Attachment 1

TANKSHIP ACCIDENTS AND RESULTING OIL OUTFLOWS, 1969-1973

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ABSTRACT

Information has been collected on 3,715 woddwlde tankship acckdent mvolvemenn during the period 1969.1973 from Lkoyd> Mly (Xsrmlty Repwti and other sauces Scope of the effort, aasumpoons and definttmns used m data collection, and uncertatn. ttes obout datu are descrtbtd For 3,183 in&ements of tonkshps over 3,t30f3 duxftvaght tons. frequencies of occurrence of brcok. downs. coflk$ions, exploswms, jires, groundmgs, tummtngs, and strucmml failures are presented Fadure consequences mcludmg deaths. mmries. vessel damage, and accu!enml otk oulffows are tabu. hted ami refationshrp of vessel nze, age, and focalwn of tnvolve. ment are exammed In fcwmatton collected, once analyzed, should be useful m fvafualrng meamves for reducing occidentsand resulting od outffows and evaluating risks associated with od tmnsport and pro. ductwn decutons

INTRODUCTION

In formal#on IS an essential prercquiwte for understanding and mtefhgent decwwn makmg In formatmn on tanksh]p acodents M essential to tientify hazards and evaluate rwks associated wtth marure transportation of 011 and to make mtelbgent decmons con- tirnmg faws and reguf.atmns affecting vessel demgn, construction, operatton, and traffic-control systems Recausc of decmon com- pkx!ty, sy$temat}c approach IS essenttal If we are to make the right cholw The need for a systemal!c approach to marme tran$portatlon safety M recogmzed m the Ports and Waterways Safety Act of 1972, wh}ch gives the Secretary of the Lkpatment of Transportation and the U.S. Coast Guard broad regulatory authority over tank vessel des~n and operation as well as authority to estabbdt vessel traffic- mntml systems The act provides that a number of factors must be conmdered in developing regukatlons, among them are the scope and deg~ of hazard, vessel traff]c cbaractenstlcs, port and waterway con ftgurat]on, environmental factors, economic Impact, extent to whwh propored ruks WIO contribute to rafety or protectum of the marme enwronment, and theu cost and technmal feaabthty [11 Information about tank$hlp acadents M essent#al to understanding the mfluen.x of each of these factors on safety and envuonmental protection

There have been a number of studtes of tanker accidents over the last few years The effort reported here or]gmated m 1971 when Porrtcelft, Ketth, and Storch recogmzrd that although tanker caw- alty mformatmn was available from varmu% wurces, there was no mmpcmte collection of mformatfion on mternatlonal tanker casual- tm$ which included pollutton data [2] Pomceib ct al reported and analyzed 1,416 tanker cawalt!e~ w!th the assomted 269 polluting tncidents occurrinfi dumw 1969-1970. Porricefb and Keith later added utformatlon on mf-outflow amounts for the 269 f.toffutmg mmtenls *[3].* Referenw 4, comp!kd for the Coast Guard by the naval arch!lectural firm of J.J. Henry Company, Inc., extended the data base to include 1971 and 1972. The informal}on presented here includes both these efforts and adds 1973 for a total of fwe years.

Referencz 5, wbmltted to the International Mantlme Consulta- twe Organmrt]on (IMCO) by France and discussed m 131. pre=nted mfmmatmn on mctients mvofwng tankers over 7,000 deadwelgbt tons. t%mes [6] reported on 13,379 tanker accmtents worldwnde during the penmt 1959-1968 as part of an effort to prcdtct probabk future frequency of accufents ftkely to result m polfutton of the Ututed Kingdom coastltne Qudfe [7] prexnts ntformalwn on actual and constructwe total losses colkcted by the Lwcrpool Underwr!tem As$ocmtlon and diwusses the growth m recent years of constructwe total losses and the worwtmg tanker loss ratios, both actual and comtructwe Rectntly, the Tanker Adwsory Center, a reporting servme for the tanker industry located m New York, has rekased reports of tanker losses [81. Most of the= efforts have not included esttmates of ml outflows resulting from acctdcn!s

Data collection

The basic source for the tanker acculent in formatwn reported here M *Lloyd's Weekly Casualty Repcws.* pubhshed by the Corpora- tmn of Lloyd's al Lloyd's, London, England. Information from Ll~yd's has been supplemented and crow-checked with Coast Guard acodent and plluuon reports, pubfished news accounts, *Lloyd's RWSIU of Sh]ppmg CasmdtY Returns,* pubfi$bed by Lloyd's Relw. ter of Shlppmg, and mformatmn from oil compames m some m- instances

