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PORT PLANNING AND MANAGEMENT ASPECTS OF THE SAFE SHIPMENT OF LNG AND LPG

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1.0 INTRODUCTION

The successful planning and management of port facilities has traditionally required and involved a fine understanding of the characteristics and behaviour of the ships being handled. This background of centuries of experience in coping with the risks, natural and man-made, has always made the mariner aware of those aspects of maritime safety that are necessary both to his personal survival and to the economics of his trade.

The introduction of large scale hazardous cargoes into the area of marine transportation has, however, added another dimension of safety consciousness. With the advent of maritime LNG/LPG transport as a significant percentage of world shipping (see Figure 1) there is a need for greater knowledge and experience in the behaviour of spillages of LNG and LPG, particularly in the areas of most concern - the ports. In the following sections we will refer to this area of technical expertise in evaluating and assessing the potential impact of hazardous cargoes as 'Technical Safety', to distinguish it from the many other safety aspects of maritime transport. This knowledge and experience of technical safety forms the background on which to base decisions during emergencies, where these hazards may be present, and in port layout and vessel design, where many of the potential hazards can be designed out of the system.

2.0 THE ROLE OF TECHNICAL SAFETY

The potential for injury of crew and those working or living adjacent to the port area arises from several sources:

- personal accidents;
- accidents involving the vessels;
- accidents on shore;
- accidents specifically involving a vessel's cargo, or cargo stored on shore.

Of these, personal safety, vessel safety and shore safety have always been an integral part of maritime transport and port design, well understood, well respected, with well defined procedures and regulations serving to minimise the number and severity of accidents. The potential dangers from the vessel's cargo on the other hand depend on the properties of the cargo; safety measures to minimise these dangers have gradually been introduced as the trade in that cargo has increased and sufficient experience has been gained from incidents to establish the extent to which the potential hazard of the cargo is realised in practice.

The transport of liquefied gases, particularly the large scale transport of refrigerated LNG and LPG, introduced a new type of hazard into maritime transport. Although the potential for personal accidents and vessel accidents were common to other cargo vessels, the nature of the cargo was different, in that, were a cargo spillage to occur, the resulting vapour cloud could affect the lives of people remote from the source of the accident.

The technical assessment of this new type of marine hazard and the potential consequences with respect to vessel design constituted the first application of technical safety to LNG/LPG transport, through the introduction by IMCO of measures designed significantly to reduce the likelihood of cargo spillage in the event of a vessel accident. These measures were based on technical and statistical grounds. Thus the introduction of minimum separation distances between the outer skin of the vessel and the cargo tanks was based on statistical data relating to the depth of hull penetration of the affected vessel in the event of collision or grounding, the separation distance being specified so that the majority of accidents would not penetrate the hull deeply enough to damage the cargo tanks. It is measures such as these that are responsible not so much for any improvement in the historical accident record of gas carriers relative to other vessels (as this largely relies on traditional seamanship qualities), but for the very low frequency with which serious gas carrier incidents lead to cargo spillage. This can be clearly seen when gas carrier incidents are compared to oil carrier incidents (Table 1). The remaining special hazards that might affect the vessel and its cargo occur where the vessel may be vulnerable to severe collision, hard grounding on an inhospitable sea bed, exceptionally severe fire and explosion, or suffer unfavourable follow-on events after an accident. These potential hazards, still of considerable importance, provide a more limited role for technical safety in evaluating the need for, or effectiveness of, traffic regulatory measures designed to minimise the risk of an accident in ports or port approaches.

Having addressed the question of technical safety with respect to vessel design, where there has clearly been a positive benefit, it is possible to identify two other areas where technical safety can play a similarly positive role: port design and contingency planning.

In port planning, the prime technical safety concern is to ensure adequate separation of the areas processing, storing, discharging or loading LNG/LPG from other vulnerable areas of the port. In particular this involves storage tank to storage tank separation, storage tank to berthed vessel separation, inter plant separation, and loading/unloading arms to passing ship separation. The separation distances are determined by the criteria required, e.g. for crew to be able to take remedial action on a vessel if the land storage tanks are ablaze, for one blazing tank not to threaten another, and so on.

In the case of contingency planning, the ability to coordinate actions in the event of LNG/LPG emergencies requires technical information about the behaviour of the materials in the event of a spillage, such as the likely travel distance of any vapour cloud or the effect of waves and winds on a spill from a grounded ship.

