Henry Persson, Anders Lönnermark

Tank Fires

Review of fire incidents 1951–2003

BRANDFORSK Project 513-021

The Orion Tank Fire in 2001, world record in tank fire fighting.
Photo courtesy of Industrial Fire World

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Abstract

A literature review has been conducted to gather information related to the extinguishment of actual tank fires and relevant large-scale fire extinguishing tests. The aim was to search for data that could be used for validation of foam spread models. In total, 480 tank fire incidents have been identified worldwide since the 1950s and the information collected has been compiled into a database. A list of the incidents with some data is provided in this report. Out of the 480 fire incidents, only about 30 fires have provided relevant information for model validation. A more detailed summary of the existing data from these fires is also provided in this report.

Key words: Tank fires, foam extinguishment, large-scale tests, literature review

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Postal address:
Box 857,
SE-501 15 BORÅS, Sweden
Telephone: +46 33 16 50 00

Telefax: +46 33 13 55 02
E-mail: info@sp.se
http://www.sp.se

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Preface

This report presents the results from a literature review aiming at collecting information about tank fires and in particular their extinguishment. Attempts have also been made to identify large-scale fire extinguishing tests relevant for tank fire protection. The intention was to find detailed data to be used for the validation of the foam spread model developed in the FOAMSPEX*-project (EC-project ENV4-CT97-0624) reported in 2001.

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Swedish Fire Research Board (BRANDFORSK),
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Swedish Petroleum Institute (SPI).

A large number of individuals worldwide have been instrumental in collection of the information summarised in this report. All are gratefully acknowledged for their contribution, without their help this project would not have been possible.

Much of the information originates from the USA and is therefore often given in empirical units. We have converted the data into SI units and give the original data in empirical units within parenthesis.

Although great effort has been expended to collect information, there are probably a significant number of fire incidents, which have not been identified. Further, more detailed information and experience is probably available concerning most of the identified fires that could contribute to an improved understanding of tank fire protection. Such information is not available in the open literature but could no doubt be obtained through indepth interviews with site personnel etc. Based on the information gained in this project, it is apparent that there are gaps in the available information, e.g tank fire fighting using fixed systems.

We would therefore like to invite all people, companies and organisations involved in tank fire protection to submit further details on identified or unidentified tank fires to be included in the established database. Let’s follow the motto, “In Safety-No Secrets”.

Information could be sent to:

Henry Persson
SP-Fire Technology
Box 857
501 15 BORÅS
SWEDEN

Tel: +46 33 16 51 98
Fax: +46 33 41 77 59
e-mail: henry.persson@sp.se

*FOAMSPEX - Large-scale Foam Application - Modelling of Foam Spread and Extinguishment

Summary

The objective of this literature review was to gather information related to the extinguishment of actual tank fires. In addition, information regarding relevant large-scale fire extinguishing tests has been collected.

The project is a continuation of the research project, FOAMSPEX, which was completed 2001. Through comprehensive theoretical and experimental work, engineering models to predict the spread of foam and fire extinguishment under large-scale fire conditions were developed. However, FOAMSPEX concluded that there was a need for validation data from large-scale fires, which initiated this project.

Information has been collected through various reports and proceedings, fire magazines, Internet and through personal communications. In total 480 tank fire incidents have been identified worldwide since the 1950s and the collected information has been compiled in a database. The available information for each of the incidents varies from just a short notice in a newspaper to very detailed information regarding the cause of the fire and the fire fighting response. The extent of each of the identified fire incidents may vary considerably, from just a rim seal fire, being extinguished without difficulty, to fires involving a complete tank storage facility with 30 to 40 burning tanks. Assuming that the data is complete for the 1990s and 2000s, this indicates that the number of tank fire incidents, serious enough to be reported by news media, are in the range of 15 to 20 fires per year. Of all the identified fires, lightning was declared to be the cause for ignition in about 150 of the fires.

Out of the 480 fires, only about 30 fires have provided detailed information about extinguishment, relevant for the validation of the FOAMSPEX models. However, there are still many uncertainties in the data regarding e.g. fuel and foam properties, which could be crucial for the modelling results. It can also be noted that practical fire fighting experience is generally limited to tanks having a diameter of 40 m to 50 m or less and the largest tank ever successfully extinguished was 82 m in diameter. With a few exceptions where sub-surface injection was used in parallel, although over-the-top application using mobile equipment seems to be the dominating methodology. There are no fires where detailed information has been found on extinguishment using fixed or semi-fixed over-the top foam pouring systems.

There are only a few large-scale tank fire tests conducted, the largest performed in 1967, having a diameter of 34,8 m (115 ft) using single point sub-surface injection. Combined with a large number of fire tests in smaller tanks (2,4 m/8 ft and 7,6 m/25 ft) and some non-fire foam flow tests in tanks up to 35,7 m (117 ft) in diameter, these seem to be the most important tests, partly forming the basis for the existing NFPA 11 foam standard.

As this review shows, there is a the lack of well-documented data on the extinguishment from tank fires in the range from 50 m in diameter and larger, such large-scale fire tests would be of great importance to provide further experience and validation data for foam spread models. Having access to validated foam spread models would not only be relevant to confirm the limitations of existing equipment and foams, but also contribute to a better fundamental understanding of foam spread and possibilities for the development of foam concentrates and foam equipment. In light of the present debate concerning the environmental acceptability of the most high-efficiency foams today, containing flouro-surfactants, such a foam-spread model seems even more important.

1 Introduction

Although large-scale tank fires are very rare, they present a huge challenge to fire fighters, oil companies and the environment. There are only two alternatives for combating such a fire, either to let it burn out and thereby self-extinguish or, alternatively, to actively extinguish the fire, using fire fighting foams.

As the burn out procedure will result in a fire that is likely to last several days, complete loss of the stored product, environmental problems, large cooling operations to protect fire spread to adjacent tanks and in some cases potential for a boil-over, this is often not an acceptable alternative.

Extinguishment of a tank fire can only be obtained by using fire fighting foams. However, historically the chances of successful fire control and extinguishment have been low, especially for larger tanks. Even tanks exceeding 20 m diameter have caused problems in many cases, and for many years, there had been no successful extinguishment of tanks larger than 45 m in diameter. Presently, the largest tank fire ever extinguished occurred in June 2001 and had a diameter of 82,4 m (270 ft). However, tanks that exceed 100 m in diameter exist and there are some debate concerning whether it would be possible to extinguish a fire in the largest tanks at all.

Standards, such as the highly influential USA standard NFPA 11 [1], provide very limited guidance on how to extrapolate fire protection guidelines from smaller tanks to the huge fire risks of today. Even assuming that extinction is possible, it is not fully known what type of equipment, type of foam, application rate and tactics should be used.

One of the reasons for this lack of guidance is that there has not been any fundamental understanding of the extinguishing process. In order to improve this understanding, a large research project, FOAMSPEX [2], was undertaken several years ago. Through comprehensive theoretical and experimental work, engineering models to predict foam spread and fire extinction under *large-scale* fire conditions were developed.

Some of the conclusions from the FOAMSPEX project were that:

- The results support the existing recommendations according to NFPA 11 referring to the number of fixed foam discharge outlets and the limitation of maximum foam flow length.

- The model indicates that tanks up to 120 m in diameter can be extinguished provided the application rate is sufficiently increased above the recommended value of 6,5 L/m^2 /min.

- The model has been compared to a number of actual, large-scale tank fires, ranging in diameters from 40 m to 80 m. The difference between the predicted time to cover the whole burning surface and the observed time to knock down is in the range of 10 to 20 minutes.

- The models are based on friction data from laboratory experiments with cold foam flow. A remaining uncertainty in the models is how to scale the friction data when increasing the length scale by orders of magnitude (e.g. from about 10 m to tank diameters of 100 m to 120 m). More work is needed to improve the accuracy of the friction data for larger tanks and for various types of foam.

- Further work is needed to incorporate the break down of foam at the foam front and to quantify the initial delay of the extinguishment phase caused by foam break down. This will call for additional large-scale experiments and more detailed observations from large-scale tank fires.

The benefits of being able to predict the foam spread is clearly shown by the FOAMSPEX project. For the first time, it is possible to study the influence of various parameters such as the viscosity of the fuel, the foam quality and the influence of the application rate versus tank diameter. However, there are uncertainties in the models when applied to large-scale conditions, as all test data has been obtained in small and medium size tests. There were few data available from large-scale tank fires, which could be used for comparing to the model calculations, and there is therefore a need for further validation to estimate the uncertainty of the model.

The project reported here was therefore initiated in order to establish a database by collecting as much information as possible from actual tank fires and large-scale foam tests. Even if tank fires are rare, a significant number of fires occur annually on a worldwide basis. On a local basis, every single tank fire is a very expensive event and it has therefore been our hope that a lot of information and experience collected in e.g. fire investigation reports, would be available and could be very valuable for the future.

Although the search for information is focused on the extinguishing part of the fire, it was also recognised that information about tank fire incidents could be a valuable source of knowledge, both for the oil industry and fire protection community. Thus, even data on incidents where only limited information was available concerning the extinguishment tactics, have been included in this search and compilation.

2 The collection of information

There is no easy way to collect detailed information about tank fires. Even though each full surface tank fire seems to receive quite a lot of attention on a local basis, the information given to local media is normally very limited from a technical point of view. In some cases, such local events are summarized in various fire magazines, mostly just as one fire in a list of incidents. However, from time to time there is a comprehensive report from such fires. Oil companies typically try to minimise the publicity about fire incidents as it might give an impression that these facilities are very hazardous. Public reports are available that provides full data about the fire incident in only very few cases.

Based on this, information has been collected using as many types of sources as possible. Even though a significant number of tank fires have been identified, it is still possible that some number have been overlooked. However, by identifying the fires and summarizing the information available in a database, this provides a useful source of information for those who might have a particular interest in e.g. a specific fire or specific types of fires. It also provides a possibility to continue the collection and compilation of information of this kind in the future.

2.1 Sources

A large number of various sources have been used to collect information. Below is a brief description of the main sources used in the project. In many cases, the information regarding a specific fire is based on information from several sources, usually in combination with personal communication with someone closely involved in the fire to obtain the most detailed information. However, in many cases, it has not been possible to achieve these personal contacts. In such cases the lack of information might be easily overcome if the correct person could be identified, provided they are willing to share this information.

2.1.1 The LASTFIRE project

The LASTFIRE project is one of the most comprehensive studies on the fire hazards associated with large diameter (greater than 40 m), open top floating roof storage tanks. Resource Protection International (RPI) carried out the study on behalf of 16 oil companies and the report was issued in 1997. One part of the study was a review of the cause of fires and the escalation mechanisms. As a part of this, a survey of major tank fire incidents was made. The information was collected by the distribution of a questionnaire to all the participating oil companies, asking for details about tank fire incidents within their facilities. Parts of the information were confidential and in the LASTFIRE report [3], full details (e.g. oil company, location specific date) are not given. According to the LASTFIRE project group, it was also difficult to obtain detailed technical data from the fires even though the oil companies participated in the study. Besides collecting the information from the oil companies, a literature review was also made and in total about 80 fires were identified and reported. Some were rim seal fires, other full surface fires also involving other types and sizes of tanks actually outside the scope of the LASTFIRE project.

Being the perhaps most important study, the LASTFIRE project group was contacted and asked to review their material to analyse if they could contribute to our project with more detailed information, in particular on the extinguishment of the tanks. Very limited new information could be gained beyond what was already presented in the LASTFIRE report.

2.1.2 The Technica report

As a consequence of a major tank fire in 1988 in Singapore, which started in a floating roof tank that escalated to two nearby tanks, a study escalation mechanisms was made by Technica Ltd [4]. The study was made on behalf of a number of oil companies located in Singapore and one aim was to develop an engineering model in order to predict fire spread from one tank to another. The model allowed Technica to study the influence of a variety of parameters such as the effect of wind, cooling water sprays, type of floating roof, tank diameter, tank spacing, etc. As a part of this study, a literature review was made, both regarding full surface tank fires and large spill/bund fires and some brief information is given for about 120 fires. As the information in the report is very limited, it did not contribute to the collection of detailed information but a significant number of additional tank fires were identified.

2.1.3 The API report

In 1995, Loss Control Associates, Inc prepared a report for the American Petroleum Industry (API), “Prevention and suppression of fires in large aboveground storage tanks” [5]. The study applied to storage of flammable and combustible liquids in vertical atmospheric tanks having a diameter of 30,5 m (100 feet) or larger and/or storage capacities of 80 000 barrels or greater. In this particular study, an analysis was made of past fires and a brief summary of case histories is given for 128 fires.

2.1.4 The Sedwick report

On behalf of the LASTFIRE project group, a search for tank fires was made 1996 by the company Sedgwick Energy & Marine Limited in their database [6]. This study identified 141 incidents and contributed with many new tank fires, especially outside the USA. As the information in the report is very limited it did not contribute to the collection of detailed information.

2.1.5 The NFPA Special Data Information Package

On request, NFPA provides various forms of statistics and a specific search was made of tank fire incidents [7]. Parts of the report provide statistical data from 1980 to 1998. However, the statistics cover fires in flammable or combustible liquid storage tank facilities in general and not only tank fires specifically. The statistics are therefore presented in various forms, e.g. related to incident type, by year, ignition factor, etc. This does not provide specific information but in an annex to the report, some technical information was given specifically related to some few tank fires.

2.1.6 Lists of reference

Several foam manufacturers and fire protection companies publish lists of references to fires where the company has been involved in the extinguishing operation, their foam concentrate or foam equipment has been used, etc. These lists have been important in identifying several tank fires. Further, personal contacts contributed significantly to obtaining more detailed technical information. Some manufacturers also publish their own company magazines providing more detailed information on referenced fires.

2.1.7 Reports and proceedings

Some fires have become very well known because of their size, the successful or unsuccessful extinguishment, etc. and details have been summarised in reports or presented at various symposiums. In a few cases, these kinds of reports have been a source of technical information, e.g. for the fires at Milford Haven, Sunoco and Neste, respectively.

A report, presenting a synopsis of major incidents in the oil industry during 1991-96 in India has also been studied. Proceedings from various conferences have also been a source of data, primarily for identifying tank fires as they are normally giving an overview of various aspects of tank fire protection. (References listed in the summary of each fire).

2.1.8 Fire magazines

The most important source of information, apart from personal communications, has been various fire magazines. There are several magazines, which are focused on industrial hazards and have a good coverage of fires occurring in e.g. the petroleum industry. The most important for this study has been Industrial Fire World (IFW), Industrial Fire Journal (IFJ), Industrial Fire Protection (IFP), Fire International (FI), and Industrial Fire Safety (IFS).

For many tank fires, there have been articles published where the fire incident and the extinguishing operation has been described in detail, making it possible to extract most or sometimes all the information we have been seeking. (References listed in the summary of each fire).

2.1.9 Internet

Internet has become an important source of information, especially for more recent fires. Many tank fires have been identified by searching on some of the main web search engines (Alta Vista, Google, etc.). The advantage of using Internet is that there is a continuous update; in some cases it gives quite detailed reports, very often in combination with photos from the incident. It is also a good source of contact persons for a specific fire. Internet has also been used as a complement by several fire magazines where they provide incident logs, links to relevant web sites, etc. The fire magazine “Fire International” is now only published on the Internet and provides the possibility to receive weekly newsletters via e-mail. (References listed in the summary of each fire). A disadvantage with Internet is that some information (web pages) are available for a limited period of time only, and that data reliability is difficult to verify.

2.1.10 Local newspapers

Local newspapers often provide general information about fire incidents when they occur. As tank fires are rare, the main news agencies often collect this information providing information for national and international newspapers to publish short notices about such incidents. In the project, a search was made by the news agency “Observer” in more than 5000 newspapers published in English, which identified more than 80 fires from 1975 and forward. Many of these were already known from other sources, but in several cases it provided some extra information, e.g. specific information about date and location which sometimes was missing in other sources, e.g. LASTFIRE [3]. For some of the most

recent fires, these articles have provided substantial information. (References to these articles are given in the summary of each fire.)

2.1.11 Personal communication

Although mentioned last among the sources for information, personal communication with people involved in the fire fighting business, directly involved in some fire fighting operations, etc has been the main source for the very detailed information. A letter describing the aim and background of the project together with a questionnaire was sent to about 40 people worldwide with various relations to tank fire fighting. Response has been achieved from most of these and in many cases a great deal of help has been obtained, also leading to further contacts. However, also for these people, the search for detailed information is a time consuming issue with the need to collect information from a variety people involved in the fire fighting operation. In certain cases, some information is classified as confidential. The practical consequence is that there might be much more detailed information to collect than actually achieved in this project if further time and resources could be spent on this search. (References listed in the summary of each fire.)