Some terms need to be defined for the dwmsslon to foUow. An acc!dent ts an unexpected and undestred event It may revolve one or more vessels. An mvolvcmenf IS the participation of a vessel m an acctdent One vessel m one accident results m one involvement A colfmon between Iwo tank=.hips is one accident but two mvolve- nwnts Involvement *rype* refers to categories or group% of evolve- ments, such as breakdowns, colbstons, groundmgs, fme$, explosions, etc The term *total toss* IS ured here to refer to the smkmg or breakup of a vewel, tt IS an event rather than a condltmn The term *occtdenkd od outffow,* refers to ml cargo or bunkers lost to the sea as a result of a tankshlp involvement

'flu? marme !ransport.ttmn system used for moving ml mcludcs the followq ekment~ tankvhtps, tank barges ind tugs, lermmals (onshore and offshore) with theu Pwrs, plpebnc$, buoys, tank,, and other compiment$, the tramportdtton pitthw~y, and the envtron- menl (weather, wind, currents, etc) We are concerned w!tb the tankshlp portmn of the system, the vessel !twlf PIU, the factors ksfkmnckng its pmform-ce. These factors may ba categorized cc human, equipment, urgu, path, or enviromnarst [91. The tarskskup performance goal is tfm mfe cnd efllcbnt tmnaportction of oil cargo from the locdmg terminal to the dmharge terminal. Accidents are undesired events wluch k-pus from achkwing that gual.

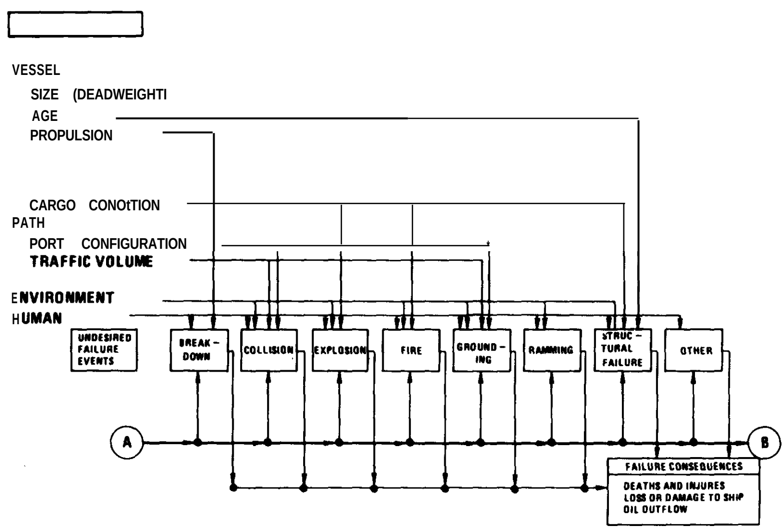
FKUX 1 shows the relationship bet-n the system factors, undesired failure events, ● nd failure cmmqracnces. A succe=ful voyage from point A, the loadmg terminal, to point B, the discharge termi. Ml, can be represented by a strcight L@ connecting the two puints. A voyase can change f:om a mcm$s to a failure due to occurrenm of a fadum event Failure events rmult from interaction of the tcnksfup system and various system factors. Eacb of the failure events can result in *failure consequences.* Some of the most common are listed. We cm tnterewed in armral thugs. One is the *pvhbiliry* of an undedmd failure event oczurrmg, Another M the ceucrlly of the conecqumces associated with such an event. And when it comes time for decisions on action to rcdua the probability and mcvemty of fsiiurc events, we ncad to cmssidm cosf and effecfivcneas of the aftemative actions wailabb to us.

TfM acope of this study includes ship-movement acsidents to tcnkships carrying oil. Tank barges are not kncluded, Combinadon carriers, such as om/okl card bufk/oil vassals, am kncludcd if the ● cckdent occurred whik the vessel was in tanker service. Not included am hackdents of hostifa action. akdpyard acidents, mdsinery derangements not requirkng tow to port, mad fucdirag mad discharge mishaps such as broke.n how aasd overfllk?d tanks. Fhes, explosions, daskings, wsd upaizhgs nccmfng whife a ship u at a pkr am inckudad even tfauugh the ahkp was not "moving." O*i/* includes petrokum in any form; tankships carrybtg wine, grafts, molasses, dudge, fish oU, vegetabk oil, or the like am not kncJuded. Casualties to od/chamical cawkm am incfudad even if cugo was not petJokum Tlwee uc caded m they may be studied sepcmtely, B$ am the m-involvements of kiquefii gas tcnkships,

