Le transport par mer des matières radioactives	Safe stowage and securing of cargo on board ships
Authors	P. Gilles + C. Ringot	P. Anderson
Organization	CEA 83-108	Mariterm AB 1982
PROBABILITIES		
a. Per ship/year		
a.1. Swedish territorial Waters		
- ship lost by collision	2.10^{-4}	
- ship lost by stranding	4.10^{-4}	
- loss of cargo	10^{-5}	
- cargo damaged by collision	10^{-4}	
- fire lasting a long time	10^{-7}	
a.2. Japanese data		
- total loss	$7,6.10^{-7}$	
b. Per voyage		
b.1. French data		
- heavy collision (Channel-North Sea)	10^{-4}	
- ship lost by collision	10^{-5}	
c. Per ship/km		
- collision with tanker (Channel-North Sea)	7.10^{-9}	
d. Per 1.000 ships/year		
- total loss/period 78-80		
. Ro/Ro		4,6
. tanker		4,2
. World Fleet		7,2

Table 1. Collected data concerning ship accident probabilities

Scenarios / Information	1°case	2°case	3°case	4°case	5°case	6°case	7°case	8°case
Type of accident	Collision	Collision	Collision	Collision	Collis./ Fire	Collision	collision	Contact
Year	1979	1980	1979	1985	1983	1982	1984	1980
Location	River/Est	Sea	Sea	River/Est	River/Est	Sea	Sea	Restr. Waters
Struck ship								
. type	Cargo	Cargo	Cargo	Tr. cont.	Tr. cont.	RoRo pass.	RoRo	Cargo
. deadweight (t)	5.960	13.600	16.500	13.100	28.900	3.950	5.900	2.800
. speed (km)	5,6 à 7,4	25,9	27,8	18,5	16,7	28,1	20,4	18,5
. loaded/ballast conditions	Unknown	loaded cont.	loaded cont.	loaded cont.	loaded cont.	laden vehicles	laden cont/veh.	Loaded cont.
. angle of collision	120°	80°	Unknown	180°	120°	94°	90°	/
. depth of penetration in m	2 à 3	/	1 à 2	1 à 2	1,5	3,9	7	2
Striking ship								
. type	Cargo	RoRo cargo	Cargo	Ore Transp.	Cargo/ tr. cont.	RoRo cargo	RoRo ferry	Nihil
. deadweight (t)	15.200	4.300	3.000	117.600	14.000	5.600	2.900	
. speed (km)	5,6 à 7,4	37	20,4	16,7	16,7	10,4	22,2	

Table 2. Information concerning the 8 suggested reference scenarios

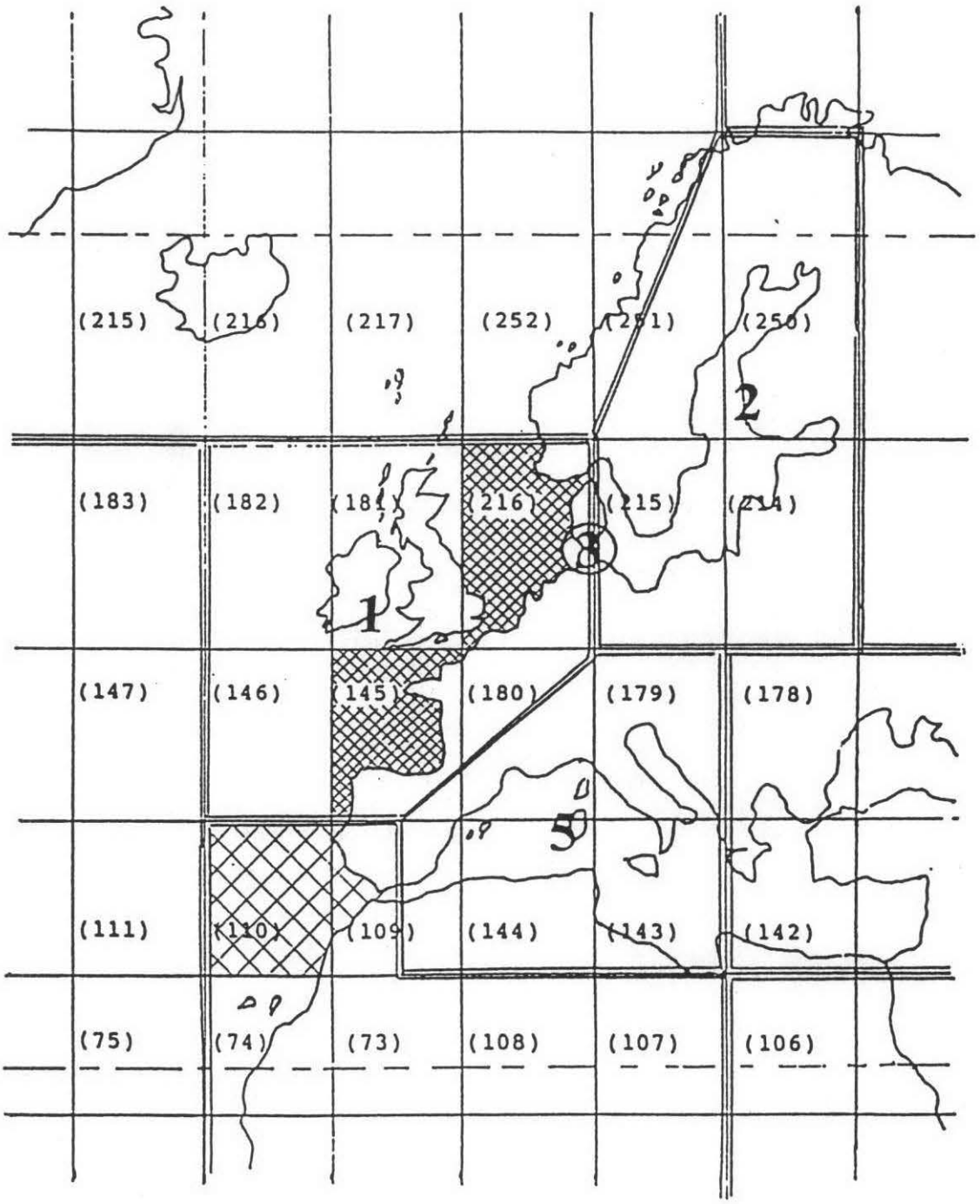

Figure 1. Considered European Waters and their approaches