2.2 Information of interest

The primary information we have been gathering has focused on basic data about the tank fire (or large-scale fire test), important data related to the extinguishment and the general fire brigade response. Based on this, the questionnaire contained the following specific questions:

Basic data about the tank fire (or large-scale fire test)

1. Date and location of the fire
2. Type of tank
3. Diameter and height
4. Type of fuel, filling ratio
5. Cause of ignition
6. Type of fire (rim seal, full surface)

Data related to the extinguishment

7. Weather conditions
8. Mobile attack/fixed system
9. Type of equipment (fixed/mobile, etc)
10. Type of foam
11. Application rate
12. Time to knockdown
13. Time to complete extinguishment

The general fire brigade response

14. Preburn time
15. The need for cooling of adjacent tanks
16. Totally used amount of cooling/extinguishing water and foam concentrate
17. Number of involved personnel
18. General positive/negative experience from the operation

If there are any articles in fire magazines or other reports available related to a specific fire giving the requested information, please give a reference.

3 Data and experience from actual tank fires

In total, 480 fire incidents have been identified dated from 1951 to 2003. However, only limited data has been obtained concerning fires during 2003. The total number of tank fire incidents during this 50 years period is probably considerably higher, which is evident when studying the increasing numbers of identified fires for each decade as shown in Table 1.

Table 1 Number of identified tank fire incidents per decade from the 1950s.

Decade	1950s	1960s	1970s	1980s	1990s	2000s
No. of fires	13	28	80	135	161	62*

*) Last fire identified 2003-09-28

The types of fires that were identified range from minor incidents, such as partial rim seal fires, to fires more or less involving the complete oil storage facility. This means that the actual number of tanks involved is considerably higher than the number of incidents. In a few cases, a fire might have been reported twice, due to lack of detailed information. There might also be some incidents, which by definition are not true tank fires, e.g. some foam coverage operations in tanks with sunken floating roofs are reported although there was no fire. However, during the analysis of the reported fire incidents, e.g. in the Technica report [4] or the Sedgwick listing [6], all fires which were not possible to clearly define as a tank fire have been excluded.

Assuming that the data collection is complete for the 1990s and so far during the 2000s, this indicates that the number of tank fire incidents per year worldwide, large enough to receive some attention by the media, should be in the order of 15 - 20 fires as an average. In a worldwide perspective, there are probably even more tank fire incidents as the sources for information mainly cover USA, Europe and some other English speaking countries. If all fire incidents, e.g. rim seal fires would be reported, the number would probably increase significantly (see also Table 2). If the number of each tank involved in fire were counted, the number would increase even more.

3.1 Data base information

The information collected about each fire has been summarised in a database (presently in an Excel spreadsheet). An extract from the database, giving some basic information about all identified fires is presented in Annex B. In the complete database, the following information is included, if available:

- Identification number
- Date
- Location
- Type of object/facility
- Rating 1-7 (indicates type of fire and information available, see below)
- Description of objects involved
- Tank diameter (m or ft)
- Tank area (m^2 or sq ft)
- Height (m or ft)
- Type of fuel
- Amount of fuel at the incident (m^3 or gallons/barrels)

- Type of foam application equipment
- Flow rate (L/min or gpm)
- Application rate (L/m^2/min or gpm/sq ft)
- Estimated application rate (L/m^2/min or gpm/sq ft)
- Total amount of foam used (L or gallons)
- Type of foam
- Time to knock down (min)
- Time to extinction (minutes or hours)
- Fire / no fire (“no fire” for foam coverage operations)
- Other measurements
- Ignition source/cause of ignition
- Weather
- Comments (very brief information about the incident)
- Indication if there are photos or video recordings available
- References
- Any additional information

As the type of fire varies considerably, as does the information available, a subjective ranking has been introduced in order to make the analysis of data more efficient. The following ranking has been used:

1. Very interesting case, full surface fire and detailed data about surfaces, application rates, time to knockdown and extinguishment are available.
2. Interesting case, full surface fire and with detailed data available, Additional data would be helpful.
3. Possibly interesting case, full surface fire, considerable lack of information.
4. Rim seal fire.
5. Several tanks involved, burnout, etc. Not possible to evaluate the fire fighting operation.
6. Very limited information or without interest for other reasons.
7. Foam coverage of fuel surface - no actual fire.

These ranking have been changed during the project as more information has been obtained and the ranking could be changed in the future if additional information becomes available. The present number of fire incidents classified into each ranking category is shown in Table 2.

Table 2 Number of tank fire incidents in each ranking category

Ranking	1	2	3	4	5	6	7
No of fires	17	14	23	79	80	252	14

As shown in Table 2, the majority of the identified fire incidents are not relevant for the main purpose of this study, i.e. to provide detailed information about the fire fighting operation. The main reason is that the available information is very brief, resulting in ranking category 6. It is also apparent that a substantial part of the fires were very serious, involving several tanks and in many cases resulted essentially in a burnout (ranking 5). As rim seal fires very often seem to be extinguished without any significant problems, either manually or by fixed systems, it is very likely that those incidents are not reported in media. Thus, estimating the true number of rim seal fires worldwide is not possible on the basis on this literature search.

Without stating any statistical relevance, it is possible to note that among the 480 identified fire incidents, lightning is declared to be the cause of ignition for about 150 fires. This confirms the conclusions from both the LASTFIRE [3] and Technica [4] studies stating that lightning is the most common source of ignition. It should be noted that for about 190 of the fires, there is no information available about the ignition source.

Of all fires identified, there are only about 30 tank fires where it has been possible to obtain full or almost full information about the fire and the extinguishing operation (ranking 1 or 2). In Table 3, a summary of those fires is presented showing some specific information about the extinguishing operation. In the table, there are also several fires included which have been judged to be of great interest for other reasons. Further details about the fires in Table 3 are presented in Appendix A including a brief summary of the fire incident and the extinguishing operation.

Some of the fires listed in Table 3 could be defined as very “complex” fires involving several tanks, several extinguishing attempts due to various problems, use of combined foam application methods, etc. In such cases, the figures given in Table 3 and Appendix A are related to a specific tank or extinguishing attempt where it has been possible to extract detailed information. It is important to note that time to knockdown and extinguishment is given from start of foam application while the whole tank fire operation sometimes involves several days.

Several general conclusions can be drawn based on the data in Table 3. With few exceptions, all full surface fires have been attacked using mobile foam equipment. Although great effort has been expended some fires were not really extinguished, the cessation of the fire was a combination of foam application and a burn out. The main reasons for unsuccessful fire fighting attemps have been lack of suitable equipment and thereby too low application rate, lack of foam concentrate, problems with logistics, and severe weather conditions. Examples of such fires are Milford Haven (no 6) and Neste (no 14). In the Czechowice (no 0) and Milford Haven incidents, the situation became very serious and complicated due to boil-over.

Fires in cone roof tanks with internal floaters are potentially a real challenge from the fire fighting point of view. The cone roof and the internal floater might form pockets, which are very difficult to reach by monitor application. If the tank is full, there is also a problem with overflowing product causing fires in the bund area resulting in very complex fire situations and risk for escalation. In Table 3, there are three examples of such fires: Collegedale, Rialto and Jacksonville (no. 1, 3 and 16) where several attempts were made using sub-surface injection in combination with over-the-top application before extinguishment could be achieved. Tanks without internal floaters might also cause similar problems if part of the cone roof remains and obstructs the fuel surface. An example of such a situation is the Romeoville fire (no 2) where high-back-pressure foam makers were installed on a product line to enable sub-surface injection to achieve extinguishment. A common experience from these fires is that the actual flow rates of water for extinguishment and cooling, quantities of foam concentrate, duration of operation, etc far exceed recommendations given in NFPA 11 and similar standards.

The review also shows that there are several examples where large tank fires have been successfully extinguished using mobile equipment. Significant for these successful extinguishments are good planning of tactics and logistics before the attack is initiated, the use of large-scale equipment and high quality foam concentrates. Further, one can see that knock-down normally is achieved within 10-30 minutes under these circumstances, although the time to complete extinguishment is more difficult to estimate. Most recommendations specify a foam stock equivalent for not less than one 1 hour of

operation but this might be too optimistic in many situations. If the foam supply is interrupted, the fire will quickly develop again and all that has been achieved is lost. Such situations occurred e.g. in Romeoville, Milford Haven and twice in Peninsula (no. 2, 6 and 9). The influence of the foam concentrate quality is indicated in the two polish tank fires (no. 27 and 30) where application rates in the order of 25 to 30 L/m^2/min had to be used although the tanks were of reasonable size (30-40 m in diameter). Although FP foam concentrates probably represent the most common foam type in the oil industry for tank fire protection, very few incidents are reported where FP foam was used, alone or in combination with AFFF.

The Tenneco fire of 1983, tank diameter 45,7 m (150 ft), was the largest tank fire successfully extinguished for many years. Since then, a number of fires of equivalent size have been successfully extinguished (e.g. no 15, 19, 20, 21, and 23). In 2001, a new break through was gained when the Orion fire, tank diameter 82,4 m (270 ft), was successfully extinguished in 65 minutes using an application rate of 8,55 L/m^2/min. It is important to realize that fighting this size of fire places enormous stress on all links in the chain of events leading to extinguishment. The application rate of 8,55 L/m^2/min equals a flow rate of about 45000 L/min. Using 3 % proportioning 1350 L/min of foam concentrate is consumed. The need for large-scale equipment, very good logistics, high quality foam and a well-coordinated operation becomes very imperitive.

In Table 3, some fires are listed which are somewhat different, and from that respect interesting, despite the fact that some important information is missing. A tank involving IPA was extinguished by dilution (no. 8), as the use of detergent foam (non-AR) was ineffective. A fire in heated oil (no. 18) took two days to cool down and extinguish while two fires in heated, liquid asphalt (no. 25, 26) were extinguished in about 1 hour.

Except for the few fires where sub-surface injection was used, no information has been found of full surface tank fires extinguished by fixed systems. There are some foam system manufacturers claiming successful extinguishments in their list of references but it has not been possible to obtain any corroborating details.

In about 20 of the 79 identified as rim seal fires, the information indicates that extinguishment was obtained by using fixed foam systems. In one case, a halon 1211 system was used in combination with foam. However, in about 40 incidents, the rim seal fire was extinguished by using portable fire extinguishers, foam handlines or a combination of these. In one case, the fixed system failed and the fire had to be extinguished manually. In the remaining incidents, there is no information available.

The LASTFIRE study [3] indicates a very low probability of full surface fires on floating roof tanks as a result of rim seal fires. However, if there is a spill fire on the roof or an impinging bund fire, the probability for a full surface increases. Due to the fact that floating roof tanks very often are large diameter tanks, they will also create one of the most challanging situations in a tank farm. Studying the tank fires in Table 3, most of the largest tanks reported are in fact floating roof tanks, e.g. Milford Haven, Tenneco, Neste, Amoco, Sunoco and Orion (no. 6,7,14,19,21, and 24). These fires also show the need for good pre-planning and the necessary resources for a full surface fire in floating roof tanks in order to successfully fight such large fires.

Table 3 Summary of tank fires with some specific information about extinguishment

No.	Fire	Dia (m)	Fuel	Foam	Appl. rate ($L/m^2/min$)	Knock-down	Ext	Comments
0	Czechowice	33	Crude	Protein	8,4	No	No	Boilover
1	Collegedale-72	21,4	Gasoline	XL-3	2,45	?	1:30h	SSI Vent-fire
2	Romeoville-77	58	Diesel	FP	3,9	10-15 min	30 min (99%)	SSI 1st attempt
3	Rialto-78	?	Gasoline	AFFF	?	?	10-15 min ?	Over-top + SSI
4	Chevron-80	?	Gasoline	?	?	?	?	Video
5A	Navajo-82	24,4	Gasoline	FP+AFFF	7,7	?	65	
5B	Navajo-82	24,4	Gasoline	ATC	7,7	?	11	
6	Milford Haven-83	78	Crude	FP	2,2 3,0	3 h ?	No 7 h	1st attempt 2nd attempt
7	Tenneco-83	45,7	Gasoline	ATC	6,5	22-23 min	45min	
8	Chemischen Werke-84	29	IPA	(Det foam) water	?	25 h	27 h	Extinguished by dilution
9	Peninsula-85	36,6	Aviation gasoline	AFFF AFFF	4,3 7,9	15-20 10-15 min	No 20-25 min	2nd attempt 3rd attempt
10	Newport-86	29	Crude	ATC	3,95	20 min	40min	
11	Newport-87	29	Crude	ATC	6,9	10 min	15 min	
12	Ashland-88	36,6	Cracking tower slurry	ATC	5,4	1,5 min	10 min	
13	MAPCO-88	34,2		ATC	6,2	20 min	< 1h	Estimated ext.time
14	Neste-89	52	Isohexane	Various	7,2 5,2	30 min No	43 min No	1st fire 2nd fire
15A	Exxon-89	41	Heating oil	ATC	4,5	20 min	65 min	
15B	Exxon-89	41	Heating oil	ATC	5,4	?	?	
16	Jacksonville-93	30,5	Gasoline	?	7,9 (max 51)	55 min	1:57 h	SSI+over-top "Fishmouth"
17	France	36	Platformate	?	?	?	About 1 h	
18	Ultramar-95	47,6	Heated fuel	ATC 1%	?	?	About 2 days	
19	Amoco-96	41	MTBE	AFFF-AR	11,4	20-30 min	2,5 h	
20	Woodbridge-96	42,7	Gasoline	AFFF	10,6	?	2-2:30 h	
21	Sunoco-96	42,7	Raffinate	AFFF+ATC	10,6	10-12 min	3:10 h	
22	Nedalco-98	?	Ethanol	Alcoseal	?	20 min	2 h	
23	Conoco-99	60,4	Gas-oil	CNF UnivP	7,94	19-25 min	1:18 h	
24	Orion-01	82,4	Gasoline	ATC	8,55	20-25 min	1:05 h	Record in size!
25	Granite City-01	?	Heated asphalt	?	?	?	1:10 h	
26	Granite City-01	?	Heated asphalt	?	?	?	1:00 h	

?=Information missing

Table 3 Summary of tank fires with some specific information about extinguishment, cont.

No.	Fire	Dia (m)	Fuel	Foam	Appl. rate ($L/m^2/min$)	Knock-down	Ext	Comments
27	Trzebinia-02	30 ?	Crude	Det foam	About 30 ?	15 min	40 min	
28	Houston-02	?	Residual fuel oil	?	?	?	<4:45	
29	Digboi-03	50 ?	Petrol	AFFF+FP	?	?	3,5 h	Dia uncertain
30	Gdansk-03	40	Gasoline	Various	About 24	17 min	37 min	

?=Information missing

4 Data and experience from large-scale foam extinguishing fire tests

The typical characteristics of a tank fire are a large fire area, a thick fuel layer and a pre-burn time of several hours. On the other hand, fire-extinguishing tests are often characterised by small or medium size pool areas, limited fuel layer thickness and short pre-burn times, mainly due to economic and environmental reasons.

In some standards and recommendations for tank fire fighting, e.g. NFPA 11 [1], large-scale tank fire tests are referenced to form an important basis for the recommendations but there are no detailed results or references given. In order to verify what tests have been conducted, under what conditions and the results achieved, a literature review of foam extinguishing tank fire tests or other large-scale extinguishing tests has been conducted.

The summary of the research work involving large-scale fire tests has been divided into those more specifically aimed towards tank fire protection and those more relevant for spill fire protection.

4.1 Tank fires

Based on the result from the literature review regarding fire tests related to tank fire protection, it is obvious that there is very limited experience from large-scale fire tests. By evaluating old literature it is found that a great concern about tank fire fighting was raised already during the late part of 1940s and a considerable amount of research was conducted during the 1960s and 1970s. Most test and research work appears to have focused on sub-surface tank fire protection, primarily using sub-surface injection but later also on semi-sub-surface injection.

Among the reviewed literature, there are some papers [8-13] from the 1960s and 1970s providing a good summary of different test work and research, listing the most important work of that time. In principle, the various authors make reference to the same large-scale fire tests, NRL (Naval Research Laboratory) in 1945 [14], NRL in 1950 [15], FRS (Fire Research Station) in 1954 [16], ICI in 1959 [17], ESSO in 1967 [18], Angus in 1972 [19], and Lorcon Inc in 1973 – 1976 [20]. Among these, the ESSO test in 1967, known as the Aruba test, seems to be the largest test of all, conducted on a 34,8 m (115 ft) in diameter and 8,2 m (27 ft) deep open tank with a single point sub-surface injection (SSI). The tank was filled with hexane and after a one-minute pre-burn time FP foam was injected at an application rate of 4,9 L/m^2/min, an expansion 3,0 and an inlet velocity of 3,1 m/s. The fire was half out in about 3 minutes and control was achieved after about 14 minutes. However, after 22 minutes when the test was terminated, the fire was still not completely extinguished. The reason for the “negative” result was considered to be the single point application and the high inlet velocity causing excessive turbulence at the fuel surface hindering complete extinction. Presently, NFPA 11 requires two injection points for a tank of this size.