I%a data record of tmkatnp involvements *covers* the five-year pemod 1969-1973. For aach mvolvmnem the fcdlowmg information is recorded:

Vesd name
International cdl sagn
Country of registry
Grosc tonnage
Deadweight tommge
Year wasel bult
Type of involvement
Month and year of mvolvemcnt
Ship's loading rendition
Occurren= and amount of ml outllow
Methnd u$ed to detennuw amount of outflow
Severity of damage to the ve%scl
Portion of vcsd mvcdved
Number of persons kilkd OK mjurcd
Ce~aphiccl ama of involvement
Reketaon of area to lcnd and harbors
Source of reformation

Since the reasilts are mflumrmd by the aammptions mcdc in data cdkcction, some of the mom important ones cre worm notkng. In detarmkning mvolvemant type, if more then one uncle srmd event nccurmd (shrp gnes aground after a breakdown) the whok chain of events was considered m im'ofvement of the type that fkmt ocammd. Ihddown inckudes canes where the Wsml lost p?opufakon power or anchored when bsc of propulsion power seamed imminent, cnd later was towed to port for repairs. Cases where a vewel proccded to port under IIS own pnwer after making mpaira were not included. *Collicions are* lsmited to cases of a lankship striking of being struck by another ves~l. Ramming mcludcs tankship hitting a pier, breakwater, tuck wall, dolphin, or other umikar fixed object. Reports of "stnkmg a subnwrged object" were



F$gure 1 Tanksh!p sysrem faolure dmgram

considered rammings unless it was apparent from the report that the object struck was some part of the bottom Groundings include strandings where the ship remained aground for some time, as well as "touching bottom" and striking a submerged object where it appeared from the report that the ship contacted the bottom Strucrural *failures* include tankships breaking up and reports of "heavy weather damage" ranging from shell plating failure down to dam. aged piping, catwalks, bulwarks, and the like on deck due to boarding seas. Failure of structural components due to deterioration with age, inadequate design, or unusual loadings are all included The category *other* includes those movements not fitting into one of the previous categories. Capsizing of a tankship or sinking *at the* pier due to flooding of machinery space are two examples of involvement in this category

The seventy of damage to a tankshlp was recorded as one of the following

1 *Sunk,* including cases where a vessel broke m two and part of it sank, or where the vessel was raised later,
2 Heavily *damaged,* where huff structure was weakened so ship was in danger of breaking up, a major fire occurred involving most of ship, or other damage was sustained with estimated repair costs exceeding $250,000. Note that this category would include a number of ships regarded as total losses or constructive total losses for insurance purposes, even though the vessel did not actually sink,
3 *Light damage* include% cases where ship was not in danger of sinking and estimated repair costs were less than $250,000;
4 No *damage* include% all cases where no damage or only superfical damage occurred

Location of tankship at the time the accident occurred is given m terms of a two-digit code for the area of the world's ocean and a code for pier, harbor including rivers and canal-,), entranceway m harbor. coastal area (within 50 miles of land), or at sea (over 50 miles from land)

Probably the most difficult part of the data collection, the one subject to the most uncertainty, and yet one essential to the whole effort is the problem of determining oil-outflow occurrence and amount In some cases, outflow amounts appear in the incident reports, generally without any indication of how they are deter. mined. These have generally been accepted at face value as the best information available. Where outflow amounts were not reported, but information on vessel damage was available, an attempt was made to estimate outflow amounts Where a loaded vessel sank, the involvement was credited with outflow equal to the vessel's deadweight. Where a tankship on a ballast voyage sank, an outflow amount equal to the ship'! bunker capacity was used In other cases, amounts were based on damage location and extent, loading condition, tanks reported open to sea, and other information available One serious problem is that of estimating what portion of a tankship's cargo burns if a fire follows a collision or grounding. This appears to be a highly variable factor and each case was estimated on basis of best information available Where the report indicated there was visible sign of oil outflow but there was no great volume of outflow, a minimum quantity of one ton was attributed to the involvement. In the remaining involvements where it could be inferred from the information available that oil outflow did occur. but neither outflow data nor damage details were available, the follow. ing procedure was used: It was assumed that none of these involvements resulted in an outflow greater than 500 long tons. An oil outflow amount equal to the mean value of the outflows less than 500 long Ions for similar involvement type (e.g., groundings, collisions, etc.) was attributed to each of these involvements This is the same procedure used and discussed at some length in [3 and 4].