The experience so far in the application of technical safety to port design, traffic regulatory considerations and contingency planning is limited, but the examples in the next section provide an outline of some recent applications.

3.0 THE EXPERIENCE SO FAR

3.1 Traffic Regulatory Measures

3.1.1 The necessity

In many busy shipping areas throughout the world the movement of traffic is regulated by shore-based marine traffic services with the capacity for surveillance of all movements within their areas of jurisdiction. The areas are usually those covering ports and their approaches, although a few such services do operate by international agreement over international waters, such as the Dover Strait. The overall aim of these services is, of course, to improve the safety of shipping movements without incurring unnecessary delays.

It is most common for these services to be operated by the State or a State Agency, although in the UK all services covering port areas are operated by individual and autonomous port authorities. The degree of sophistication of many services now, in terms of regulatory powers and equipment, are such that they have the ability to impose a wide range of limitations and restrictions on the movement of shipping through their areas.

Nevertheless, the need for any traffic regulatory measures must be established before their introduction is proposed, either by reference to the historical accident record of similar operations, or by attempting to predict the degree of safety to be expected from the operation taking into account the local environment. This must be related either to the historical safety record of the port, or to an appropriate safety criterion. As LNG/LPG carriers have only a comparatively short history in terms of vessel-years, the expected degree of safety in any one particular port is generally estimated by predictive methods. Such methods start out by considering the local environment and the cargo to be carried, as set out in the checklist in Figure 2, and then to consider all the possible accident scenarios following a procedure similar to that shown in the diagram in Figure 3. Following such a formal procedure, the potential hazards can be systematically evaluated and the consequences considered quantitatively in terms of hazard distances, estimates of risk, or generation of risk contours (1, 2).

Such predictive studies have been carried out for several ports and port approaches where LNG/LPG shipments were planned, for example at Porsgrunn, Norway (3), Cove Point, USA (4), Rotterdam, The Netherlands (5) and for other planned operations such as Zeebrugge, Belgium (LNG), Eemshaven, The Netherlands (LNG), Dampier, N.W. Australia (LNG), Nigg Bay, Scotland (LPG), Braefoot Bay, Scotland (LPG).

3.1.2 The application

There have been a number of instances where consideration of the nature of the cargo has been used as a background to selecting appropriate regulations, with consideration of the effect that these might have on the overall traffic flow. Much of the pioneering work in technical safety application has been carried out in the USA, by the US Coastguard. In the UK two such studies have been undertaken, at the River Tees (6) and within the Forth Estuary (7), with the regulatory procedures then adopted as the general practice.

In both of these cases the investigations centred around the selection of ships carrying those cargoes having the potential to cause the greatest danger or damage at distances remote from the accident source and then selecting ships carrying those cargoes for specific regulatory measures. The general principle adopted was that where traffic regulatory requirements imposed delay on any shipping movements, they should apply to those ships carrying the hazardous cargo.

The Forth Study

In the case of the Forth, the total traffic at the time of the study amounted to just less than 4,000 vessel arrivals per annum with an anticipated growth of about 40% forecast, including a large growth of petrochemical shipments.

The layout of the port is shown in Figure 4 with the approaches to Grangemouth Dock divided into five sectors for traffic regulatory purposes. In general terms the regulatory measure reflected the funnel effect of the port.

Within the outer sector 1 sufficient water exists to permit free movement of shipping, but the traffic regulatory requirement was for ships to make initial contact with the shore base and confirm their berthing arrangements. For sector 2 it was recommended that any designated hazardous cargo ship should not enter that sector until and unless its berth availability was confirmed to avoid an unnecessary transit of the port or having to wait in a location exposed to other shipping movements. An area near to Inchkeith was designated as a waiting anchorage area for hazardous ships only.

For sector 3, where the channel becomes more restricted, it was recommended that no overtaking manoeuvre involving a hazardous ship should take place without confirmation from the shore base. The prime reason for this was that ships' speeds within this sector would be very similar, thus any overtaking manoeuvre would mean that the ships would be in close proximity to each other for a prolonged period of time.

Within sector 4 it was recommended that as the channel narrowed to about 120 metres a one-way system of movement should apply with hazardous ships, although the width of the channel was sufficient to permit normal two-way traffic movements for all but the largest vessels using the dock.

Within the dock system Sector 5 it was considered that no hazardous cargo ship would leave its berth until there was direct access to the entrance lock and that no other vessel should be moving between the berth and lock.