Other large-scale fire tests were conducted in 1946 by McElroy [21] (probably conducted together with NRL [10, 11]). The tank was 28,4 m in diameter and protein foam was tested using crude oil and gasoline as the fuel. After a three-minute pre-burn time, the foam was injected with an expansion ratio 3,4, and at an application rate of 21,5 to 25,5 L/m^2/min. Time to extinguishment was 8 to 12 minutes. There is no information on fuel depth, inlet velocity or time to control of the fire.

Two sub-surface fire tests were conducted on a segment of a tank in 1974 [20]. The segment was 18,3 m (60 ft) long (simulating a 36,6 m/120 ft diameter tank) with a diameter of 0,9 m (3 ft) at the foam application point (1,2 m/4 ft deep) widening to 4,3 m (14 ft) at the " tank rim". Although the fire area was not very large (about 47 m^2 /525 sq ft) the foam flow distance is simulating full scale conditions. Light crude oil was used as the fuel and the pre-burn time was one minute. The foam application rate was 2,45 $L/m^2/min$ (0,06 gpm/sq ft) using FP foam and the expansion rate was 3,0. Unfortunately, no fire control time is reported but time to extinguishment was 12:00 minutes using 3 % proportioning rate and 15:10 using 4 %. One reason for the different extinguishment times might be the varying wind conditions during the tests.

These are the only "real" large-scale tests that have been identified simulating tank fire conditions. However, there might be important tests conducted by e.g. various oil companies, which we have missed or that have not been officially published. Apart from these, there are a numerous of tests and research projects performed where extinguishment, foam spread, and fuel pick-up has been investigated on smaller tanks which are not relevant for our purposes, i.e., to validate foam spread under large-scale fire conditions [22-32]. Although not conducted in large scale, they have been very important for improving both foam system design, types of foam concentrates, and fire fighting tactics.

Probably the most important research projects were those conducted by Mobile Oil Corp. in the period 1964 - 1967 studying sub-surface injection [9]. In total, several hundred fire tests were conducted on tanks having a diameter of 2,4 m (8 ft) and 7,6 m (25 ft), respectively. A number of non-fire tests were also conducted studying foam spread patterns and fuel pick-up in a 27,4 m (90 ft) diameter and 13,7 m (45 ft) deep open top floating roof gasoline tank and in a 35,7 m (117 ft) cone roof tank containing crude oil. Various numbers and locations of injection points, inlet velocities, etc were used. Based on the results of these tests in the various scales, attempts were made to extrapolate the results to larger tanks and predict whether a fire could be extinguished or not. Fuel pick-up was considered to be the most important factor, but also factors like the fuel vapour pressure, fuel depth, foam expansion ratio, inlet velocity, etc. were used in the model.

In a summary of the development of sub-surface injection techniques in 1975, Mahley mention that the Mobile tests were the starting point to gain a full acceptance of this technique [12]. The protein foams were replaced by newly developed FP-foams that had better fuel tolerance. AFFF's were also used but had, according to tests, problems to seal along the tank shell. One other important factor was the development of the high-pressure foam generators, significantly reducing the cost for the foam generation equipment. In his paper, Mahley also noted that it has been almost impossible to conduct fire tests in tanks significantly larger than 30,5 m (100 ft) in diameter and that fire experience is limited to tanks up to 61 m (200 ft). Therefore, mathematical studies have been made to examine the validity of extrapolation of small-scale test data to large-scale tanks [33].

A good summary of some of the European work, mainly conducted by Shell Research and Fire Research Station is given by Nash and Whittle [13]. The largest tank diameter used was about 15 m and a large portion of the tests were non-fire tests, studying the flow pattern using various locations of the injection points and the fuel pick-up and its correlation with expansion ratio.

The Mobile Oil work and the Aruba tests also seem to form an important basis for the guidelines for sub-surface application given in NFPA 11. In Table 5.2.6.2.8 (NFPA 11-

2002) regarding minimum number of sub-surface discharge outlets, it is mentioned in Note 2 that:

- "Table 5.2.6.2.8 is based on extrapolation of fire test data on 7,5m (25 ft), 27,9 m (93 ft) and 34,5 m (115 ft) diameter tanks containing gasoline, crude oil, and hexane, respectively."

It is also mentioned in A-5.2.5.2.1, that:

- "Tests have shown that foam can travel effectively across at least 30 m (100 ft) of burning liquid surface."

No references have been found regarding large-scale tank fire tests using fixed or mobile over-the-top applications. Some tank fire tests have been identified, but these tests have all been on smaller tanks, less than about 10 m in diameter [23, 25-28].

In recent years, a tank fire protection system has been developed by IFEX in Hungary, using a "Superintensive Foam Flooding" (SFF) technique where the foam is applied along the rim of the tank using a "Continues Linear Nozzle" at a very high application rate. The foam is applied from a "Self Expanding Foam" (SEF) storage pressure vessel and due to the high application rate a very quick knockdown and extinguishment was achieved. Tests were conducted using a simulated tank with an area of 500 m^2, with gasoline as the fuel and a one-minute pre-burn time. The fire was extinguished in about 30 seconds [34]. Up to now, the system has not gained any wide acceptance but the technique seems very interesting.

Despite the lack of large-scale tank fire tests in the last 15 to 20 years, significant improvements have been made regarding tank fire fighting using mobile equipment. The pioneers in this development have been Williams Fire & Hazard Control Inc. (WFHC) drawing attention to the need for solving the logistics during a fire and to use relevant tactics. By using large capacity monitors, large diameter hose and foam concentrate stored in bulk containers, the logistics become manageable. The use of large-scale monitors has also made it possible to achieve sufficiently high application rates in order to compensate for foam losses due to wind and thermal updraft. Williams have also introduced the "Footprint" technology where all the foam streams are aimed towards one single landing zone on the fuel surface, resulting in a very high local application rate making the foam spread more rapidly and efficiently. One of the main factors in achieving an efficient extinguishment, according to Williams, is the use of a high quality foam, suited for tank fire protection and until recently, they were primarily using 3M AFFF/ATC. Due to 3M's withdrawal from the foam business a similar foam type is now used, manufactured by Ansul, "Thunderstorm ATC". In 1983, Williams extinguished a 45,7 m (150 ft) diameter gasoline tank in Chalmette, Louisiana ("Tenneco fire"), which at that time was the largest tank ever extinguished using mobile equipment. A new record was set in 2001 when an 82,4 m diameter (270 ft) gasoline tank was extinguished in Norco, Louisiana ("Orion fire"). The concept for tank fire fighting used by Williams has been shown to be successful in many other fires [35] and the concept has also been successfully used by other companies, e.g. during the Sunoco fire in Canada 1996.

4.2 Spill fire tests

Various organisations and companies have conducted a huge number of fire tests, which are directly relevant for fire fighting of small (10 m^2 to 50 m^2) and medium size (100 m^2 to 500 m^2) spill fires. Also here, large-scale test fire data is unusual, but some tests have been identified.

In 1968, a simulated bund fire of 1400 m^2 was extinguished using high expansion foam generators [36]. In 1969, four tests were made on a 2000 m^2 JP4 fire in Esbjerg [37]. The aim was to evaluate which type of equipment and foams were suitable for airport protection when introducing jumbo jets. Between 1979 and 1982, a study was made to define the minimum requirements for fire fighting at U.S. Air Force Airfields [38]. A large series of fire tests were conducted in various scales and included in these tests were two tests on a spill fire area of about 1850 m^2 (20 554 ft^2) and 900 m^2 (10 028 ft^2), respectively.

For several reasons, none of these test series are relevant for the purpose of this report. The first test was made with high expansion foam while the foam-spread models developed are related to low expansion foam. The two latter test series focus on airport protection, using obstructions in the pool area and several crash tenders applying foam simultaneously on several locations.

A systematic study of foam extinguishment and foam spread properties was made on behalf of DGMK in Germany during the 1980s using fire test areas from 0,2 m^2 up to 500 m^2 [39]. In total, 14 different fuels, with boiling points ranging from 36 ºC to 360 ºC were used. Based on this work, the term “specific extinguishing time” (t_{spec}) was introduced for extrapolation of the test data to larger fire areas. The specific extinguishing time was defined as $t_{spec} \sim A^{-1,1}$ (s/m^2). Also in this study, the conclusion was that there is no large-scale data available for verification and therefore they planned to conduct two fire tests, one with a spill area of 1500 m^2 and one test with a spill area of 5000 m^2 [40]. However, these tests were never conducted, probably due to lack of funding and environmental concerns.

4.3 Other large-scale fire tests

Some large-scale fire test series, using kerosene and crude oil and pool diameters up to 80 m in diameter have been performed in Japan [41, 42]. However, the intention of these tests was to study the burning characteristics (flame height, burning rate, external radiation, smoke emission, etc.) and the tests did not involve any extinction phase.

5 Conclusions

In total, 480 tank fire incidents have been identified worldwide since the 1950s and assuming that the data collection is complete for the 1990s and thus far for the first decade of 2000, this indicates that the number of tank fires per year worldwide is in the order of 15 to 20. From a worldwide perspective, there are probably even more tank fire incidents as the sources for information in this project mainly cover USA, Europe and some other english speaking countries. If all fire incidents were be reported, also including rim seal fires, the number would probably increase significantly.

It should also be noted that the extent of each identified fire may vary considerably, from just a rim seal fire (extinguished without any problem) to fires involving a complete tank storage facility with 30 to 40 burning tanks. If the number of each tank involved in fire would be counted, the figure would of course be much higher than the 480 incidents.

The primary aim was to gain experience from these tank fires, in particular regarding fire extinguishment, in order to be able to validate the foam spread model developed in the FOAMSPEX project.

The necessary information (the area of the tank, the application rate, time to fire control and extinguishment) was only obtained for about 30 full surface fires. Practical experience is limited to tanks with a diameter of about 40 m to 50 m or less and the largest tank ever extinguished is 82,4 m (270 ft) in diameter. All fires were attacked using mobile equipment and over-the-top application, although in some few fires sub-surface injection was used in parallel. No information has been found of full surface tank fires extinguished by fixed systems only.

The practical experience from these fires exemplifies the importance of using large-scale equipment, proper logistics and tactics, high quality foam, the need for an increased application rate when fighting large diameter tanks, etc. However, there are still discussions about e.g. what application rates should be used for even larger tanks, as well as the influence of the foam and fuel properties, respectively. It can be noted that no full surface fires have been extinguished by monitor application where FP foam has been used although this is probably the most common type of foam concentrate for tank fire protection in the oil industry.

Although over-the-top application using mobile equipment seems to be the dominating methodology for tank fire fighting, most tank fire testing and research have been focused on fixed systems. Only a few large-scale tank fire tests have been conducted. The largest was called the Aruba-test in 1967, having a diameter of 34,8 m (115 ft) and using single point sub-surface injection. Combined with a large number of fire tests in smaller tanks (2,4 m/8 ft and 7,6 m/25 ft) and some non-fire foam flow tests in tanks up to 35,7 m (117 ft) in diameter, these seem to be the primary basis for the recommendations in the current NFPA 11 foam standard. The background to the specific figure on maximum foam spread distance, 30 m (100 ft), given in NFPA 11 is still not clear as we have not been able to find the full test reports from these fire tests.

The literature review has provided some additional tank fires with basic information about the extinguishment, such as application rate and time to control, which could be used for comparison with the FOAMSPEX foam spread model. However, the information from real tank fire incidents is often not very detailed and there are still a lot of uncertainties in the data regarding fuel and foam properties, how time to control and extinguishment was defined etc. As shown in the FOAMSPEX project, such parameters

could be crucial for e.g. the maximum foam spread distance during a fire. The FOAMSPEX project has also indicated that the maximum foam spread distance is not necessarily a fixed figure, as mentioned in NFPA 11, but could vary considerably depending on fuel and foam properties.

Based on this fact, it is not possible to give any general guidance on how to extrapolate fire protection guidelines from smaller tanks to the huge tanks of today without using scientifically based foam spread models, as there are many factors influencing the results. The FOAMSPEX models are a first step in this direction but validating data is crucial. Having access to a foam spread model, validated by large scale tests, is not only relevant to confirm the limitations of existing equipment and foams but could also contribute to a better fundamental understanding and possibilities for the development of foam concentrates and foam equipment. Keeping in mind that the most high-efficiency foams today, containing flouro-surfactants, are under debate due to environmental concerns, such a foam-spread model seems even more important.

Before such a large-scale test series is conducted, a variety of parameters should be studied more in detail, e.g. influence of the viscosity of the fuel and the fuel temperature. Such tests could to a large extent be made in smaller scale and under non-fire conditions. There is also a need to study foam properties from typical full-scale equipment and foam concentrates to obtain true input data to the model.

A large-scale fire test series would be expensive and may cause environmental problems locally. However, it would provide information to ensure relevant fire protection of existing jumbo-tanks in the range of 100 m or more in diameter. If even one single fire in such a tank could be extinguished quickly, instead of resulting in a burn out, the proposed project would give significant economic and environmental payback. Such a research project should be conducted on an international basis involving oil companies, foam manufacturers, hardware manufacturers, insurance companies, fire research expertise and authorities on national level from participating countries.

The existing models should of course be used to design the test set-up, relevant measurements and the specific parameters used in each test, in order to gain maximum information from a minimum number of tests.

6 References

The references below are those providing general information about tank fire fighting, lists of fire incidents or results from various fire tests. The references giving specific information about the selected fires presented in Appendix A are listed in connection to the description of each fire.

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Appendix A Summary of tank fire information

Of the 480 fire incidents identified during the project, there are about 30 tank fires where it has been possible to obtain full or almost full information about the fire and the extinguishing operation (ranking 1 or 2). Below are a summary of the most important data and a brief description of the incident and the fire fighting response related to each of those fires. Among the selected fires, there are also some tank fires of special character although they are not providing any data useful for foam-spread validation. The fires presented in this Appendix A are listed below.

Basic information

Date	1971-06-26
Location	Czechowice-Dziedzice Refinery
Cause of ignition	Lightning
Type of tank	Cone roof (in total four tanks)
Diameter (D), height (H), area (A)	D=33 m, H=14,7, A=854 m^2
Volume	12500 m^3
Amount of fuel	Tank I-oil level 13,5m (10 020 tons), II-12,9m (9670 tons), III-11,7m (8770 tons), IV-3,4m (2450 tons)
Type of fuel	Crude oil

Data related to the tank fire extinguishment-Tank III-initial attack

Type of equipment	3x2400 L/min monitors
Type of foam	Protein
Preburn time	1-10 min
Application rate	8,43 L/m^2/min
Time to knockdown	Flame intensity reduced after 5:30 hours (01:20) when a boil over occured
Time to extinguishment	No extinction (boil-over)
Total consumption of foam	No information

General description of incident

On June 26, 1971 at 19:50, a lightning hit Tank III (33 m in diameter), causing the roof to collapse and causing a full surface fire and oil flowing into the bund. In total there were four identical crude oil tanks nearby each other, each one in a separate bund designed for 100 % of tank volume + 0,6 m high foam layer. At 19:51 the refinery fire brigade arrived to the scene and attacked Tank III with 2x2400 L/min monitors using low expansion foam (corresponding to 5,6 L/m^2/min) and the bund with two medium expansion foam handlines (2x25 m^3/min).
At 20:00 support from refinery fire brigade arrived and attacked Tank III and it's bund fire with low expansion foam using 1x2400 L/min monitor (increasing application rate to 8,43 L/m^2/min) and high expansion foam using 1x200 m^3/min generator. 3 tons of dry chemical powder was applied on the bund of Tank III from a powder fire truck using a monitor. The effect was little and temporary. Further resources were still incoming.

At 01:00 (June 27) Tank III was being attacked with 3x2400 L/min monitors using low expansion protein foam, corresponding to an application rate of 8,43 L/m^2min. The bund fire was attacked by using one high expansion foam generator (200 m^3/min) and four medium expansion foam handlines (4x25 m^3 /min). Surrounding tanks were cooled with water and foam monitors. Tank II bund area was being protected by additional high expansion foam generator.

At 01:20 (June 27), the flame intensity and fire size had been highly reduced when a rapid boilover occurred from Tank III throwing oil in all directions up to 250 m away. Several seconds later, Tank I exploded due to ignition of flammable vapours inside the tank. The fire spread to the entire bund area for the four tanks but also into the refinery area far outside the bund area. 33 people died due to the boilover and about 100 people were injured (40 people severely).