Before moving on to the data analysis, let us look at some of the uncertainties involved in the data collection process. It is possible that the list of tankship involvements is not complete, either due to incidents not reported m the data sources used or because they were missed during the collection process. Experience during collection and cross-checking of data supports the belief that the list IS relatively complete, particularly for the more serious accidents. It is also possible that tome of the information recorded IS not accurate due to misreading reports or miscoding data. This could include incidents being included which do not meet our definition of tanker involvement, or wrong data, year built, loading condition, etc., being recorded Again, cross-checking and rereading reports. particularly for more serious accidents, gives confidence that relatively few errors of this type remain.

There is also uncertainty regarding outflow amounts, considering the quality and amount of information upon which these figures are based. *In* fact, even the reported values are probably no more than estimates. The problem of estimating what portion of a tankship's cargo burns after collision or grounding is particularly troublesome considering the *influence that a* few large outflows nave on overall amounts All of the outflow amounts must be considered estimates and used with caution The figures on deaths and injuries reported m the information sources have been accepted at face value, and no specific effort has been made to verify or cross-check them since the overall lost of life and injury occurrence are not large.

Data analysis

During the course of tankship operations, some undesired failure events or tankship involvements which interrupt the trip from A to B may occur Some (we hope all) of these involvements are reported and are now accurately represented in our data file. Figure 2, representing our data records, shows how reported tankship involvements can be subdivided into those with oil outflow and those without oil outflow And some portion of those involvements where damage is serious enough to result m outflow also result in sinking of the tankship. (Because of the outflow assumptions we have made, any sinking is considered to result in outflow, although it is not uncommon for oil to remain in intact tanks rather than escape immediately to the sea when a vessel sinks.)

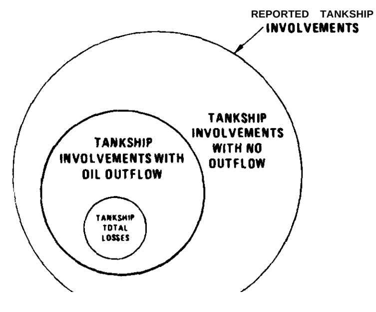


Figure 2 Relationship of #evolvements outflow and total losses to reported *tankship involvements*

The complete data record contains information on 3,715 tankship involvements during the period 1969.1973 These involvements range m seriousness from from bumps and scrapes to major casualties. The analysts reported here includes vessels larger than 3,000 deadweight tons, which is roughly equivalent to a size of 2,000 gross tons. Tankships smaller than this are generally used for specialized service, such as product distribution among terminals within a harbor or on short coastwise routes. They are not used on long-haul voyages and the differences between them and larger ships warrant separate consideration. The choice of a dividing line between these two classes of vessels IS of some concern An analysis by Exxon [10] of the previously published 1969.1970 data used 6,000 deadweight tons as a dividing line. Further study and discussion of fleet composition and vessel utilization would help to clarify this point. For tankships over 3.000 deadweight tons, over the five-year period there were *3,183* involvements. Of these, there were 452 involvements where accidental oil outflows totaling an estimated 950,000 long tons occurred. During the period 1971-1973 there were 381 reported deaths and 178 injuries.

Referring back to figure 1, we will look first at the frequency of occurrence of the various undesired failure events and the resulting failure consequences. Then we will look for relationships between some of the system factors and the failure events.

The frequency of occurrence during the five-year period of the various undesired failure events or involvement types is shown in table 1, and the percentage figures are shown graphically in figure 3.

Table 2 shows the distributions of deaths and injuries among incident types for the period 1971.1973. Collisions and explosions account for the bulk of deaths and injuries; and. in fact, most of the deaths and injuries caused by collisions are the result of fire or explosion following the collision. The total of 381 deaths over three years is not a very large number-approximately 1,500 persons are killed in the U.S. every year in recreational boating accidents, therefore, the loss of life associated with tankship accidents is not great. Table 3 presents information on loss or damage to tankships resulting from involvements. These must be thought of in terms of repair or replacement costs, lost revenue, sailing delays, and increased insurance premiums. The true cost of these depends a great deal on tanker, shipyard, and insurance market conditions.

Table 1. Tankship involvements, 1969-1973, tankships over 3000 deadweight tons

TYPE OF INVOLVEMENT	NUMBER
Breakdown	355
Co his ion	744
Explosion	104
Fire	197
Grounding	790
Ramming	473
Structural Failure	515
Other	5
TOTALS	3,183

information on 011 outflows appears in table 4 and IS shown graphically in figure 4.

Size distribution of oil outflows fot various involvement types is shown in figures S and 6. Most outflows resulting from breakdowns and rammings and fires are relatively small (90% less than 850 long tons), Outflows resulting from collisions, grounding, explosions, and structural failures tend to be larger as indicated in Figure 6.