The Tees Study

In the case of the River Tees, a port accepting about 10,000 vessel movements per annum with a high percentage carrying petrochemical products, restrictions on movements of large ships applied due to tidal availability in the port and due to the limiting width of the channel approach. Traffic regulation for the larger ships was based on physical ship handling requirements and the maximum sizes of ships able to pass each other in the channel were defined (8). The selected hazardous cargo ships were therefore regulated such that they would avoid the high water times (which would be the only periods in which the larger ships would be able to move) and also to find a time slot when they would have a one-way movement through a section of the river.

3.1.3 The effects

Ideally, of course, there are two effects to be measured or assessed when considering the desirability of introducing any traffic regulatory measures. The first of these is the likely reduction in the chance of a ship accident and the second is the increase in delays to shipping movements, if any, which may result. The gain in safety is likely to be large in the above two cases, since the possibility of the hazardous ships having an accident with another is virtually zero, barring gross cases of human error. The second criterion, that of delays to shipping movements, was assessed by comparing the original level of delays to the delays incurred with the new measures by computer simulation of the traffic flows, validated by the records, in the harbour-master's office, of the actual delays experienced.

In the investigation of regulatory procedures introduced for the Forth, it was concluded that the delay would affect only 10% of hazardous ship movements, the delay being approx. 15 minutes. In the more complex traffic situation applying in the River Tees, with the higher overall levels of traffic, it was found that a hazardous vessel was three times more likely to be delayed than an ordinary non-hazardous vessel of similar size, but the average delay when it occurred was in the order of 35 minutes.

In both cases it was considered that the levels of delay were small when compared with the accumulated delays which usually occur during a normal voyage of a vessel, which may amount to several hours. These additional delays were considered to be a small price to pay for the large gain in ship movement safety and the regulatory procedures have therefore been adopted by both these ports, so far without any accident involving a selected hazardous ship and without any undue delays to the overall port's traffic.

3.2 Port Layout

Where new ports are planned, or existing ports have sufficient free area to allow a choice of locations or layout for a proposed LNG/LPG operation, the formal procedure shown in Figure 3 can be applied to ensure adequate personnel safety and to minimise economic loss or loss of efficiency to other sectors of the port in the event of a major accident. The use of such procedures is considered to be preferable to the rules of thumb used, for example, in the separation of shore storage, where reasonably accurate quantitative calculations can be made (e.g. Ref. 9). Figure 5 shows an example for the separation distance between an LNG storage tank and a berthed LNG carrier in the event of a major storage tank fire.

The Port of Jubail is one example of a practical application in the authors' experience where the principles of technical safety were applied to port design and layout (10). Separation distances between important items such as ships and shore storage tanks were specified on the basis of flame radiation and blast overpressure levels, as shown in Figure 6.

An alternative way of presenting hazard information so that decision can be made on the implications of industrial activity for the port area, and the surrounding communities, is the use of risk contours. A good example can be seen in the risk study done for the Rijnmond Authority in Rotterdam (11), Fig 7.

In existing ports, there is less scope for technical safety as there is rarely a sufficient degree of flexibility. There is nevertheless useful application in assessing the need for remedial measures to reduce particularly high risks, and in evaluating their effectiveness.

3.3 Contingency Planning

3.3.1 The necessity

The necessity for a comprehensive port marine emergency plan is hopefully self-evident. In many ports, such emergency plans do exist, although they are largely structured as a communications exercise for the mobilisation of appropriate services under a prescribed chain of command. Thus, only some three ports within the UK ever conduct a live exercise to test the effectiveness of their plans. Bearing in mind that within the UK particularly, a large variety of organisations may be involved (in one major port some 28 separate bodies are actively involved in the emergency plans), this low frequency of live exercises can only be regretted.

To the authors' knowledge no port emergency plans within the UK deal specifically with large-scale releases of liquefied gases and chemicals, although it is known that some 13 ports, not all of them major ports, handle large quantities of such cargoes.

3.3.2 Existing examples

There are cases, of course, of emergency plans which consider possible spillages of liquefied gases and chemicals, sometimes even on a design spill basis. Examples of these can be seen in the USA (New York (13) and Rhode Island (14)) and in the port of Rotterdam (15), where the plans are based on the information contained within the Chemical Hazards Response Information System (CHRIS) provided for the US Coastguard. In general terms, these emergency plans are based on the likely behaviour of hazardous cargoes if released during an accident, taking particular account of the ranges of adverse affects likely to be experienced. Such considerations permit the emergency services to take action in the anticipated areas of danger and put into effect appropriate evacuation plans.