After half an hour, some firefighters were organised again and about 02:00 they started to attack the fire again. Further resources were ordered from the entire Poland but also Czechoslovakia. At 10:00 (June 27), the fire was reduced to the bund area and tanks again. Until 14:00 on June 27,
86 fire trucks and 55 tons of foam agents had arrived. Meanwhile, tanks III and IV had collapsed to about 2 and 4 m, respectively and the total fire area (bunds+tanks) was about 12500 m2.

After receiving even further resources from Poland and Czechoslovakia, a final attack was initiated on June 29 at 15:10.

The Tank I bund fire was extinguished in about 20 minutes using high expansion foam. The Tank I fire was controlled in about 15 minutes and completely extinguished in 50 minutes. 4 monitors, each 2400 L/min were used for extinguishing the Tank I fire corresponding to an application rate of 11,2 L/m^2/min. The final extinguishment was delayed by a difficult 3D-fire from damaged pipes.

The Tank II bund fire was extinguished using 4 medium expansion handlines, 25 m^3/min each. The Tank II fire was extinguished directly following Tank I using the same 4 monitors. Extinction was achieved in about 15 minutes.

The Tank III bund fire was extinguished in about 30 minutes using high expansion foam. The Tank III fire was extinguished in parallel with Tank I and II using 3x2400 L/min monitors corresponding to 8,43 L/m^2min. Extinction was achieved in less than 50 minutes.

The Tank IV bund fire was extinguished in about 20 minutes using high expansion foam. The Tank IV fire was controlled in about 20 minutes using 1x2400 L/min monitor and completely extinguished using 2x600 L/min low expansion foam branchpipes and one high expansion foam generator (200 m^3 /min). Extinction was achieved in about 10 minutes.

After extinguishing all fires, foam was applied on all bunds until 17:00 for securing purpose.

During the final attack, the following quantities of extinguishing agents were used:
90 tons of protein foam concentrate (Spumogen) used for low expansion foam (of 113 tons collected)
15 tons of synthetic foam concentrate (Meteor) for medium and high expansion foam (of 20 tons collected)
2000 m^3 of water
3 tons of sodium bicarbonate dry chemical powder.

The conclusion was that low and medium expansion foam was most effective while the high expansion foam was easily disturbed by wind and destroyed by heat. However, high expansion foam was also effective - used in proper quantity it quickly flooded bunds and reduced fire to tanks and pipes only. Dry chemical powder was ineffective due to very windy weather conditions.

There is no information of how much of oil left in tanks after extinguishment and how much of oil was finally saved.

References:
Personal communication Michal Baran-Baranski; Technica report

Basic information

Date	1972-09-25
Location	Collegedale (Chattanooga), Tenn., USA
Cause of ignition	Overfilling ignited, undetermined source
Type of tank	Internal floating roof (in total five tanks)
Diameter (D), height (H), area (A)	Tank 20: D=21.4 m, H=no info, A=357 m^2
Volume	No information
Amount of fuel	No information
Type of fuel	Gasoline

Data related to the tank fire extinguishment-Tank 20

Type of equipment	Sub-surface injection
Type of foam	XL-3 (FP foam)
Preburn time	About 30 hours (not full surface fire)
Application rate	2,45 L/m^2/min (0,06 gpm/sq ft)
Time to knockdown	No information
Time to extinguishment	About 1:30 hours
Total consumption of foam	No information

General description of incident

An alarm about gasoline spill was achieved at 06:19, Sept 25, 1972 and it was observed that tank 21 was overflowing. While preparing to foam the spill surface, this ignited from an undetermined source. Tank 21 (16,8 m/55 ft dia) and tank 22 (14,6 m/48 ft dia), both filled with gasoline ignited immediately. Tank 23 and 24 (both 11 m/36 ft dia, filled with diesel) exploded within one hour and tank 20 (21,3 m/70 ft filled with gasoline) ignited at 07:30. At 16:00 when extra supply of foam arrived, the entire dike around tanks 20, 21, 22, 23, 24 and part of 25 was fully involved in the fire due to leaking flanges, manways etc. By 04:00, Sept 26, the dike fires were attacked and extinguished within about 20 minutes. One nozzle, 950 L/min (250 gpm) was then directed into tank 22 and another 950 L/min (250 gpm) nozzle into tank 21. Following this, tank 23 was extinguished after about 30 minutes of foam application. Due to lack of foam supply, the efforts were then aimed towards securing the dikes and to extinguish the fire in tank 20 by directing nozzle streams through the vents. hThe latter was, however, without success. Although the tank had been burning for more than 24 hours, the roof was still in place and flames were only visible in the vents. It was also believed that the internal floater still was afloat. At 12:10, more foam arrived and the subsurface injection was started using a 880 L/min (232 gpm) high back pressure foam maker corresponding to a application rate of 2,45 L/m^2/min (0,06 gpm/sq ft). After about 1:30 hour of subsurface injection, the flames and smoke changed to steam and the fire was extinguished.

After extinguishment there was more than 7,9 m (26 ft) of gasoline left in tank 20 and it was also determined that the internal floater had sunk. When this happened was not possible to determine. By this time, this was the first time a tank with an internal floating roof had been successfully extinguished by subsurface injection.

References:
Edward C. Avant-Fire Journal July 1974 (reprint from Fire Engineering April 1973); Herzog G. R.- reprint Fire Journal July 1974; Mahley H. S.-reprint Hydrocarbon Processing, Aug 1975

Basic information

Date	1977-09-24
Location	Union Oil, Romeoville, Illinois, USA
Cause of ignition	Lightning
Type of tank	Cone roof tank (tank no 413)
Diameter (D), height (H), area (A)	Tank 413: D=58 m, H=15,9 m, A=2640 m^2 (D=190 ft, H=52 ft)
Volume	No information available
Amount of fuel	Nearly full
Type of fuel	No 2 diesel fuel

Data related to the tank fire extinguishment (1st foam attack)

Type of equipment	SSI (10x300 gpm)
Type of foam	FP
Preburn time	About 24 hours
Application rate	3,9 L/m^2/min (0,095 gpm/sq ft)
Time to knockdown	10 to 15 min
Time to extinguishment	30 minutes (99 % extinguished)
Total consumption of foam	SSI (10x300 gpm)

Note: Only the 1st foam attack is reported as the 2nd attack was a combined subsurface/over-the-top application

General description of incident

The fire started at 02:15 when a lightning ignited tank no. 413, a 58 m (190 ft) diameter and 15,9 m (52 ft) high cone roof tank nearly full with No. 2 diesel fuel. The roof blew off damaging tank no. 115, a 33,5 m (110 ft) diameter tank containing unleaded gasoline, which also ignited. Cooling efforts were initiated to protect tank no. 312 and a spherical vessel containing butane-butylene. The latter could be successfully protected while tank no. 312 ignited about 04:00. On the midmorning, it was decided to try to extinguish tank no. 115 by over-the-top application. Two boom mounted 1890 L/min (500 gpm) nozzles and one 1135 L/min (300 gpm) handline nozzle was used and by 13:00 the fire was squelched. Preparations started for a SSI-attack of tank no. 413 using ten 1135 L/min (300 gpm) high back pressure foam makers connected to a 610 mm (24 inch) product line about 550 m (1800 ft) from the tank. Subsurface injection commenced at 02:25 on September 25 using 11350 L/min (3000 gpm), but had to be reduced to 10220 L/min (2700 gpm) after 8 minutes due to cavitations in one of the pumps, corresponding to about 3,9 L/m^2 min (0,095 gpm/sq ft). Fire control was achieved within 10 - 15 minutes (information varies) and the fire was almost extinguished after one-half hour. However, parts of the roof had fallen into the tank forming small pockets and the fire could not be completely extinguished. After another 45 minutes, foam supply ran out and within one hour, the tank was fully involved again. A second extinguishing attack was started about 18:00 on September 25 as a combined subsurface/over-the-top attack and by 22:30 the fire was completely out.

By that time, tank no. 413 was the largest cone roof tank where subsurface injection was used for extinguishment.

References:
Fire Command, February 1978; Lindsay C.H., “Extinguishment of hydrocarbon tank fires by sub-surface injection”.Lorcon Inc., March 1978; Herzog G.R., “When there’s a tank farm fire…”, reprint Hydrocarbon Processing, February 1979

Basic information

Date	1978-02-21
Location	Rialto, California, USA
Cause of ignition	Overfilling, vapour ignition
Type of tank	Internal floating roof
Diameter (D), height (H), area (A)	D=no info, H=15,3 m, A=no info
Volume	4790 m^3 (30140 barrels)
Amount of fuel	No information
Type of fuel	Regular gasoline

Data related to the tank fire extinguishment

Type of equipment	Subsurface injection
Type of foam	3M Light Water AFFF
Preburn time	No information
Application rate	No information
Time to knockdown	No information
Time to extinguishment	No information
Total consumption of foam	About 55700 l (14726 gallons) in total

General description of incident

About 08:30 on Febr 21, 1978, an alarm about a tank being overfilled was achieved and shortly afterwards the vapours ignited fully involving the tank. A valve had been open by mistake and about 30300 L/min (8000 gpm) was spilling out of the tank vents into the dike. A 1000 gpm deluge gun was set up next to the dike area, and a few minutes after the foam attack was started, the dike area was extinguished. A subsurface attack was initiated but was only partially successful in extinguishing the fire at the top of the tank. Incomplete aeration of the AFFF and an overflow of fuel forced discontinuance of this effort. Except for the tank fire, there was also a flange fire from spraying gasoline. A high back foam maker was welded into an inlet about 600 m (2000 ft) from the tank. When the aerated AFFF foam reached the leaking flange, it replaced the fuel and the fire went out in 10 to 15 minutes. The incident was over by 09:30 Febr 22 and 42000 L (11106 gallons) 6 % AFFF and 13700 L (3620 gallons) of 3 % foam had been used.

Reference:
3M Case History 7; Fire Engineering, August 1978

Basic information

Date	1980-??-??
Location	Chevron Tank Terminal, Honolulu, Hawaii, USA
Cause of ignition	Overfilling, vapours ignited
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=no info, H=no info, A=no info
Volume	No information
Amount of fuel	No information
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	Monitors mounted on fire trucks
Type of foam	No information
Preburn time	Less than 2 hours to first attack
Application rate	No information
Time to knockdown	No information
Time to extinguishment	No information
Total consumption of foam	No information

General description of incident

The fire started at about 10:30 due to an overfilling of the tank. The vapours were ignited when they reached an electrical switch-room. The fire brigade started to cool, both the burning and surrounding tanks and to extinguish the spill fires in the dike area. At about 12:45, the fire was almost brought under control when the roof and the tank became fully involved again.

References:
Video (CD) “A gasoline terminal fire”; personal communication Lindsay Hamilton-Caltex New Zealand Ltd

Basic information

Date	1982-11-??
Location	Navajo refinery, Artesia, New Mexico, USA
Cause of ignition	No information
Type of tank	No information
Diameter (D), height (H), area (A)	D=24,4 m, H=no info, A=467 m^2 (D=80 ft)
Volume	No information
Amount of fuel	No information
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	One 1000 gpm foam nozzle
Type of foam	Tank 1-FP+AFFF, Tank 2-3M ATC
Preburn time	No information
Application rate	7,7 L/m^2/min (both tanks)
Time to knockdown	Tank 1-no info , Tank 2-no info
Time to extinguishment	Tank 1-65 minutes, Tank 2-11 minutes
Total consumption of foam	Tank 1-no info, Tank 2-no info

General description of incident

Two identical tanks with a diameter of 24,4 m (80 ft) containing gasoline were on fire. The first tank was extinguished using a combination of FP foam and “Mil Spec” AFFF foam using a 3785 L/min (1000 gpm) self-educting non-aspirating nozzle. The application rate was 7,7 L/m^2/min (0,19 gpm/sq ft) and the extinguishment time was 65 minutes.

The second tank was extinguished using the same equipment and application rate but using 3M ATC foam concentrate. Extinguishment was the obtained after 11 minutes.

References:
Personal commmunication Eric Lavergne WFHC; IFW March/April 1995

Basic information

Date	1983-08-30
Location	Amoco refinery, Milford Haven, UK
Cause of ignition	Carbon particles from flare stack
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=78 m, H=20 m, A=4775 m^2
Volume	94110 m^3
Amount of fuel	46376 ton
Type of fuel	North Sea crude oil

Data related to the tank fire extinguishment

Type of equipment	Four super jet monitors
Type of foam	FP foam
Preburn time	Attempt #1 approx 27 h, #2 approx 45 h
Application rate	#1-2,2 L/m^2/min, #2-3,0 L/m^2/min
Time to knockdown	#1-approx 3 h, #2-no information
Time to extinguishment	#1-Not extinguished, #2-approx.7 h
Total consumption of foam	763 000 litres (167899 imp gall) for the entire operation

General description of incident

The fire in Tank 011, a 78 m diameter floating roof tank, was detected 10:48 on Aug 30, 1983. The first observation at about 11:05 showed a fire covering a quadrant equal to about 50 % of the roof area. A foam attack, using a 750 gpm monitor (5000 gpm *), was initiated through a hydraulic platform but this foam application was not able to prevent fire spread. At about 11:20 the tank was declared “well alight”. The foam attack was later on interrupted, as a major foam attack was needed. Oil was transferred to other tanks while waiting for trying to establish the necessary amount of foam concentrate calculated to about 205 000 litres and foam equipment capacity calculated to about 182 000 L/min. A limited attack was initiated at 23:30 with a single foam stream from a roof monitor on a R.A.F. MK9 foam tender using 6 % FP foam to assess the reaction of the tank. An encouraging split of the flames was observed although some oil spilled into the bund. As the conditions in the tank was monitored and considered stable, it was decided to defer the foam attack for a further 4 hours to allow further transfer of oil and more foam concentrate to arrive. Just after this decision (about 00:15, Aug 31) a boil-over occurred very suddenly. At 02:10, a second boil-over occurred. During this eruption, the tank shell-to-base seam was ruptured in four places around the circumference allowing oil into the diked area. At 08:00, it was decided to launch a foam attack as the necessary foam equipment and about 305 000 L of foam was available. At 9:15, extinguishment of the dike (approx 90 by 180 m) commenced using an application of 29500 L/min (6500 imp gpm) corresponding to an application rate of 2,6 L/m^2/min, using one RAF foam tender with AFFF and two trailer super jet monitors discharging FP foam. The dike fire was progressively controlled and extinguished and was successfully concluded at 14:00. Promptly after extinguishing the dike fire, a foam attack was made on Tank 011 (attempt #1). Foam was applied at a rate of 10400 L/min (2300 imp gpm), corresponding to an application rate of 2,2 L/m^2/min, using four super jet monitors positioned to project the foam directly into the vessel. At 17:00, three pockets of fire remained behind the folded tank shell. Intermittent quantities of foam were applied to contain the fire there. However, by 02:00 on Sept 1 the foam supplies were depleted, and before additional quatities could be delivered, the fire spread to engulf the entire tank again. After receiving additional foam concentrate, another attempt (#2) to extinguish the tank was initiated at 08:00. Approx. 14500 L/min (3200 imp gpm) of foam solution was applied, corresponding to an application rate of 3,0 L/m^2/min, and three cannons were lifted onto the collapsed tank shell to extinguish the folded shell area. The tank fire was extinguished by 15:00 and at 22:30 on Sept 1, the stop message was sent.

*) Information differs between various sources. Although this summary is based on a number of reports and papers summarizing the fire, it is difficult to find specific figures related to the actual extinguishment operation. A lot of figures is related to the available resources (foam stock, water supply and pump capacities, various types of vehicles, calculated need of resources, etc.), but it is difficult to find specific figures of what was actually used during the operation and detailed information about the progress of each foam attack.

References:
Personal communication E A Davies Fire Officer Total Refinery Milford Haven; personal communication Mike Wilson Angus Fire; Fire Investigation report “Report of the Investigation into the Fire at Amoco Refinery-30th August, 1993”; Hydrocarbon Processing Oct 1985; copies of personal communication between Chief Fire Officer R King and Angus Fire (1986); IFPO Journal, Fire & Safety News nov 1983; Fire Prevention 169; FIRE Febr 1984; Fire Eng Journal 47 (1987); FIRE Febr 1987; video- “Tank 11 fire”

Basic information

Date	1983-08-31
Location	Tenneco, Chalmette, LA, USA
Cause of ignition	No information available
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=45,7 m, H=12,2 m, A=1640 m^2 (D=150 ft, H=40 ft)
Volume	No information available
Amount of fuel	18 900 m^3 (5 000 000 gallon)
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	5 self educting hydro foam nozzles
Type of foam	Light Water AFFF/ATC at 3 %
Preburn time	About 15 hours
Application rate	6,5 L/m^2/min (0,16 gpm/sq ft)
Time to knockdown	About 22 - 23 minutes
Time to extinguishment	About 45 minutes
Total consumption of foam	11 000 litres (2900 gallons)

General description of incident

The fire started at 21:30 on August 31, causing the floating roof to sink. The tank fire problem was aggravated by a three-dimensional fire inside the dike area caused by leaking flanges. Cooling water was applied to the surrounding area including a nearby butane tank to stabilize the situation and prevent further escalation. About 15 hours after the start of the fire, the necessary resources were in place and a foam attack was started using a capacity of 10 825 L/min (2860 gpm) at an application rate of 6,5 L/m^2/min (0,16 gpm/sq ft). Initially, five streams of water only were directed over the tank rim into the fire plume, in order to break the thermal updraft caused by the fire. Four minutes later, three of the five streams were switched to foam and repositioned under the two remaining water streams until 99 % of the fire was extinguished. At this time, one foam stream was repositioned to assist in extinguishing an area where the tank had curled in. The tank fire was declared extinguished at 13:45 on September 1 and the remaining fire at the manifold was extinguished shortly afterwards, using foam in combination with dry chemical.