Table 5 shows that most of the total oil outflow (81%) is a result of tankship sinkings, even though less than 2% of all tankship involvements result in the vessel sinking, The 15 vessels lost due to structural failure accounted for 34% of the total 011 outflow from tankship accidents. Because of their contribution to oil outflows, a more detailed study was made of tankship total losses. There were 47 tankships of over 10,000 deadweight tons that were total losses during the 1969-1973 period. They were responsible for 81% of the total oil outflows of 951,000 long tons. Table 6 shows that most of these revolved a sequence of failure events, Table 7 gives additional detail on the events leading to loss of structural integrity and sinking of the tankship.

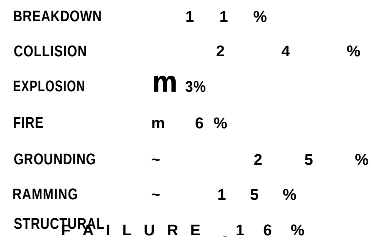


Figure 3. Distribution of tankship involvements, 1969-1973, tankships over 3000 deadweight tom

Table 2. Deaths and injuries resulting from tankship accidents, 1971-1973, vessels over 3000 deadweight tons

Accident Type	No.	Deaths	Injuries
Breakdown	4	5	53
Collision	26	259	130
Explosion	33	46	47
Fire	14	34	10
Grounding	0	0	0
Ramming	0	0	0
Structural Failure	6	37	32
Other	0	0	0
TOTALS	83	381	178

NoTE: Deaths and injuries include those occurring on other vessel or ashore as a result of the accident.

This kind of reformation on the occurrence of various failure events and then consequences should help us answer questions such as, Gwen a failure of a given type, what m the probability of various losses or failure consequences occurring? Referring again to figure 1, we will now look for relationships between some of the system factors and the failure events m an attempt to better understand accident experience. Since our interest here m m preventing accidental oil outflows, we will look at the 452 cases (14 2% of all involvements) where outflow occurred

Vessel size is an important and impressive variable whenever tankships are talked about Figure 7 gives the distribution of tankship size and also the distribution of deadweight tonnage or cargo-carrying capacity as of July 197 I (the midpoint of the five-year period) for reference purposes. Figure 8 gives the distribution of involvements where outflow occurred and the outflow amounts

Table 3. Damage or loss of tankships, 1969-1973, tankships over 3000 deadweight tons

TYPE OF Involvement	TOTAL LOSS	HEAVY DAMAGE	LIGHT DAMAGE	NO DAMAGE	DAMAGE UNKNOWN
Breakdown	2	lb	197	131	9
collision	7	64	570	78	25
Explosion	11	30	52	10	1
Fire	1	26	149	14	7
Grounding	12	63	487	206	22
Ramming	0	23	412	35	3
structural Failure	15	39	445	2	14
Other	3	1	1	0	0
TOTAL	51	262	2313	476	81

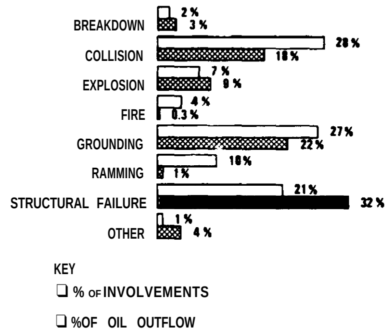


Figure 4 Distribution of involvments resulting in oil outflows and amount of oil outflow, 1969-1973, tankships over 3000 deadweight tom

Table 4. Tankship involvements resulting in all outflow, 1%9-1973, tankships over 30000 deadweight tons

Involvment TYPE	NUMBER RESULTING IN OUTFLOW	Amount Of OIL OUTFLOW ([illegible] Tons
Breakdown	11	29,940
COllision	126	185,08.9
Explosion	31	94,803
Fire	1 -	2,935
Grounding	123	230,306
Ramming	46	13,645
structural Failure	94	339,101
Other	4	54,911
TOTALS	452	951,317

Table S. Tankship total losses and their influence on oil outflow, 1%9-1973, tankships over 3000 deadweight tons

Involement Type	No.	oil, outflow (Long Tons)	OF Total Outflow From All Involvements
●.nkdo.n	2	29,350	3
Collision	7	140,779	15
Explosion	11	68,700	9
Fire	1	1,233	0.1
Grounding	12	134,449	14
Ramming	0	0	0
Structural rail.,.	15	322,519	34
Other	3	54,790	
TOTALS	51	771,917	81