In the case of Rotterdam, the emergency services use the basic, but effective tool of a map showing potential danger areas depending on type and amount of cargo spilled and prevailing weather conditions which can then be superimposed on the location of the source of spillage. This allows the services to identify the areas of concern whilst at the same time giving them some indication of the time available to the services to effect their emergency plans.

In many cases it would be impractical to try and provide emergency services with a capability of dealing with the worst possible accident. It is however quite within the bounds of practicability to provide emergency response capability for a range of smaller but more likely accidents. For this to be effective, however, such plans can only be drawn up in full knowledge of the technical safety aspects referred to earlier, if they are to minimise the catastrophic effects of an accident involving liquefied gases or chemicals in a congested waterway.

4.0 CONCLUSIONS

Modern methods of Risk Assessment and Hazard Analysis allow the definition of potential hazards in ports handling hazardous cargoes. The relevant factors identified in this formal and comprehensive way allow a measured response to be made in terms of traffic regulations, port layout and contingency planning on a cost-effective basis.

The incorporation of safety as a technical exercise into the preplanning and normal operational management of ports handling hazardous cargoes would be a positive contribution to maintaining and improving the good safety record of handling LNG and LPG cargoes.

5.0 REFERENCES

1. Cox R.A., Pyman M.A.F., Sheppard P.A. and Cooper J.P.S. "A model for evaluating the probabilities and consequences of possible outcomes following releases of toxic or flammable gases". "Heavy Gas and Risk Assessment" (Proc. Symposium on Heavy Gas.) Ed. S.Hartwig, D.Reidel Publishing Company, 1980.

2. Comer P.J., Cox R.A., and Sylvester-Evans R. "A formalised procedure for the analysis of risks posed by complex petrochemical developments". Bulletin of the Institute of Mathematics and its Applications, 16, May/June 1980.

3. Jenssen T.K. "Risk analysis of LPG transportation in the Porsgrunn harbour area" Veritas 94 December 1978.

4. Science Applications Inc. "Risk assessment study for the Cove Point, Maryland, LNG facility", March 1978.

5. Dienst Centraal Milieubeheer Rijnmond "LNG-aanvoer via Rotterdam" Rotterdam October 1977.

6. Pope R. O'C., Siebols J. "The effects of regulating the movement of ships carrying hazardous cargoes" National Ports Council 1976.

7. Lyon P.R. and Pope R.O'C. "Hazardous cargoes in port approaches" National Ports Council 1976.

8. Younger M.J., Siebols J. and Lyon P.R. "Planning for increased ship traffic through port approach channels". National Ports Council 1973.

9. Raj. P.P.K. "Calculations of thermal radiation hazards from LNG fires - A review of the state of the art" American Gas Association Operating Section Proceedings 1977.

10. Simmons P., Ramsay C.G. and Sylvester-Evans R. "Hazards at petro-chemical ports" Consulting Engineer, June 1980.

11. Openbaar lichaam Rijnmond "Risico-analyse voor zes industriële objecten in Rijnmond". Rijnmond, Rotterdam Nov. 1980.

12. Blokker E.F., Cox R.A., Lans H.J.D. and Meppelder F.M. "Evaluation of risks associated with process industries in the Rijnmond area. A pilot study". 3rd International Symposium on "Loss prevention and safety promotion in the process industries" Basle, Switzerland, Sept. 1980.

13. U.S. Coastguard "Procedures for the movement of LNG/LPG". Captain of theport, New York, October 1975.

14. U.S. Coastguard "LNG/LPG contingency plan" Captain of the port, Rhode Island, August 1975.

15. See Rotterdam Newsreel, January 1978.

16. Cox R.A. "Improving risk assessment methods", 2nd National Conference on engineering hazards, Oyez, Jan. 1981.

TABLE 1

Comparison of the ratio of cargo spillage to vessel accidents between gas carriers and oil carriers.

Vessel type	Ratios		
	All spills to all incidents	All major spills to all serious incidents	All major spills as a result of a total loss
Oil tankers	1:9 (1)	1:6 (2)	1:3 (3)
Gas carriers (over 10,000m^3)	1:150 (4)	< 1:22 (5)	-

Notes

(1) 452/3183 polluting incidents : casualties for 1969-1973. (≥ 3000 DWT) U.S. Coastguard, based mainly on Lloyds List. Quoted in Gray W.O. "Vessel operating casualty records" International Tanker Safety Conference 1975, Norway. 234/3089 oil outflows : casualties for 1974-1980, Tanker Advisory Centre "Trends in Tanker oil spills and losses" Aug. 1980, based on Lloyds List (≥6000 DWT).