In total, about 11 000 L (2 900 gallons) of Light Water AFFF/ATC was used for the extinguishment and it was estimated that about 7600 m^3 (2 000 000 gallon) of gasoline was left in the tank after extinguishment.

References:
Personal communication Eric Lavergne-WFHC; personal communication Ulf Meyer-3M; Fire International 198?-no?,

Basic information

Date	1984-08-05
Location	Chemischen Werke Huls, Herne, Germany
Cause of ignition	Lightning
Type of tank	Cone roof tank
Diameter (D), height (H), area (A)	D=29 m, H=15 m, A=660 m^2
Volume	10 000 m^3
Amount of fuel	4000 m^3 to5000 m^3
Type of fuel	Isopropyl-Alcohol (IPA)

Data related to the tank fire extinguishment

Type of equipment	Various water and foam nozzles
Type of foam	Syntetic detergent (Mehrberichschaummittel)
Preburn time	< 1 hour to 1st foam attack, 1:30 2nd foam attack
Application rate	No information
Time to knockdown	About 25 hours due to dilution
Time to extinguishment	About 27 hours
Total consumption of foam	57,6 m^3

General description of incident

The fire started about 17:30 on Aug 5, 1984 by a lightning strike in tank 13, a 29 m diameter and about 15 m high cone roof tank containing IPA. The tank was located in a concrete bund and the roof had been blown away at ignition and windows were broken and other damage occurred on nearby buildings in a radius of 500 m to1000 m from the tank. The first fire fighting units started to cool nearby tanks using two “B-rohre” and a foam attack was initiated and a small spill fire close to the tank was quickly controlled and extinguished using a water/foam nozzle, “TLF 24/50”. Further resources were ordered from nearby communities and a second foam attack was initiated at 19:00. A large portion of the foam was blown away by the thermal updraft and as no control was gained and the foam stock was almost consumed, the foam attack was terminated at about 20:00. At 21:00, the decision was taken to extinguish the fire by diluting the product instead of further foam attacks. Water started to be pumped in to the tank through the product line and the cooling operation of nearby tanks continued all night and during the following day. At 18:00 on Aug 6, the fire intensity was considerably reduced due to the dilution operation and at 19:30 the fire was fully controlled. At 20:00, almost 27 hours after ignition, the fire was declared out.

In total 54144 m^3 of water and 57,6 m^3 foam concentrate was used during the operation.

Reference:
Copy of german fire magazine; personal communication Reinhard Heintze-Fire chief Degussa Herne; personal communication Hans-Gunter Neumann H.-G.-Infracor; personal communication Oswald Sthamer-Dr Sthamer,

Basic information

Date	1985-10-23
Location	Peninsula Naval Fuel Depot, Pearl City, USA
Cause of ignition	Sunken floating roof, static charge during foam application
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=36,6 m, H=no info, A=1052 m^2 (D=120 ft)
Volume	No information available
Amount of fuel	8580 m^3 (54 000 barrels)
Type of fuel	Aviation gasoline

Data related to the tank fire extinguishment 2nd and 3rd attack

Type of equipment	Air force crash trucks, one 1000 gpm, one 1200 gpm
Type of foam	6 % AFFF
Preburn time	10 to 30 minutes before each attack
Application rate	2nd attack: 4,3 L/m^2/min, 3rd attack: 7,9 L/m^2/min
Time to knockdown	2nd attack: about 15 - 20 min, 3rd attack: about 10 - 15 min
Time to extinguishment	2nd attack: not ext., 3rd attack: about 20 - 25 minutes
Total consumption of foam	No information available

General description of incident

Due to a storm, water accumulated on the floating roof and sunk, three days before the start of the fire. The plan was to keep the fuel surface foamed until the fuel could be transferred. On October 23, at about 11:30, just when another foam application was started, a static charge was generated and ignited the tank. Through a mutual aid system, an air force crash truck arrived at the scene about 12:25. The truck was carrying 7570 L (2000 gallons) of water and 760 L (200 gallons) of 6 % AFFF foam and was equipped with a 3785 L/min (1000 gpm) turret and started the attack immediately after arrival. After about 20 minutes, the fire was brought to about 80 % control when it ran out of foam, quickly resulting in a full surface fire again. One additional crash truck arrived to the scene, carrying 19000 L (5000 gallons) of water, 1890 L (500 gallons) of 6 % AFFF foam and started a second attack having a flow rate of 4540 L/min (1200 gpm), corresponding to an application rate of approx. 4,3 L/m^2/min. At about 13:10, 15 to 20 minutes* after the start of the second foam application, knockdown and 90 % fire control was achieved. However, at this moment also this truck ran out of foam as no connections had been made for a continuous supply of water and foam. Within a couple of minutes, there was a full surface fire again. An order was given that no further attack would be started until a continuous supply of water and foam was guaranteed. At about 13:20 the foam attack was resumed. At this point it was realised that the use of the 1200 gpm crash truck only would result in a too low application rate compared to the NFPA 11 recommendations of 6,5 L/m^2/min (0,16 gpm/sq ft) and the first crash truck was quickly brought up along side, resulting in a flow rate of 8330 L/min (2200 gpm) resulting in an application rate of 7,9 L/m^2/min (0,195 gpm/sq ft). The foam attack quickly broke the thermal column and at 13:35, 10 –to 15 minutes* after the start of full foam application, knockdown was once again and finally achieved. At 13:44 the fire was declared extinguished, about 2:15 hours after start of the fire.

Some of the most important lessons learned from the fire were:

- Do not start an attack before an uninterrupted supply of water and foam can be guarantied.

- Follow the minimum application rate given in the NFPA recommendations.

- Communication might be a problem; a mutual aid channel would have been of extreme assistance.

- There is only one “best position” for an attack of a tank fire, be sure that this is remained clear.

- The use of helicopter for an aerial view is invaluable. Helicopters are, however, noisy and the rotor wash may disturbe the foam blanket.

- The logistics of supplying enough foam concentrate to the foam vehicles must be given consideration.

References:
IFW-no5/6-1990; personal communication White D.-IFW

*) Estimated time based on the reported actions

Basic information

Date	1986-10-01
Location	Newport, Ohio, USA
Cause of ignition	Lightning
Type of tank	Wooden roof tank
Diameter (D), height (H), area (A)	D=29 m, H=8,5 m, A= 660 m^2 (D=95 ft, H=27-10 ft)
Volume	No information available
Amount of fuel	5500 m^3 (35 000 barrels)
Type of fuel	Pennsylvania crude oil

Data related to the tank fire extinguishment

Type of equipment	One monitor and two handlines
Type of foam	Light Water AFFF/ATC
Preburn time	About 5 hours
Application rate	3,95 L/m^2/min
Time to knockdown	About 20 minutes
Time to extinguishment	About 40 minutes
Total consumption of foam	3200 litres (850 gallons)

General description of incident

The fire started at 17:15 when a lightning struck the tank containing crude oil. The tank was built in the 1930s and had a wooden roof construction. At the time for the fire, the fuel level was about 125 mm (5 inches) from the top. Initially, water was applied for quenching the fuel surface using a deck gun equipped with a 3785 L/min (1000 gpm) adjustable fog nozzle. At about 22:00 a moderate frothover was observed which lasted for about 1 minute and it was decided to start a foam attack as quickly as possible. At 22:20 the foam attack was started using the deck gun manually adjusted to 1890 L/min (500 gpm) to match the foam proportioning equipment and two 360 L/min (95 gpm) handlines aimed towards the same landing zone as the 500 gpm foam stream. Within 20 minutes, the intensity of the fire was noticeably reduced and around 23:00, about 40 minutes from start of foam application, the fire was extinguished.

About 3200 L (850 gallons) of Light Water AFFF/ATC were used for the extinguishment and another 2300 L (600 gallons) were used for security. About 32 000 barrels of crude oil were saved after separation of water foam and debris.

References:
3M Hotline February 1988

Basic information

Date	1987-07-26
Location	Newport, Ohio, USA
Cause of ignition	Lightning
Type of tank	Wooden roof tank
Diameter (D), height (H), area (A)	D=29 m, H=8,5 m, A= 660 m^2 (D=95 ft, H=27-10 ft)
Volume	No information available
Amount of fuel	4480 m^3 (28 182 barrels)
Type of fuel	Crude oil

Data related to the tank fire extinguishment

Type of equipment	Two monitors
Type of foam	Light Water AFFF/ATC
Preburn time	About 4:20 hours
Application rate	6,9 L/m^2/min
Time to knockdown	About 10 minutes
Time to extinguishment	About 15 minutes
Total consumption of foam	3400 litres (900 gallons) in total

General description of incident

The fire started at 13:15 when a lightning struck the tank containing crude oil. The tank was of the same type as during the fire in 1986, was built in the 1930s and had a wooden roof construction. At the time of the fire, the fuel level was about 1,8 m (5 feet 10 inches) from the top. Initially, water was applied for quenching the fuel surface using a 2840 L/min (750 gpm) deck gun. When the foam monitors were in place, this nozzle was switched to thermal column break-up duty.

At 16:35 the foam attack was started with a total flow rate of 4540 L/min (1200 gpm) using a 2650 L/min (700 gpm) nozzle and one 1890 L/min (500 gpm) nozzle aimed towards the same landing zone. Within 10 minutes, the fire intensity was noticeably reduced at around 16:50, about 15 minutes from start of foam application the fire was extinguished.

For security reasons, foam was applied for another 10 minutes using a total of 3400 litres (900 gallons) of Light Water AFFF/ATC. About 25 000 barrels of crude oil were saved.

The faster extinguishment in this fire was attributed to the shorter preburn time and the higher application rate.

References:
3M Hotline February 1988

Basic information

Date	1988-04-11
Location	Ashland Oil, Minneapolis/St.Paul, Minnesota, USA
Cause of ignition	Unknown
Type of tank	Cone roof tank
Diameter (D), height (H), area (A)	D=36,6 m, H=no info, A=1052 m^2 (D=120 ft)
Volume	No information available
Amount of fuel	6360 m^3 (40 000 barrels)
Type of fuel	Cracking tower slurry

Data related to the tank fire extinguishment

Type of equipment	Four nozzles (2x500+300+200 gpm)
Type of foam	Light Water AFFF/ATC
Preburn time	About 1:20 hours
Application rate	5,4 L/m^2/min (0,13 gpm/sq ft)
Time to knockdown	1,5 minutes
Time to extinguishment	About 10 minutes
Total consumption of foam	2000 litres (530 gallons)

General description of incident

The fire started for unknown reasons shortly after 02:00 in the morning, blowing off the roof and eventually melting the sides of the tank 3 m down to near the level of the product. In order to keep the water in the dike to a minimum and because no other object were considered to be severely exposed to heat, cooling was judged unnecessary.

At 03:20 the foam attack was started with a total flow rate of 5680 L/min (1500 gpm) using two 1890 L/min (500 gpm) nozzles, one 1135 L/min (300 gpm) nozzle and one 760 L/min (200 gpm). Within 1½ minutes, a dramatic knockdown was achieved and at around 03:30, about 10 minutes from start of foam application, the fire was declared out.

About 2000 litres (530 gallons) of Light Water AFFF/ATC was used for the extinguishment. About 38 000 barrels of product were saved.

Although the very quick extinguishment, some lessons were learned. This type of fires requires high-volume, long-range foam nozzles to enable fire fighter to stay out of the diked area. The 1½ inch and 2½ inch foam nozzles used had a very short range and the personnel were required to operate too close to the tank. Foam application from one direction into a tank is also more effective than the old-fashioned techniques like the “four-corner” approach. Favourable weather, no violent frothing, more than adequate water supply, preparedness and training, and in-plant stock of the foam were also key factors for successful operation.

References:
3M Hotline May 1988

Basic information

Date	1988-06-17
Location	MAPCO refinery, Memphis, Tennessee, USA
Cause of ignition	Contracting workers
Type of tank	Insulated cone roof tank
Diameter (D), height (H), area (A)	D=34,2 m, H=12,2 m, A=918 m^2 (D=112 ft, H=40 ft)
Volume	12720 m^3 (80 000 barrels)
Amount of fuel	4770 m^3 (30 000 barrels)
Type of fuel	#6 fuel oil

Data related to the tank fire extinguishment

Type of equipment	3x500 gpm ground-based foam nozzles
Type of foam	3M Light Water ATC
Preburn time	1-2 hours (estimated figure)
Application rate	6,2 L/m^2/min
Time to knockdown	20 minutes
Time to extinguishment	Less than 1 hour (estimated figure)
Total consumption of foam	7570 litres (2000 gallons, 1000 gallon in each attack)

General description of incident

Some days before the accident, a thunderstorm had ripped off much of the insulation of the 34,2 m (112 ft) diameter tank. Two contract workers were working on the tank top repairing the insulation when an explosion occurred at about 13:54. The blast blew the cone-shaped roof completely away from the 40 ft high tank and the tank was fully involved in fire. Three ground-based multiversals, each with a capacity of 1890 L/min (500 gpm), were set up to apply foam while nearby tanks were cooled by hose streams. Using 5680 L/min (1500 gpm) corresponding to 6,2 L/m^2/min the fire was controlled within 20 minutes with only small rim fires remaining. A thunderstorm came up disrupting the foam streams. After a regrouping, the foam attack was started again and by 16:24 the fire was declared out. In each attack, about 3785 L (1000 gallons) of Light Water ATC were used.

References:
3M Hotline febr 1989

Basic information

Date	1989-03-23
Location	Neste OY refinery, Borgå, Finland
Cause of ignition	Fuel on roof, electrostatic discharge due to foam application
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=52 m, H=14,3 m, A=2124 m^2
Volume	30 000 m^3
Amount of fuel	22000 ton
Type of fuel	Isohexan

Data related to the tank fire extinguishment-1st fire

Type of equipment	5 fixed foam pourers on the wall, 4 foam monitors on roof of fire trucks and 1 foam nozzle on a hydraulic boom
Type of foam	Alcohol resistant ATC, Expyrol FAS
Preburn time	~10 min
Application rate	~7,2 L/m^2/min
Time to knockdown	30 min
Time to extinguishment	43 min
Total consumption of foam	~15,5 m^3

Data related to the tank fire extinguishment-2nd fire

Type of equipment	5 fixed foam pourers on the wall, 3 foam monitors on roof of fire trucks and 1 foam nozzle on a hydraulic boom
Type of foam	Various types, e.g. ATC, Expyrol FAS, various low expansion foams
Preburn time	~3 min
Application rate	~5,2 L/m^2/min
Time to knockdown	Foam application was stopped after 15 min because application rate was too low
Time to extinguishment	13,5 h (burnout)
Total consumption of foam	~275 m^3 , most of it to protect nearby tanks with foam

General description of incident

The incident started in the evening on March 22, 1989, when it was observed that there was isohexan on the floating roof. The roof was immediately foamed and repair work of the drainage rain water system, which caused the leakage, started and pumps were also used to pump the fuel back into the tank again. However, the leakage could not be stopped and on the midmorning there was still a lot of fuel on the roof. Although the roof was continously foamed, the fuel was ignited at 12:26, March 23 at a small area that was not covered by foam close to the fuel leakage due to currents in the fuel. Ignition was probably caused by electrostatic discharge due to the foaming operation. The preburn time was approx. 10 minutes as the fire trucks had to be moved. There was, however, not a full surface fire when the foam application started. Foam was applied to the burning fuel surface using five fixed foam pourers mounted on the tank wall, four monitors mounted on fire trucks and one nozzle mounted on a hydraulic platform, having a total flowrate of 15300 L/min, correponding to 7,2 L/m^2/min. The foam application was complicated by strong winds but after 30 minutes of foam application the fire was controlled. At 13:29, the fire was declared out. After extinguishment, the roof was inspected and the foam layer thickness was estimated to about 0,3 m to0,4 m.