NOTE TOTAL OIL OUTFLOW FROM ALL 111=-S EQUALS 951,317 LONG TONS (FROM TABLE 4)

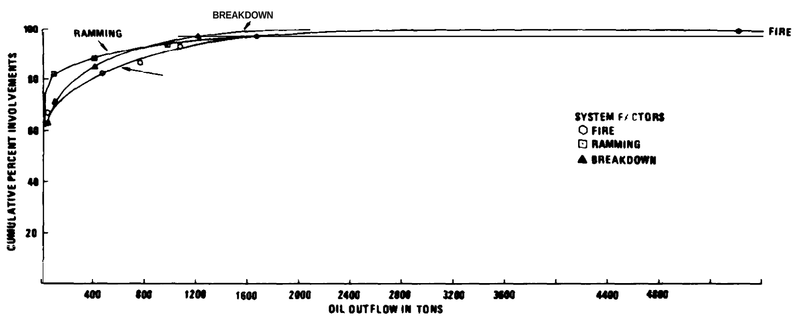


Figure 5. Size distribution of oil outflows for breakdowns, fires, and rammings.

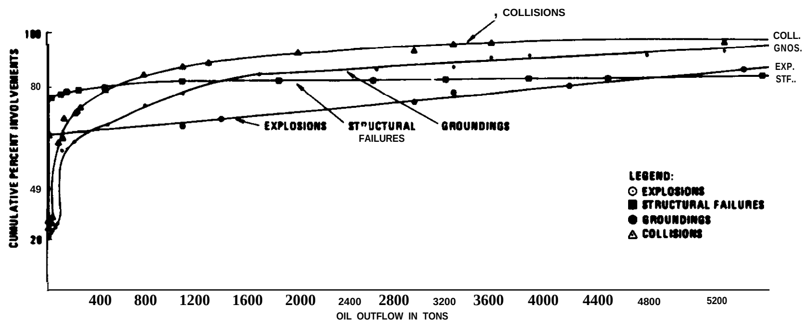


Figure 6. Size distribution of oil outflows for collisions, ● xplc.ciom, groundings, and structural failures,

Table 6. Accident for-47 tankship losses, 1969-1973, tankships over 10,000 deadweight tons

Accident Sequence	Number	Oil Outflow (Long Tons)
Breakdown-Structural Failure-Sink	1	1*, 350
Breakdown-Grounding-Sink	1	13,000
Collision-Sink	2	4,138
Collision-Explosion/Fire-Sink	4	136,163
Explosion/Fire-Sink	12	90,030
Grounding-Explosion/Fire-Sink	1	2,500
Grounding-Sink	9	134,726
Flooding-Sink	2	54,669
Structural mil.,.-aro".di"~-sinb	1	40,000
Structural Failure-Sink	14	282,519
Totals	47	774,.%.,

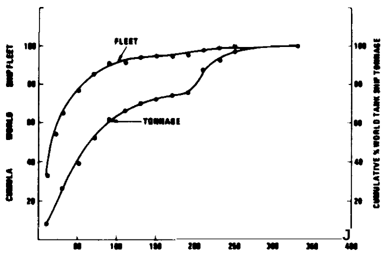


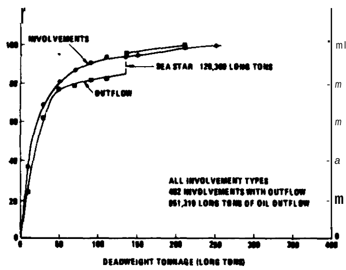
Figure 7 Size distribution of world tankship vessels and tonnage, vessels over 2000 gross tom, 197t

Table 7. Description of loss of structural integrity for 47 tankship losses 1969-1973, tankships Over 10,000 deadweight tons

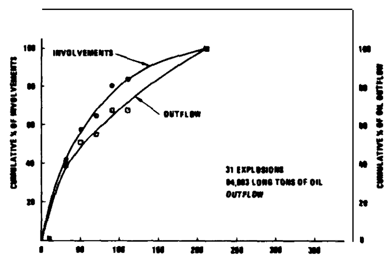
Description	Number	Oil Outflow (Long Tons)
A. Loss of structural integrity of hull caused F., i- ily by -t. rnal forces or where local ",..1.1 conditions deteriorated. No explosion . r fire was associated with the ... ident. These may be broken down into:		
1. Structural failure of main hull girder from excess bending or shear loading	12	243,619
2. Local structural failure of hull envelope		
. .Failure of hull penetration	2	36,750
b. Local hull plating failure	2	39,169
. . Unknown local structure failure	1	34,000
3. Hull damage C.". *4 by C.111,1OII or grounding		
a. Collision	2	4,138
b. Grounding	11	187,726
	30	343,402
B. k... of str UC, ural I., egrit" from damage ..... d primarily by explosion or 11,. or where explos ion or fire contributed to loss of structural integrity. These may be broken down into ,		
1. Explosion or fire initiated in own ship cargo tanks	12	90,030
2. Explos I." or fire set off by vessel collision or grounding		
a. Collis i..	4	136,163
b. Grounding	1	2,500
		228,693