(2) 14/74 major oil spills : serious casualties for year ending Dec. 1979, 5/38 for year ending Dec. 1980. Lloyds Shipping Economist.

(3) 14/25, 5/25 oil spills : total losses for years ending Dec. 1979, 1980 (≥ 10,000 DWT) Lloyds shipping economist.

(4) 2/285 cargo spillage : reported casualties over the period 1964-1979 (≥ 10,000 cum). From Poten and Partners Inc. "Liquefied gas ship safety" May 1980.

(5) 2/44 cargo spillage : serious casualties. The ratio is clearly a maximum as the cargo spillage events cannot really be considered the equivalent of the major oil spills. Ref as (4) above.

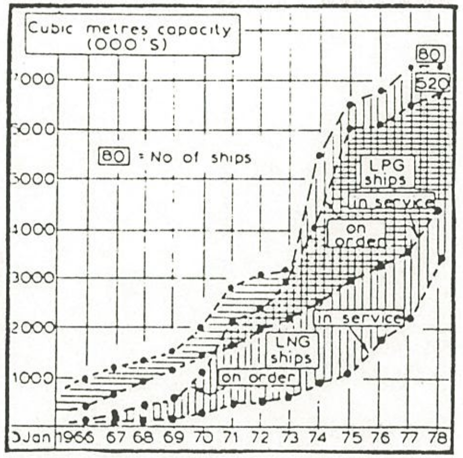

Fig.1 : The rapid growth in LNG and LPG trade. Reprinted by permission of the Council of the Institution of Mechanical Engineers from R.C. Ffooks "The shipping of LNG and other gases" Proceedings 1979 Vol. 193 No.16

FIGURE 2 - PRELIMINARY CONSIDERATIONS TO ESTABLISH THE EXPECTED LEVEL OF TECHNICAL SAFETY

Stage I PHYSICAL LIMITATIONS	I. Layout of port and approaches in terms of channel lengths, widths, bends, depths, manoeuvring and turning areas. 2. Prevailing winds, currents, tides, waves, visibility. 3. Proximity of approach channel to residential, industrial, agricultural and amenity areas, as well as any areas of particular environmental interest.
Stage 2 TRAFFIC CONSIDERATIONS	I. The numbers, sizes and types of shipping, both current and expected. 2. The need for any particular traffic to have priority of movement, e.g. passenger ferries.
Stage 3 ACCIDENT RECORD	I. Examination of port accident records to identify any particular accident 'blackspots' with reasons for or circumstances of their occurrence. 2. Examination of port accident rate.
Stage 4 NATURE OF CARGOES	I. The properties of cargoes being accepted and their method of carriage and containment. 2. The likely behaviour of the cargoes in the event of spillage or leakage to air and water. 3. The types of accident likely to result in spillages. 4. Likely accident scenarios.

FIGURE 3 - FORMALISED PROCEDURE FOR THE RISK ANALYSIS OF PROPOSED HAZARDOUS OPERATION

STAGE 1 DEFINITION	1. Identify the potential accidents a) minor, b) major, c) catastrophic 2. Define the potential accidents in terms of a) location, b) detailed circumstances of spill
STAGE 2 QUANTIFICATION	1. a) Quantify the release conditions Rate of discharge, duration of discharge, material released etc. b) Estimate frequency of release case
STAGE 3 IMPACT	1. Estimate the consequences of the defined releases a) Vapour cloud travel b) Fire c) Explosion 2. Estimate the impact that these consequences will have on the environment a) People b) Property c) Pollution d) Economic
STAGE 4 ASSESSMENT	1. Order the accidents in terms of their likelihood of occurrence 2. Assess the need for any reduction in risk from the proposed operation 3. Assess the effect that any remedial measures may have on the risks