At 14:10, the thickness had been reduced to about 0,03 m and foam application was started again. After 2 minutes (14:12) the fuel ignited again, rapidly involving the entire tank due to the thin foam layer. At this time, the roof was probably completely sunken. Foam application started after 3 minutes of preburn using five fixed foam pourers mounted on the tank wall, three monitors mounted on fire trucks and one nozzle mounted

on a hydraulic platform, having a total flowrate of 11100 L/min, corresponding to 5,2 L/m^2/min. However, the foam attack was terminated after about 15 min as the application rate was judged to be too low and there was lack of water capacity due to the need of cooling nearby tanks. The decision was made to focus all the available resources on protecting nearby tanks (using in total about 60 000 L/min) and allow for a burnout.

Protection of adjacent tanks was immediately started by foam and water application. At about 14:30, transfer of fuel started as well, both from the burning tank and from the neighbour tanks. During the late evening, the fire intensity reached its maximum but sufficient cooling could be obtained and no fire spread occurred. In the morning on March 24, the fire started to be reduced due to lack of fuel and the fire was completely out at 16:00. By then, approx. 6000 ton had been transferred and the fire had consumed about 16000 ton. The average burning rate was estimated to about 1000 m^3/hour to 2000 m^3/hour. In total, 275000 litres of foam concentrate was used during the entire operation, most of it for cooling purposes.

The most important lessons learned was the importance of a high enough application rate and to use gentle foam application via the tank wall (back-board system), when there is no fire to avoid electrostatic discharge.

References:
Personal communikation-Jyrki Karppala Fortum; Industriförsäkring 3/1989; Neste Fire-video; Brand o Räddning 6-7/89

Basic information

Date	1989-12-24
Location	Exxon refinery, Baton Rouge, LA, USA
Cause of ignition	Explosion due to gas release
Type of tank	No information (two similar tanks on fire)
Diameter (D), height (H), area (A)	D=41m, H=no info, A=1320 m^2 (D=134 ft)
Volume	No information
Amount of fuel	36560 m^3 (230 000 barrels) in total in both tanks
Type of fuel	Heating oil

Data related to the tank fire extinguishment

Type of equipment	One 2000 gpm foam monitor
Type of foam	3M Light Water AFFF/ATC at 3%
Preburn time	About 13:30 hours
Application rate	Tank 1-4,5 L/m^2/min, Tank 2-5,4 L/m^2/min
Time to knockdown	Tank 1-about 20 min, Tank 2-no info
Time to extinguishment	Tank 1-65 min, Tank 2-no info
Total consumption of foam	181700 litres (48 000 gallons) in total

General description of incident

The fire started 13:27 on Christmas Eve 1989 by an explosion due to a gas release. The blast ignited tanks containing 5 000 000 gallons of heating oil and 882 000 gallons of lubrication oil. In total, 16 tanks and a major product shipping pipeband were on fire covering approx. six to eight acres. Fourteen of the tanks were small, having a diameter of about 9 m while two tanks had a diameter of 41 m (134 ft). Problems occurred with water delivery as most of the water system was knocked out by the explosion and some fire water lines were frozen.

The fires in and around the 14 smaller tanks were handled by the Exxon's Fire Brigade, while the two largest tanks on fire containing heating oil, required additional resources. Due to the water supply problems, a pressure of only 4,7 bar (68 psi) could be obtained which was far below the target pressure of 6,9 bar (100 psi).

At about 03:00 on Dec 25 the foam attack was started using one 7570 L/min (2000 gpm) monitor on each tank and two 3785 L/min (1000 gpm) nozzles for the dike areas. Because of the low water pressure, the delivered flow rate into the "tank 1" was about 6240 L/min (1649 gpm) corresponding to an application rate of 4,5 L/m^2/min (0,11 gpm/sq ft). Knockdown was achieved within 20 minutes and total extinguishment after 65 min.

The application rate on "tank 2" was slightly higher, about 5,4 L/m^2/min (0,133 gpm/sq ft). There is no information about time to control and extinguishment, respectively.

All fires were extinguished after about 14 ½ hours using in total 181700 litres (48 000 gallons) of 3M ATC.

One thing that was learned during the battle was the use of a helicopter to get an aerial view of the situation. This is something that will be included in their future planning.

References:
Personal commmunication Eric Lavergne WFHC; 3M Hotline Sept 1990; Fire International Aug/Sept 1990

Basic information

Date	1993-01-02
Location	Steuart Petroleum, Jacksonville, Florida, USA
Cause of ignition	Overfilling, vapours ignited by a car
Type of tank	Internal floating roof tank
Diameter (D), height (H), area (A)	D=30,5 m, H=no info, A=730 m^2 (D=100 ft)
Volume	8700 m^3 (2,3 million gallon)
Amount of fuel	8700 m^3 (2,3 million gallon)
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	Subsurface injection, foam wands and monitors
Type of foam	No information
Preburn time	Several foam attacks, about 4,5 days until final attack
Application rate	7,9 L/m^2/min (maximum appl.rate 51 L/m^2/min)
Time to knockdown	55 minutes
Time to extinguishment	1:57 hours
Total consumption of foam	27000 L (7200 gallon) for final attack

General description of incident

An explosion occurred 03:15 on Jan 2 1993 in tank 22, a 30,5 m (100 ft) diameter gasoline tank, due to overfilling. One terminal operator was killed as he was driving into the spill area at ignition. The exact source of ignition could not be determined but the potential ignition sources included the operator's vehicle, the mechanical action of the internal floating pan being forced by the high product level into the cone roof, and the action of the flowing gasoline. A large ground fire around the tank was also impinging tank 21, 12 m away and tank 23 18 m away. The fire also exposed unprotected aboveground pipelines and manifolds and a number of flange connections were burning vigorously and the fire was covering about one acre. The ground and flange fires were quickly brought under control by foam lines and hand extinguishers. Gasoline continued to flow from the overfilled tank’s eyebrow vents complicating ground extinguishment. The external roof had partially collapsed onto the internal floating roof creating an irregular external roof line with cavities between the external and internal roofs. A fishmouth opening was formed on one side of the tank.

A foam attack was started at 4.39 a.m using a 4730 L/min (1250 gpm) foam monitor but was terminated after 15 minutes as the tank started to overflow. Five seperate attacks were then initiated during the next sixteen hours, including over-the-top, eyebrow vent, subsurface injection, and dry chemical applications. Each of these attacks consumed thousands of gallons of water and foam concentrate, along with hundreds of pounds of dry chemical. Unfortunately, each attack caused the tank to overflow, reigniting the ground fires, which drove firefighters from their forward positions. On Jan 4, a ground based over-the-top attack was started using specially fabricated foam wands. However, the tank was overflowing again and when the foam application was interrupted, the foam wands acted like a reverse siphon as the fuel level was above the outlet of the foam wand. This caused gasoline to flow out into the dike area through the high backpressure foam makers causing a new dike fire.

On Jan 6, a final foam attack was authorized using a 1890 L/min (500 gpm) subsurface application followed by activation of five foam wands with a total capacity of 3880 L/min (1025 gpm, (500+240+3x95gpm)). In total, this attack would deliver 5770 L/min (1525 gpm) of foam into the tank (corresponding to an application rate of 7,9 L/m^2/min). The foam attack was started at 21:12 and almost immediately the attack ran into difficulty. One of the wands (240 gpm) failed and a 3785 L/min (1000 gpm) and a 4730 L/min (1250 gpm) foam monitor was therefore used to compensate for this loss. As the foam attack appeared to be successful, also a 7570 L/min (2000 gpm) foam monitor was put into operation In total a foam flow of

37000 L/min (9780 gpm) was used. This corresponds to an application rate of almost 51 $L/m^2/min$, however a large portion was probably applied onto the tank rather than inside the tank. After 50 minutes of foam application, foam and burning product started to overflow through the eye-brow vents. However, after 55 minutes knockdown was achieved and after still some time only a few visible flames continued to burn at the southern “fishmouth” opening. The remaining fire was finally extinguished at 23:09 on Jan 6 but foaming continued at 15 minutes intervalls for the next seven hours. A small reignition occurred 03:00 on Jan 7 but was quickly extinguished and precautionary foaming continued therefore in intervalls during the next 32 hours. The final extinguishment required approximately 27000 L (7200 gallons) of foam. Transfer operations continued until Jan 11. Approximately 2 million gallons (7500 m^3) of gasoline in the storage tank were saved.

At that time, this was the largest internal floating roof tank ever succesfully extinguished. A number of very important lessons were learned from this fire (see IFS and Fire Eng) on how to deal with all difficulties that might occur on covered floating roof tanks.

References:
IFW-March/April 1993; IFS May/June 1993; IFW-Nov/Dec 1993; Fire Engineering Nov 1993

Basic information

Date	1994-11-07
Location	France
Cause of ignition	Sunken roof, electrostatic discharge
Type of tank	External floating roof
Diameter (D), height (H), area (A)	D=36 m, H=no info, A=1020 m^2
Volume	No information
Amount of fuel	No information
Type of fuel	Platformate

Data related to the tank fire extinguishment

Type of equipment	No information
Type of foam	No information
Preburn time	No information
Application rate	No information
Time to knockdown	No information
Time to extinguishment	About 1 hour
Total consumption of foam	No information

General description of incident

In 1994, the roof of a 36 m diameter tank in platformate service, equipped with a single deck potoon roof, sank after an extremely severe rainstorm as a result of a too low capacity roof drain. Out of precaution, the full surface of the platformate was covered with foam. The foam throwing and foam generating equipment remained installed around the tank to maintain the foam blanket. During a severe rainstorm a day later (accompanied by eletrostatic discharges in the area, but no direct lightning strikes) the tank caught fire. Since the foam throwing equipment was still in position and lined up the fire was extinguished within an hour.

Reference:
Lastfire Chapter 3, A.2.2

Basic information

Date	1995-03-30
Location	Ultramar refinery, Wilmington, CA, USA
Cause of ignition	No information
Type of tank	Insulated cone roof tank
Diameter (D), height (H), area (A)	D=47,6 m, H=no info, A=1780 m^2 (D=156 ft)
Volume	No information
Amount of fuel	No information
Type of fuel	Heated vacuum residue fuel

Data related to the tank fire extinguishment

Type of equipment	2000 gpm Hired Gun
Type of foam	3M AFFF/ATC (used at 1 %)
Preburn time	No information
Application rate	No information
Time to knockdown	No information
Time to extinguishment	About 2 days
Total consumption of foam	No information

General description of incident

The incident started by a loud rumble followed by a cloud of vapour escaping from a tear in the roof of the tank. The tank was an insulated cone roof tank containing heated vaccum residue fuel to about 150 ºC to 200 ºC (300 ºF to 400 ºF). A flood of the heavy oil was ejected from the tank and was deposited about 100 m (100 ft) from the tank. Cooling operations were started to protect nearby tanks and buildings and AFFF/ATC at 1 % was applied to the tank. The attempt was to cool off the product while depositing a small blanket of foam on the fuel to reduce burning. The effort was successful and foam was continously applied in 10 to 15 minutes increments, the fire then appeared to die down and then balls of smoke erupted once again. The situtation went on for about two days until the fuel temperature was reduced to less than 175 ºC (350 ºF), which was the auto ignition temperature.

Reference:
IFW Sept/Oct 1996

Basic information

Date	1996-06-04
Location	Amoco Refinery, Texas City, USA
Cause of ignition	Lightning
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=41 m, H=14,6 m, A=1330 m^2 (D=134 ft, H=48 ft)
Volume	No information
Amount of fuel	10000 m^3 (63 000 barrels-25 ft deep)
Type of fuel	Neat MTBE

Data related to the tank fire extinguishment

Type of equipment	Two 2000 gpm monitors (1xTerminator, 1xHired Gun)
Type of foam	Monitor 1-AFFF-AR at 3 %*), monitor 2-AFFF-AR at 6 %
Preburn time	4 hours
Application rate	11.4 L/m^2/min (0,28 gpm/sq ft)
Time to knockdown	20-30 minutes
Time to extinguishment	2,5 hours
Total consumption of foam	About 280000 litres (74000 gallons) in total

*) Only 3 % due to foam pump failure

General description of incident

A lightning caused ignition to the 41 m diameter tank filled with neat MTBE. The floating roof sunk and the annular seal protection system became inadequate. As the roof sunk into the product, the roof drain connection was carried down with it. MTBE flowed from the open roof drain valve at the side of the tank into the surrounding dike area resulting in a substantial dike fire. There was a considerable fire exposure to adjacent equipment, including a process unit, other open top floating roof tanks and above ground pipelines. Initial firefighting efforts were directed at protecting these exposures using multiple monitors and the initial extinguishing efforts were directed towards the dike area, which was fought and extinguished manually. Two trailer-mounted monitors, 7600 L/min each, were used for the foam attack on the burning tank. One of the monitors was supplied with one brand of AFFF-AR at 3 % (only 3 % due to a foam pump failure) and the other using another brand of AFFF-AR at 6 %. The 4 hours preburn was due to two wind changes requiring re-positioning the monitors three times. Noticeable reduction of the fire was accomplished within 15 to 20 minutes and knockdown was achieved within 20 to 30 minutes. Complete extinguishment was achieved after about 2,5 hours. Time to extinguishment was delayed due to persistent flickering, flashovers, and flames at the tank wall.

87000 L (23000 gallons) of foam was used to fight the tank fire, 119000 L (31400 gallons) on the dike fire and 73000 L (19200 gallons) on post-fire vapour suppression, in total about 280000 L (l74 000 gallons).

This was the first known extinguishment of a fully involved big MTBE tank fire. It clearly shows the need for increased application rate and the problems to achieve complete extinguishment, which must be considered in the fire emergency planning. To minimize these problems, it is suggested that gentle application technique should be employed to prevent foam plunging and fuel contamination. Using foam chambers producing good quality finished foam is recommended and in situations where fixed systems are not employed, the use of aspirating foam nozzles is recommended.

References:
Personal communication Eric Lavergne-WFHC; personal communication Alexander Regent; Angus website “What’s new-Slovenia MTBE article”

Basic information

Date	1996-06-11
Location	Shell oil, Woodbridge, New Jersey, USA
Cause of ignition	Lightning
Type of tank	Internal floating roof
Diameter (D), height (H), area (A)	D=42,7 m, H=12,2 m, A=1430 m^2 (D=140 ft, H=40 ft)
Volume	15 900 m^3 (4 200 000 gallons)
Amount of fuel	11 400 m^3 (3 000 000 gallons)
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	Two 2000 gpm monitors
Type of foam	AFFF
Preburn time	18-20 h until first attack
Application rate	10,6 L/m^2/min
Time to knockdown	No information
Time to extinguishment	Last attack 2:00 (2:30?) hours
Total consumption of foam	No information

General description of incident

The fire started when a lightning hit the 42,7 m (140 ft) diameter and 12,2 m (40 ft) high tank at 16:15 on June 11. The tank was filled to about 70 % (7,6 m/25 ft) with gasoline. The roof was thrown about 46 m (150 ft) up in the air and then went down on its edge into the tank again. The internal roof sunk to the bottom of the tank. The tank was in the center of five tanks in a common dike and the distance between the tanks was only 23 m (75 ft). Cooling operations of the nearby tanks were therefore started, fuel was transferred to other tanks, and about 200 neighbours were evacuated. One of the major problems for a foam attack was the distance from the tank center to the dike wall, 82 m (270 ft). Due to lack of appropriate foam equipment and foam supply a foam attack was not started until about 10:00 (12:02-information differs) on June 12. Because of the large distance, a lot of the foam landed in the dike but the fire was slowly getting controlled. However, at this moment one pump unit had to be shut down due to mechanical problems and as one monitor could not hold the fire back, foam application was terminated. A second attack was spoiled by a wind shift and before the third attack, the monitors were moved into the dike area. The foam application was started at about 18:00 and the fire was finally extinguished at about 20:00 (20:30-information differs). Assuming that two monitors were used at nominal flow rate, 15140 L/min (4000 gpm), the application rate was 10,6 L/m^2/min.

About 1200 m^3 to 1900 m^3 (300 000 to 500 000 gallons) of fuel was remaining in the tank after extinguishment.