Figures 9 through 15 show the distribution of involvements and resulting outflows for different involvement types.

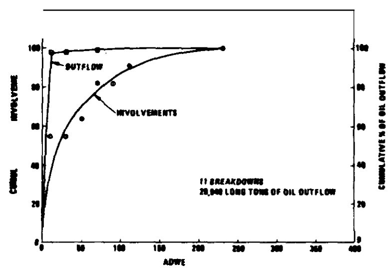
Vessel age is another factor we might suspect bears come relationship to the occurrence of future events, ● nd structural failures in particular During the five-yew period, 515 structural failures occurred Of those, 94 resulted in an estimated 339,181 long tons of 011 outflow. Fifteen total losses due to structural failure accounted for 322,5 19 long tons of outflow (95% of total outflow due 10 structural failures and 34% of all outflows). Figure 16 shows the distribution of these structural failures with vessel age, and figure 17 shows their distribution by size. Structural failures can result from



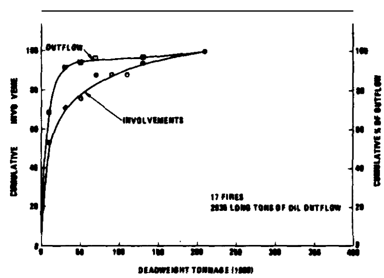
Rffurc 8. Dwtnbutwn of 452 mvol— ts wtth outflow end out. flow amounts



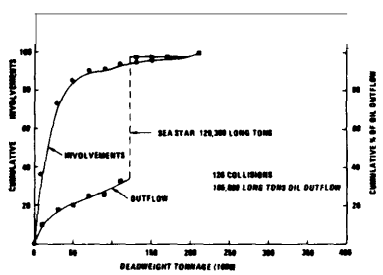
Fmwm 11. Otstr{butmn of 31 .mkwms wtth outflow ● nd rowltma Ouiflom.



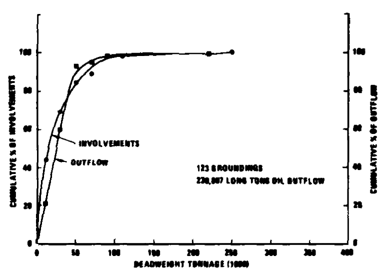
F!fpre 9, Dmrbtmon of 11 breakdowm w!th outflow and ramdtmg outflows.



Fqurc 12. Dtstr!butlon of 17 ftra with outflow ● d rmulting out- flows.



Ft~re 10 Dmr,butmn of 126 colllsmns with outflow md remdtmg Cutflowl



Flwr@ 13 O,strlbutma of 123 ground,ngs with outflow and r.. sultmg outflc+w

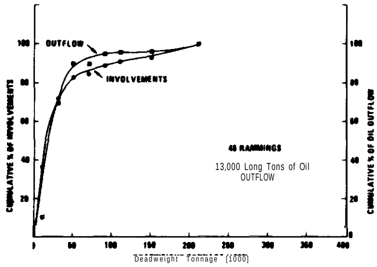


Figure 14 Distribution of 46 rammings with outflow and resultlng Outflows.

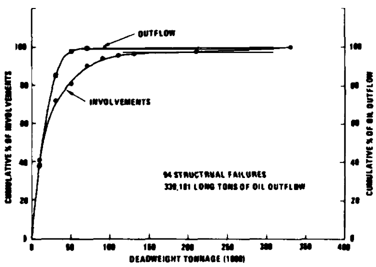


Figure 15. Distribution of 94 structural failures with outflow and resulting outflows.

poor structural design, loads exceeding the design loads due to unusual environmental conditions or improper loading, or deterioration due to corrosion or erosion. Corrosion and erosion depend cm time as well as inspection and maintenance, protective coatings, cargo, and *environmental conditions.* Time may also be required for design defects to make themselves apparent. The sharp increase in structural failures between 15 and 20 years indicates ships in this age group are more subject to loss from this cause. Quaille [7] reports m increase of tanker loss ratio (ratio of tonnage lost to tonnage in the group) for tinkers in the 15-19 year and 20-24 year age groups but does not indicate how the vessel losses occurred. At the very beat though, age can only be a gross indicator of probability of failure. We must look further into these structural failures to identify factors more directly linked with them.