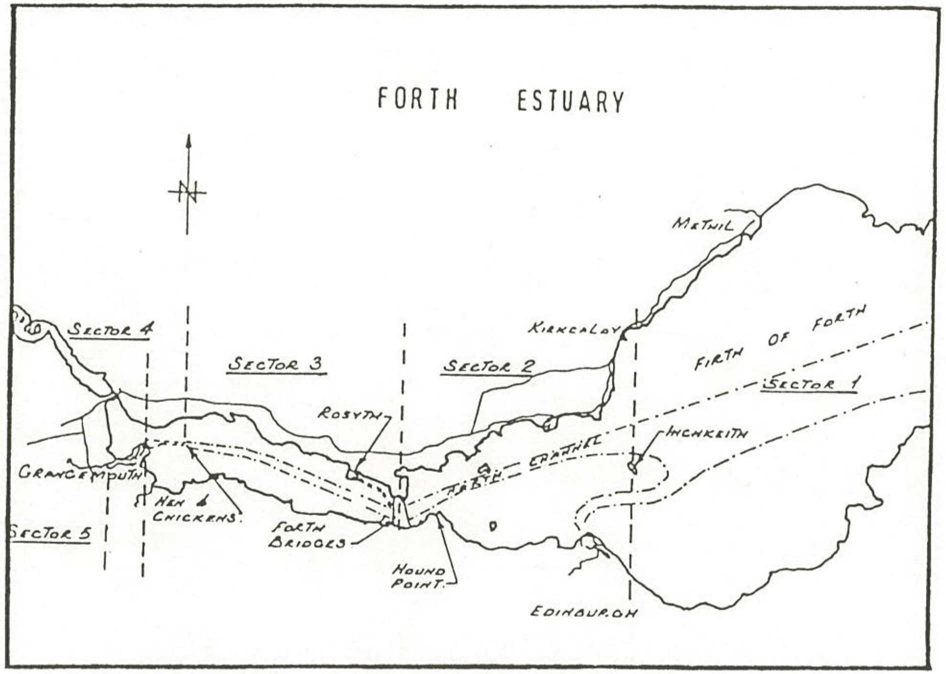

Figure 4 : Subdivision of the Forth Estuary into five sectors for traffic regulatory purposes. From reference (6).

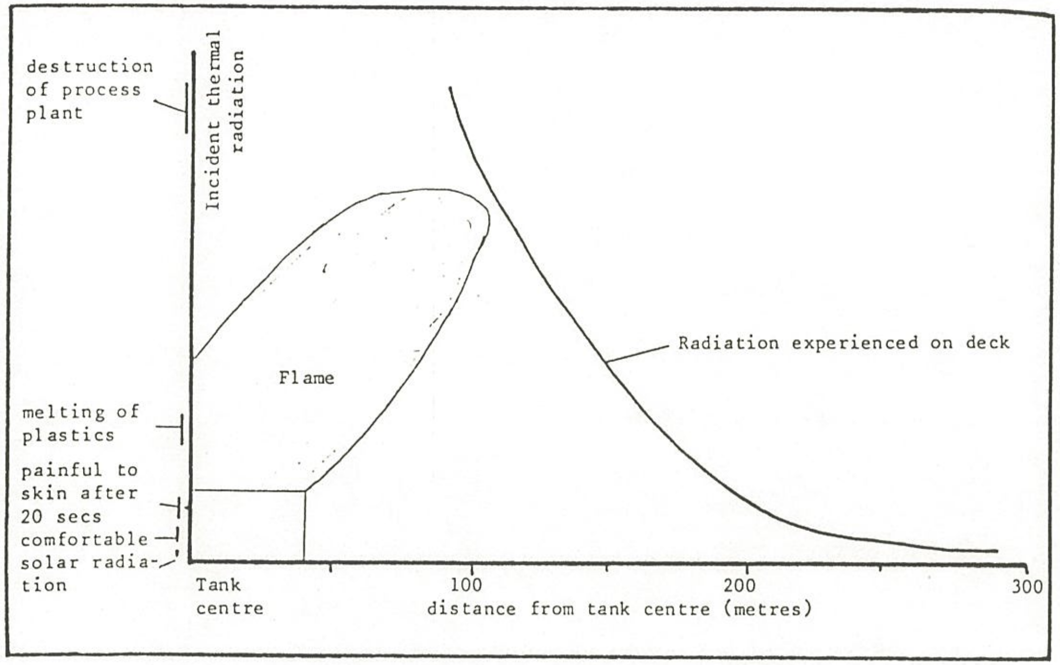

Figure 5 : Radiation experienced by an observer at deck level from a major LNG storage tank fire in a 15 knot wind.