References:
IFW July/august 1999 (webversion); Tom Avril, Tom Haydon, Jonathan Jaffe “Blanket of foam smothers inferno“; http://mhswebtvprinting.tripod.com/wrcphotos2.html; Observer-371,

Basic information

Date	1996-07-19
Location	Sunoco refinery, Sarnia, Ontario, Canada
Cause of ignition	Lightning
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=42,7 m, H=15m, A=1430 m^2 (D=140 ft, H=50 ft)
Volume	19 000 m^3 (120 000 barrels)
Amount of fuel	11400 m^3 (72 000 barrels)
Type of fuel	Raffinate (same volatility as gasoline)

Data related to the tank fire extinguishment

Type of equipment	Two 2000 gpm foam cannons
Type of foam	Monitor 1-3M ATC at 3 %, monitor 2-AFFF at 3 %
Preburn time	6:45 hours
Application rate	10,6 L/m^2/min (0,26 gpm/sq ft)
Time to knockdown	10-12 minutes
Time to extinguishment	3:10 hours
Total consumption of foam	About 51000 litres (13 500 gallons) incl securing operations

General description of incident

The fire started at 00:36 on July 19, 1996 by a lightning strike. Pieces of the roof , representing approx. 50 % of the roof, were thrown outside of the tank while the remainder of the roof stayed inside the tank and sunk resulting in a full surface fire. The 50 ft high tank was filled to the 26 ft level at ignition. The primary objective for the responding personnel was to provide cooling to the neighbouring tanks to stabilize the situation. Two possible strategies were considered, either to transfer as much fuel as possible and allow the remaining part to burn out, or to launch a massive foam attack and extinguish the fire. Based on a weather forecast, indicating a shift in the wind direction resulting in a severe heat exposure to one of the nearby tanks, the second alternative was chosen. Foam concentrate, pump capacity, and foam equipment were available via the mutual aid organisation, well exceeding the NFPA recommendations. The start of the foam attack had to wait until the wind shift had occurred in order to find the correct position for the foam monitors. At about 07:20, the foam attack was initiated using two 7570 L/min (2000 gpm) foam cannons. Both streams were combined to provide one single foam stream onto the fuel surface. After about 10 to 12 minutes of foam application, a 90 % knockdown of the fire was reached and within 15 minutes there was almost no visible smoke from the tank. After control, some remaining fires occurred along the inward curling of the tank walls, primarily closest to the foam cannons position. There were also some small fires in pockets formed where a portion of the sunken roof partly rose above the fuel surface. By 09:00, a decision was taken to relocate one of the foam cannons to a better position to reach these fires, and by 10:30, the fire was extinguished. About 7600 L (2000 gallons) of foam concentrate was used to control the fire and another 30000 L (8000 gallons) to reach compete extinguishment. Over the next two days an additional 13250 L (3500 gallons) were used to provide final cooling and vapour suppression until the tank was emptied of the 3 m of product that was left at extinguishment.

Some of the lessons learned: (there are more reported in IFW)
Minimum foam requirements such as those set by NFPA 11 are only guidelines, not gospel. It could take far more than the minimum requirement to extinguish and maintain a seal on the product left in the storage tank.
Call for plenty of manpower, even if it is more than you might immediately need. A storage tank fire might turn into a long campaign requiring a relief rotation for the original fire fighters on scene.

When purchasing large capacity foam/water nozzles, make sure it has sufficient volume and reach. The equipment should be able to handle cooling and extinguishment of a major tank fire without putting fire personnel in harm's way.

References:
Personal communication George Hatfield Fire Chief Sarnia Refinery; IFW Sept/Oct 1997; IFJ March 1997; Sunoco Sarnia Refinery Fire investigation report-"Tank 11 Fire Investigation", October 4, 1996; UKPIA Safety Report No 13/96; www.caer.ca

Basic information

Date	1998-02-18
Location	Nedalco, Bergen op Zoom, Netherlands
Cause of ignition	Fire spread from nearby production
Type of tank	Cone roof
Diameter (D), height (H), area (A)	No information
Volume	1200 m^3
Amount of fuel	1000 m^3
Type of fuel	Ethanol

Data related to the tank fire extinguishment

Type of equipment	Three monitors
Type of foam	Angus Alcoseal 3/6 LT
Preburn time	11 hours
Application rate	No information
Time to knockdown	20 minutes
Time to extinguishment	2 hours
Total consumption of foam	11 tonnes

General description of incident

The fire started in the despatch department where large quantities of ethanol were stored and the first fire appliance was on scene at 10:29. At 11:00, the intense heat caused ignition of a nearby 1200 m^3 ethanol storage tank. No cooling of nearby tanks was necessary and after 11 hours preburn, the fire was controlled in 20 minutes and extinguished in 2 hours using three monitors and Alcoseal. 10 firemen were involved in the operation and 11 tons of foam concentrate was used.

References:
Angus Fire Website; personal communication Peter Vosselman-Algebra bv

Basic information

Date	1999-10-28
Location	Conoco refinery, Ponca City, OK, USA
Cause of ignition	Spark from a man lift
Type of tank	Insulated cone roof tank
Diameter (D), height (H), area (A)	D=60,4 m, H=14,6 m, A=2860 m^2 (D=198 ft, H=48 ft)
Volume	12720 m^3 (80 000 barrels)
Amount of fuel	8475 m^3 (2 238 600 gallons)
Type of fuel	Gas-oil (about the thickness of motor oil)

Data related to the tank fire extinguishment

Type of equipment	Three 2000 gpm monitors (CNF Terminator)
Type of foam	CNF Universal Plus and XL-3
Preburn time	2:40 hours
Application rate	7,94 L/m^2/min (0,195 gpm/sq ft)
Time to knockdown	19-25 min
Time to extinguishment	78 min
Total consumption of foam	34000 litres (9000 gallons)

General description of incident

The fire started at 11:27 when a spark from a man lift with two employees ignited vapors. The ignition tore the insulated cone roof on the 60,4 m (198 ft) diameter tank into several large pieces resulting in a full surface fire. The two employees survived although with serious injuries. Preparations for a foam attack using three 7570 L/min (2000 gpm) foam monitors were immediately initiated and after 2 hours 40 minutes everything was in place. During the preparations, adjacent tanks were cooled by portable monitors. The foam attack was initiated at 14:07 and the fire was under control by 14:26, 19 minutes after start of foam application. Time to 90 % foam coverage is estimated to about 25 minutes. An unpredictable wind shift occurred and one by one, two of the three monitors were moved to new positions. When the tank ignited, the roof was shredded and some remaining twisted debris formed pockets making the final extinguishment difficult. Three times the fire was called under control but each time hidden fires would reappear. With one master stream left in operation, an industrial man-lift was brought in as a firefighting platform for fire fighters using 3-inch handlines. At 15:25, the last monitor was shut down. About 34000 L (9000 gallons) of foam concentrate was used and approx. 7200 m^3 (1 900 000 gallons) of gasoil were remaining after the fire and were able to be reprocessed and marketed.

References:
Personal communication John Coates; IFW jan-febr 2001(web version); www.amarillonet.com; www.poncacity.net; ardmoreite.com; IFJ June 2002

Basic information

Date	2001-06-07
Location	Orion Refinery, Norco, LA., USA
Cause of ignition	Sunken roof, lightning
Type of tank	Open top floating roof
Diameter (D), height (H), area (A)	D=82,4 m, H=9,8 m, A=5325 m^2 (D=270 ft, H=32 ft)
Volume	51675 m^3 (325 000 barrels)
Amount of fuel	47700 m^3 (300 000 barrels)
Type of fuel	89,7 octane gasoline (no additives)

Data related to the tank fire extinguishment

Type of equipment	2 monitors (8000, 4000 gpm)
Type of foam	3M ATC at 3 %
Preburn time	About 12 hours
Application rate	8,55 L/m^2/min (0,21 gpm/sq ft)
Time to knockdown	20-25 minutes
Time to extinguishment	65 minutes
Total consumption of foam	106000 litres (28 000 gallons) (extinguishment only)

General description of incident

The incident started on June 7, 2001 when the Tropical Storm Allison caused the roof to partly sink. The fire started at 13:30 when a lightning struck the tank containing gasoline. At the time for the fire, the product level was about 8,5 m (28 ft). Cooling of the tank shell was initiated and planning and preparation of the foam attack started. There were several practical problems to overcome, as large areas and access road to the tank were flooded due to the storm.

At 01:32 on June 8 the foam attack was started with a total flow rate of 45400 L/min (12 000 gpm) using one 30300 L/min (8000 gpm) monitor positioned at “4 o’clock” and one 15100 L/min (4000 gpm) positioned at “8 o’clock” aiming towards the tank center to achieve a maximum foam run of approx. 26 m (85 ft). Within 10 minutes the foam application was gaining a “bite” on the fire and a flame collapse was achieved after 25 minutes of foam application. After obtaining control, a 3785 L/min (1000 gpm) Telesquirt was used from the “6 o’clock” position, applying foam on the inner tank shell at the “5 o’clock” position to improve extinguishment of flames along the tank wall. At 02:37, about 65 minutes from start of foam application the fire was declared out. As lightning was still being reported in the area, foaming continued at 45400 L/min (12 000 gpm) for two hours, followed by a half-hour application at 15100 L/min (4000 gpm). Foaming then continued for 15 minutes every hour until the tank was emptied about 65 hours later.

About 106000 L (28 000 gallons) of 3M ATC were used for the extinguishment and another 140000 L (37 000 gallons) of various brands were used for security. About 25700 m^3 (6 800 000 gallons) of gasoline were saved.

For the time being, this is the largest tank fire ever successfully extinguished worldwide.

References:
Personal commmunication Eric Lavergne WFHC; IFW May/June 2001; IFW July/Aug 2001 (webversion) “Big Rain, Big Fire”; IFW website; WFHC website

Basic information

Date	1st fire: 2001-07-10, 2nd fire: 2001-08-15
Location	Petroleum Fuel and Terminal Oil Co, Granite City, I, USA
Cause of ignition	Explosion, cause not determined
Type of tank	Insulated cone roof tank
Diameter (D), height (H), area (A)	D=No info, H=25,4 m (H=80 ft)
Volume	15900 m^3 (4200000 gallons)
Amount of fuel	1st 1500 m^3 (400000 gallons), 2nd 1430 m^3 (378000 gallons)
Type of fuel	Liquid asphalt (heated)

Data related to the tank fire extinguishment (July 10 and Aug 15)

Type of equipment	No information
Type of foam	No information
Preburn time	1st about 15 hours, 2nd about 2 hours
Application rate	No information
Time to knockdown	No information
Time to extinguishment	1st 1:10 hours, 2nd 1 hour
Total consumption of foam	No information

General description of incident

An asphalt holding tank caught fire twice during 2001. On July 10, 2001, the 15900 m^3 (4,2 million gallon) insulated tank holding about 1500 m^3 (400000 gallons) of asphalt caught fire after an explosion at 12:50. Due to insufficient water capacity from the hydrants and to avoid the risk for boil-over, it was decided to let the tank burn out. However, after realizing that it would take several days, it was decided to initiate a foam attack. Foam application started at 04:00 on July 11 and foam was first applied for 45 minutes. The foam application was then shut down for 10 minutes to observe the scene before turning on the foam again for another 15 minutes before it was determined that the fire was completely out.

On August 15, the tank caught fire again. After the first fire, the asphalt had cooled down and solidified and one week before the second fire reheating had started to be able to transfer the asphalt to another tank. August 15 was the second day of transfer when the tank caught fire again just before noon. Having experience from the previous fire, a foam attack was started at 13:50 and the fire was extinguished within an hour.

References:
IFW website incident log; Observer 37, 92,96,99

Basic information

Date	2002-05-05
Location	Trzebinia Refinery, Malopolska region, Poland
Cause of ignition	Lightning
Type of tank	Cone roof+internal floating roof
Diameter (D), height (H), area (A)	No information (about 30 m equal to about 700 m^2)*)
Volume	10000 m^3
Amount of fuel	800 m^3
Type of fuel	Crude oil

Data related to the tank fire extinguishment

Type of equipment	Monitors, 4x2400 L/min, 9x1600 L/min (in total 24000 L/min)*)
Type of foam	Synthetic multipurpose (Deteor+Roteor)
Preburn time	4:15 hours (until general attack)
Application rate	No information *)
Time to knockdown	15 minutes (20:40)
Time to extinguishment	40 minutes (21:05)
Total consumption of foam	109,5 ton

General description of incident

The fire started at 16:10 on May 5 by a lightning strike in an about 30 m diameter tank, "T-41", having a total volume of 10000 m^3 and holding 800 m^3 of crude oil. The first fire fighting units were on the scene at 16:15 and could observe that the cone roof had been blown away and the internal roof construction had been destroyed resulting in a full surface fire. A foam attack was initiated through the semi-fixed system but had to be terminated immediately due to damage of the system. Between 16:20 and 17:00, cooling operations started of nearby tanks and two 2400 L/min foam monitors were directed towards the tank. Further cooling resources and foam monitors arrived between 17:00 and 17:40 but resources were still considered insufficient for a general attack. After analysing foam resources, the decision was taken to dispatch 4 tankers with foam concentrate and to make ready further 15320 L of foam from the District and Provincial Headquaters of the State Fire Service in Malopolska Province. At about 18:35, the tank wall was severely buckled and fuel started to leak into the bund area through some cracks. At about 19:00 the entire bund became involved in flames, probably due to an increased leakage. A foam attack was initiated towards the bund at about 19:20-19:30 and the bund fire was extinguished shortly before 20:00 while foam application continued until about 20:10. After a short break in foam application for necessary preparations, the general foam attack towards the tank was started about 20:25. The fire was brought under control at 20:40 and completely extinguished at 21:05. Tanks in the neighbourhood and the rest of the extinguished tank continued to be cooled using foam until 22:00. At 23:15, the number of water monitors in operation were reduced from ten to five and the complete operation was terminated on May 6. In total 105 vehicles and 362 fire fighters were involved in the operation. 35 vehicles were used to supply the 13 foam monitors. 109,5 ton of foam was used during the fire.

*) Capacity figures and diameter of tank are still uncertain but indicates an application rate in the order of 30 L/m^2 min

References:
Personal communication Michal Baran-Baranski Fire-Dam; Fire International Oct 2002; Fire International website; personal communication Emily Hough Fire International

Basic information

Date	2002-08-18
Location	Houston Fuel and Oil Terminal Co, Texas, USA
Cause of ignition	Expansion joint on a transfer line rupured
Type of tank	No information
Diameter (D), height (H), area (A)	No information
Volume	No information
Amount of fuel	30 000 barrels
Type of fuel	Residual fuel oil

Data related to the tank fire extinguishment

Type of equipment	No information
Type of foam	No information
Preburn time	No information
Application rate	No information
Time to knockdown	No information
Time to extinguishment	<4:45 hours
Total consumption of foam	No information

General description of incident

The fire started shortly after 06:45 on August 18 when a pipeline used to carry high-temperature (120 ºF) residual fuel failed. The fire started when nearby electrical lines were broken and sparked by the damaged pipeline. This fire caused a nearby tank to ignite, containing 30000 barrels of residual fuel oil, an asphalt-like residue that is a byproduct from oil refining. The fire was extinguished at about 11:30 with help of 20 fire and foam trucks from local fire departments and an emergency team of Ship Channel industries. The tank did not collapse even though its roof caved in. About 10000 to 15000 barrels of residual fuel were saved.

References:
CNNwebsite, Observer 38, (39, 40, 41, 42, 43)

Basic information

Date	2003-03-07
Location	Digboi Refinery, Guwahati, India
Cause of ignition	Mortar attack
Type of tank	Internal floating roof
Diameter (D), height (H), area (A)	D=50 m?, H=15 m, A=1963 m^2 (Based on photos, the diameter given is too large)
Volume	5000 m^3
Amount of fuel	4579 m^3
Type of fuel	Petrol

Data related to the tank fire extinguishment

Type of equipment	8 foam vehicles, 6 foam pourers, 3 x 1000 GPM monitors
Type of foam	AFFF 3 % and FP 3 %
Preburn time	56 hours
Application rate	No information
Time to knockdown	No information
Time to extinguishment	3,5 hours
Total consumption of foam	65000 L of foam during 4 hours of application

General description of incident

The fire started at 23:45 at March 7, 2003, in Tank no 559 containing petrol. The tank ignited due to a mortar attack launched from about 200 m. The tank was one of 13 tanks in the tank farm holding all together about 25179 m^3 of fuel. An initial foam attack was started but due to lack of resources the foam application was terminated and all efforts were focused on cooling adjacent tanks to prevent fire spread. After 56 hours, 8:45 on March 9 (should be March 10?), foam application was restarted again using eight foam vehicles, six foam pourers, and three 1000 gpm foam monitors simultaneously to extinguish the fire. At 12:15, the fire was extinguished.

In total 65000 L of foam was used during the 4 hours attack and 0,9 m to1,2 m (3-4 ft) of fuel was left in the tank.