Table 8 gives a breakdown by location of the 443 tankship involvements with oil outflow where location could be determined, The bulk of collisions with outflow occurred in the coastal, entranceway, and harbor areas, as one would expect Half of the explosions occur at sea. Over half of the fires with outflow occur at the pier. The majority of grounding occur in coastal or entrance areas, with a smaller contribution coming from harbors. Rammings in the harbor or at a pier are the bulk of ramming involvements. And a majority of structural failures occur at sea. This confirms that pathway plays m important role in collisions and groundings, along with the ship and human factors.

There are a number of other ways the data records could be examined ιo test for relationships between system factors and

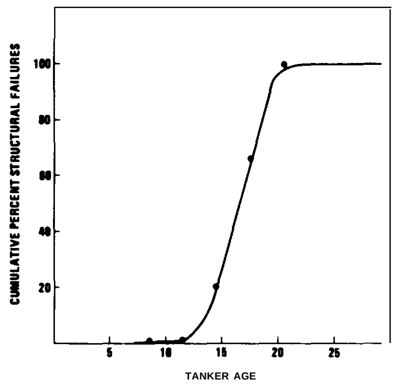


Figure 16 Distribution of 15 tankship total losses due to structural failure by vessel age

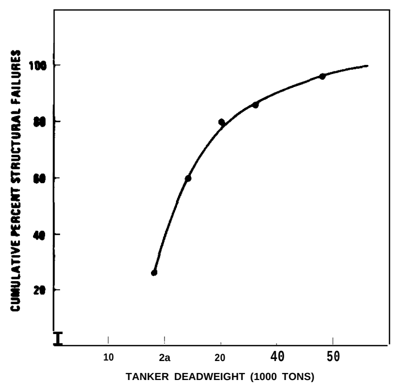


Figure 17 Distribution of 15 tankship total losses due to structural failure by vessel size.

occurrence of failure events. Additional work on several of these is underway.

Application of results

Analysts of the information collected has really just begun Properly digested, the accident information should be useful in evaluating various alternative measures for reducing accidents and resulting oil outflows, as well *as* other losses They may also be of use m evaluating risks associated with future 011 transport and production activity decisions.

Table 8. Location of 452 tankship involvements with outflow, tankships over 3000 deadweight tons

INVOLVEMENT TYPE	Pier	Harbor	Entrance	Coastal	
Breakdown	0	1	1	5	3
collision	5	41	25	45	9
Explosion	5	4	0	6	15
Fire	10	2	0	1	4
Grounding	1	27	40	53	0
Ramming	18	15	5	4	2
structural Failure	6	9	4	7	64
Other	1	0	0	2	1
TOTALS	48	99	75	123	98

REFERENCES

1 Ports and Waterways Safety Act of 1972, Public Law 92-340

2 Porricelli, J D., Keith, V F ; and Starch, R L 1971 Tankers and the ecology *Trans SNAME*

3 Keith, V F , and Porricelli, J.D 1973 An analysis of oil outflows due to tanker accidents, *Proceedings of Conference on Prevention and Control of 011 Spills*. Washington, D.C American Petroleum Institute

4 J J Henry Co , Inc. 1973 An analysts of oil outflows due to tanker accidents, 1971.1972 Report CC-D-81-74 for the U S Coast Guard Available from NTIS, AD 78031S,

5 Study on accidental marine pollution by oil Report presented to IMCO, MP XIII/2(a)/9 by France, June 1972

6 Grimes, C 1973 A survey of marine accidents with particular reference to tankers In Marine *Traffic Engineering, Proceedings of a Conference organized jointly* by the Royal Institution of Naval Architects and the Royal Institute of Navigation, London.

7 Quaille, P *1974* Ocean hull statistics *Safety at sea international*

8 Tanker Advisory Center, New York 1974 Tanker casualty returns, annual summary, 1973 Press release, April 12, 1974

9 National Transportation Safety Board 1971 Risk concepts m dangerous goods transportation regulations Report NTSB-*STS-71-1*, p 19

10 Exxon Corporation, Public Affairs Department 1973. Reducing tanker accidents A background paper

11 Devanney, J W., III, and Stewart. Robert J 1974 Bayesian analysis of oil spill statistics. *Marine Technology, October* 1974