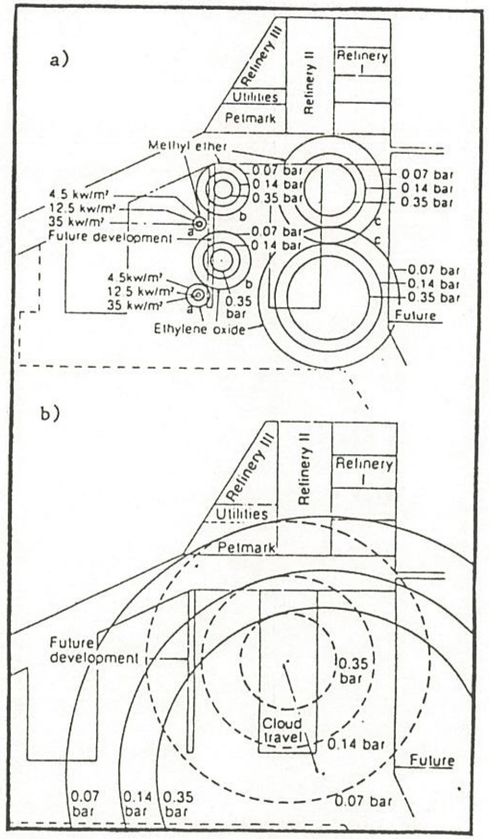

Fig.6 : Port layout safety study for the Port of Jubail. a) Blast pressure and thermal radiation levels from loading arm spills of ethylene oxide and methyl ether. b) Blast damage from worst case rupture of a ship carrying ethylene oxide.

Reprinted with the permission of Rendel, Palmer and Tritton (Economic Studies Group) from reference (10).

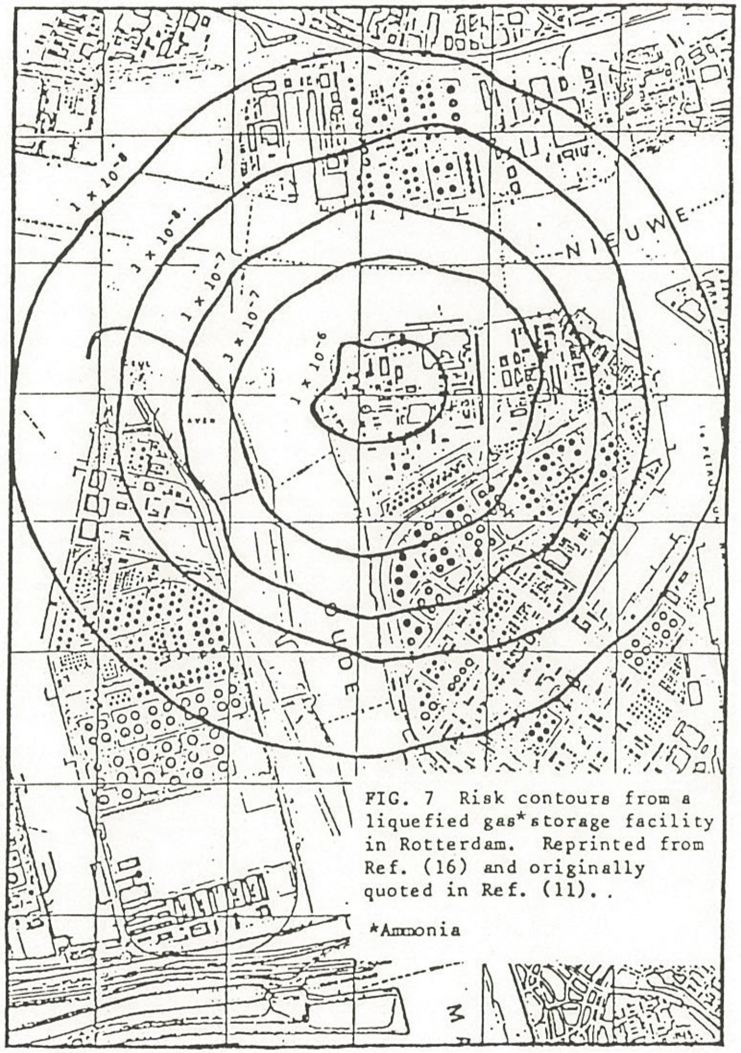

FIG. 7 Risk contours from a liquefied gas* storage facility in Rotterdam. Reprinted from Ref. (16) and originally quoted in Ref. (11).

*Ammonia