References:
Personal communication Rajesh H. Sabadra K.V.-Fire Chemicals (India) Pvt.Ltd.; personal communication B.K.Sharma-IOCL Digboi; Omega Printers and Publishers Guwahati; CNN.com website

Basic information

Date	2003-05-03
Location	Gdansk Oil Refinery, Gdansk, Poland
Cause of ignition	Mobile telephone? (investigation not completed)
Type of tank	Double shell, cone roof with internal floating roof
Diameter (D), height (H), area (A)	Dia 40 m (internal shell) 44,1 m (external shell), height 16,5 m (internal shell wall height, excluding cone roof height), 13,6 m (external shell wall), surface 1256 m^2
Volume	20 000 m^3
Amount of fuel	19 100 m^3
Type of fuel	Gasoline

Data related to the tank fire extinguishment

Type of equipment	Two "Tornado" (5000 and 8000 L/min, resp.), one monitor on 54 m "Bronto Skylift" (3600 L/min), one roof monitor on Chubb "Pathfinder" (6800 L/min), 7 foam monitors (2400 L/min)
Type of foam	Moussol APS, Finiflam (det+AFFF), Roteor (det), Petroseal, FlameOut Fire Suppressor (6 %) and FlameOut Foam Fire Suppressor (3 %)
Preburn time	About 9:20 hours
Application rate	About 24 L/m^2/min
Time to knockdown	17 minutes
Time to extinguishment	37 minutes
Total consumption of foam	No information

General description of incident

Three men were killed when an explosion occurred in the tank S 124 filled with 19 100 m^3 of gasoline at 14:47 on May 3, 2003. The men was taking a fuel sample from the top of the full tank in order to check the quality before delivery. The cone roof was blown of the tank and the internal roof sunk resulting in a full surface fire.

An initial attempt to extinguish the fire was started shortly after the explosion but was terminated due to too low capacity and range of the equipment available. Instead cooling of nearby tanks was started while waiting for further resources from nearby provinces. Meanwhile, gasoline was transferred to other tanks in order to save as much product as possible. At 01:08 on May 4, an extinguishing attack was started using two Tornado and one Pathfinder monitors and seven mobile Total-monitors using various kinds of foams, most of them of detergent type. All monitors were not used simultaneously due to need for repositioning, etc. but the average total flow rate was about 30000 L/min corresponding to an application rate of about 24 L/m^2 min. During the initial stage of the attack, the Pathfinder (6000 L/min) was used with a premix solution of FlameOut in its 12000 L water tank in order to cool the burning surface. After 2 minutes, the premix was consumed and there was a noticeable reduction in fire intensity. The tank was quickly recharged with water and then used the Petroseal in its internal foam tank for until that was consumed. FlameOut Foam was then filled into its foam tank and used for the next 1,5 minutes.

After 17 minutes (01:25), the fire was under control and after 37 minutes (01:45), the fire was extinguished.

References:
Personal communication Michal Baran-Baranski FIRE DAM; Personal communication Emily Hough-Fire International; Fire International Website; personal communication Lars Hedberg-Statoil; Press Release "PR Newswire" June 19, 2003; Borås Tidning 2003-05-03

Appendix B Extract from database

Extract from database giving some basic information about all identified fires.
In the complete database, the following information is included, if available;

- Identification number
- Date
- Location
- Type of object/facility
- Rating 1-7 (indicates type of fire and information available, see below)
- Description of objects involved
- Tank diameter (m or ft)
- Tank area (m^2 or sq ft)
- Height (m or ft)
- Type of fuel
- Amount of fuel at the incident (m^3 or gallons/barrels)
- Type of foam application equipment
- Flow rate (L/min or gpm)
- Application rate (L/m^2/min or gpm/sq ft)
- Estimated application rate (L/m^2/min or gpm/sq ft)
- Total amount of foam used (L or gallons)
- Type of foam
- Time to knock down (min)
- Time to extinction (minutes or hours)
- Fire / no fire (“no fire” for foam coverage operations)
- Other measurements
- Ignition source/cause of ignition
- Weather
- Comments (very brief information about the incident)
- Indication if there are photos or video recordings available
- References
- Any additional information

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1951-??-??		Refinery	6	4 plus tanks (3*80000 bbl); cone roof				Low flash	Static electricity	Spread by ground fire; water lines; foam lines; burned out; extensive damage
1951-07-12	Kansas City, USA	Refinery	6	80000 bbl; cone roof				Low flash	Static electricity	River floated storage tanks from their foundations. Gasoline ignited from spark caused by a tank striking a high tension line.
1953-??-??		Refinery	6	100000 bbl tank; floating roof				Low flash	Lightning	Water lines; extinguishment
1954-??-??		Refinery	6	Floating roof	100			Low flash	Lightning	Fire extinguisher; extinguishment
1954-??-??		Refinery	6	Floating roof	117			Low flash	Lightning	Chemical foam; extinguishment
1955-08-05	Whiting, Indiana, USA	Standard Oil	5	Today, just as in 1955, the largest inland refinery in the US, covering more than 1600 acres						The worst American refinery disaster of the 20th century. In the end, the fires took eight days to extinguish with 67 storage tanks destroyed. Deadly metal projectiles flung by the blast reached a residential neighbourhood adjoining the refinery, damaging
1956-??-??		Refinery	6	120000 bbl; floating					Lightning	Extinguishment
1956-??-??	Nynäshamn, Sweden	Refinery	6			32	13	Crude oil		The tank ruptured from the bottom and upwards due to severe cold. The oil overflowed the dike and into the refinery area and ignited. "Slop-overs" occured in the oil by approx. 15 minutes intervalls which made the extinguishing efforts very difficult.
1957-??-??		Refinery	6	150000 bbl; floating roof				Low flash	Lightning	Fire extinguisher; water lines; extinguishment
1957-??-??		Refinery	6	100000 bbl; floating roof				Low flash	Lightning	Water lines; extinguishment
1958-05-22	Signal Hill, California, USA	Refinery	6	80000 bbl; cone roof (four plus tanks)				Low flash	Internal frothing / overpressure	Tank containing hot oil frothed over, ignited and swept across through 2/3 of this small refinery. Water lines; burned out; extensive damage; spread by ground fire
1959-??-??		Refinery	6	80000 bbl; floating roof				Crude oil	Lightning	Fire extinguisher; water lines; extinguishment
1959-??-??		Refinery	6	150000 bbl; floating roof				Low flash	Lightning	Fire extinguisher; water lines; extinguishment
1961-??-??	UK		4			21,3		Jet fuel	Lightning	Foam hand lines, plus water cooling outside shell
1961-??-??	UK		4			43,9		Crude oil	Lightning	Foam hand lines, plus water cooling outside shell
1961-??-??		Refinery	6	100000 bbl; floating roof				Low flash	Lightning	Water lines; foam lines; extinguishment
1961-??-??		Pipeline area	6		135			Crude oil	Lightning	Fire extinguisher; extinguishment
1962-??-??		Refinery	6	80000 bbl; floating roof				High flash	Lightning	Water lines; foam lines; extinguishment
1964-??-??		Refinery	6	120000 bbl; floating				Low flash	Lightning	Seal to full surface; over-the-top foam; fixed foam; burned out; extensive damage
1964-06-16	Niigata, Japan	Refinery	5	Five open top floating roof tanks				Crude oil	Earthquake	Earthquake initiated a fire in one tank which almost immediately spread to four nearby tanks. Lack of extinguishing resources, the fire burnt out within 2 weeks; Earthquake caused two major fires. 97 tanks containing 1.1 million bbls of crude were destroy
1965-??-??		Refinery	6	Floating roof	135			Crude oil	Lightning	Fire extinguisher and chemical foams; extinguishment
1965-??-??		Refinery	6	Floating roof	134			Low flash	Lightning	Foam lines; extinguishment
1967-??-??		Bulk plant / terminal	6	Floating roof	120			Low flash	Lightning	
1967-01-17	Santurce, Bilbao, Spain		6					Crude oil	Expl butane railway tanker	Thousands evacuated and vessels put to sea as fire raged through crude oil storage tanks following explosion of butane railway tanker. 1 dead, 8 injured.
1967-02-26	Assab, Etiopia		6	Three tanks				Motor spirit		Fire followed explosion in motor spirit tank. 3 tanks burned out, 1 saved.
1967-06-09	Genoa, Italy	FINA	6	Tank					Lightning	Fina storage tank ignited during late night thunderstorm. Fire spread to other tanks but was completely extinguished. More than 700 tonnes lost.
1967-07-29	Kassala, Sudan		6	Several tanks involved					Sabotage	Police, soldiers, volunteers prevented flames reaching other tanks in area. Unknown no of 15k tonne fuel storage tanks destroyed.
1968-??-??	Caribbean		6			34		Hexane		
1968-??-??			6	Cone roof tank				Toluene	Lightning	The tank was extinguished after initiation of a subsurface injection system designed according to NFPA 11. The preburn time was one hour
1968-??-??	France		6	Floating roof		50		Processing solvent	Spill on roof	Fire on the roof of a 50 m diameter tank containing processing solvent escalated to full surface fire
1968-01-20	Pernis, Netherlands	Shell Refinery	5	80 tanks						Hot oil and water emulsion reacted and resulted in frothing, vapour release and boilover. Fire engulfed 30 acres, destroying 2 wax crackers, naptha cracker, sulphur plant and 80 tanks were destroyed or damaged.
1968-01-29	St Denis, France		6	31 tanks				Diesel	Sabotage	Night watchman set off fires. Tanks affected by heat from source. Explosion caused knock-on response. 31 tanks (diesel oil) completely destroyed.
1968-05-16	Ellesmere Port, Cheshire, UK		6	8 tanks						Explosion in blending/storage depot of Castrol refinery. Fire under control within 1 hour
1969-??-??	Spain		6	12 tanks				Gasoline	Vapor cloud of LPG	Major fire involving the destruction of 12 gasoline tanks. The initial cause of the fire was the ignition of a vapour cloud formed from the release of refrigerated LPG. The fire lasted a week.
1969-??-??	Malaysia		4			43,9		Crude oil	Lightning	
1969-02-15	Brisbane, Australia		6	More than 2 tanks				Petrol		Flames shot 100s of feet as storage tanks containing 40k gals of petrol and destillate were destroyed. 14 injured.
1969-06-29	Ingeniero White, Argentina		6	One tank				Crude oil	Sabotage suspected	10 ml tank of crude oil caught fire at storage plant. Flames prevented from reaching nearby octane tanks.
1969-07-28	USA	Bulk plant / terminal	4	External floating roof	122			Low flash	Lightning	Fire extinguisher and over-the-top foam; extinguishment
1969-09-06	Fiumcino, Italy		6	Four tanks				Oil	Lightning	Bolt of lightning cracked concrete cap of giant crude oil tank and ingited contents. Flames spread to 3 of other 15 reservoirs,flames shot 150 ft.
1969-10-01	Escombreros, Cartagena, Spain		5	39 tanks involved				Gasoline, crude, naphtha, kerosene, etc	Vapour cloud ignition?	Gas cloud accumulated aroud buried gas tanks ignited. 6 propane pressure vessels were propelled a considerable distance projecting a large trail of fire along their paths. Absence of lighting and fire pumps hampered immediate fire fighting efforts. Fire s
1969-11-20	Amsterdam, Netherlands		6	One tank				Petrol		Fire raged 32 hrs in 42 k gal petrol storage tank which burned down to just 3 m high. Flames 120 ft high. 1 injured.
1970-??-??		Refinery	4	Floating roof	117			Crude oil	Lightning	Foam lines; extinguishment

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1970-01-12	Ajjacio, Corsica	Esso	6	Two tanks				Kerosene		Two 1 ml kerosene tanks exploded at Esso storage centre. 817 tonnes destroyed.
1970-03-05			4	External floating roof	160			Low flash		Fire extinguisher and water lines; extinguishment
1970-07-23	Rio de Janerio, Brazil	Shell depot	6	Several tanks involved				Petrol		Huge fire in petrol tanks at Shell storage depot. Several gasoline tanks caught fire and fire threatnedother tanks in area where over 5 m gals of gasoline and kerosene were stored.
1970-09-17	Beaumont, Texas, USA		6	Oil tank					Lightning	Lightning on oil tank resulted in floor-shell seam faliure
1970-11-05	Hamburg, Germany	Esso AG	6	One tank				Crude oil	Lightning	Crude oil storage tank ignited by lightning. 9 000 tonnes crude lost.
1970-??-08	Le Havre, France		6					Oil	Lightning	Content of oil tanks ignited by lightning strike at midnight. Fire brigade restricted damage. 8000 tonnes lost
1971-03-02	Kampong-Som, Cambodia	Refinery	6	Four tanks				Petrol	Sabotage	Vietcong launched 2 hr attack on Cambodia's only oil refinery. Four petrol tanks reported ablaze.
1971-06-26	Czechowice, Poland		1	4 tanks, equal size		33	14,7	Crude oil	Lightning	Oil storage tanks exploded after lightning strike. Devastating fire followed. 33 dead, most firefighters
1971-07-20		Refinery	4	298000 bbl external floating roof	195			Crude oil	Lightning	The fire was extinguished using two foam towers and portable nozzles
1971-08-??			6	Internal floating	120			Gasoline	Explosion	Explosion lifted the cone roof, dropping it and the floating roof to the bottom of the tank. The fire was fought with chemical foam without succes, probably due to inadequat application rate and the fire burned out.
1971-09-10			6	External floating roof	120			High flash	Lightning	Foam lines; extinguishment
1972-??-??	Spain		6	Floating roof				Gasoline	Smoking	A pontoon explosion occured in a gasoline tank, which was causewd by a worker smoking. The fire escalated to a full surface fire. One person died
1972-??-??		Refinery	6	Floating roof	110				Lightning	Water lines; extiguishment
1972-03-??	USA		6	Three open top floating roof tanks+ ground fire	58, 67, 85			Gasoline		The three tanks were ignited by the ground fire. In one (or perhaps two) the roof had sunk. The 58 ft tank was extinguished by a combination of SSI and portable nozzles using FP foam. The 67 ft tank was controlled by SSI but due to lack of foam, it was all
1972-04-??	USA		4	Open top floating roof						The fire was extinguished with portable nozzles and FP foam
1972-04-07	Asia	Refinery	6	Cone roof tank	185			High flash	Hot work	Intentional burnout; burned out; extensive damage
1972-05-??			4	Floating roof	117					The tank had a seal fire of 80-120 ft which was extinguished with one foam nozzle and protein foam used from the stairway.
1972-05-15	USA	Bulk plant / terminal	4	External floating roof	120			Low flash	Lightning	Foam lines; extinguishment
1972-06-??	USA		4	Open top floating roof	95			Naphtha		The fire was extinguished with 1 1/2 inch portable nozzles and FP foam used from a fire department elevating platform
1972-07-17			6	External floating roof	210				Lightning	Fire extinguisher; extinguishment
1972-07-27	Europe	Refinery	4	314500 bbl; external floating roof	229,6			Crude oil	Lightning	Fixed foam and fixed water spray; extinguishment
1972-08-??	USA		4	External floating roof	120			Crude oil		The fire was extinguished with portable foam nozzles and FP foam used from the stairway
1972-08-04	Trieste, Italy	Refinery	5	Four 500 000 barrel, external floating tanks	250			Crude oil	Sabotage	Foam lines and over-the-top foam; burned out; extensive damage. Bomb attack destroyed 2 tanks. Fire damaged 6 more tanks. Pit fires spread to roof seals; roof sank and boilover occurred.
1972-08-08	Los Angeles, USA	San Pedro Chemical	5	Tank farm				chemicals		The tanks vary in diameter and range up to 45 feet in height. The average tank has a capacity of 180000 gallons.
1972-09-25	Collegedale (Chattanooga), Tenn. USA	Tank farm	2	2x Cone roof, 2 ext floating roof, 1x internal floating roof+ bund area	Cone 2x36, ext 48 + 55, int 70		14,6 m (48 + 55 ft tanks)	Kerosene, diesel, gasoline	Overfilling, unknown	Five tanks and part of bund area were involved. One 36 ft, the 48 ft and 55 ft tanks were extingushed using all together three 250 gpm foam nozzles. The 2:nd 36 ft tank was allowed to burn out. The 70 ft tank had it's external roof intact and extinguishin
1972-11-??	USA?		6	Three open top floating roof tanks+ ground fire	2x60, 1x78			Naphtha		Rim seal fires that had been burning for three days when extinguishment operations started. First tank was initially attacted with a SSI-system which reduced the intensity and final extinguishment was achieved from the stairway with a 250 gpm foam nozzle
1973-03-24	Ellesmere Port, UK		6	Tanks				Lubrication oil	Explosion	More than 100 firemen fought blaze at Shell refinery after explosion in a tank of lubrication oil. Fire controlled in 2,5 hours.
1973-05-23	Gamlakarleby stad, Finland	Outokompu Oy	5	15 tanks of varied sizes				Gasoline, Paraffin (kerosene), heating oil		
1973-07-27			4	External floating roof	140			Low flash	Lightning	Fire extinguisher, water lines and foam lines; extinguishment
1973-12-27	USA		6	Internal floating	120			Low flash	Ground fire	Fixed foam; extinguishment
1974-07-06			4	External floating roof	140			High flash	Lightning	Fire extinguisher and water lines; extinguishment
1974-07-26	USA		6	Cone roof tank	114			Crude oil		Over-the-top foam; extinguishment
1974-07-30			4	120 600 bbl floating roof				High flash	Lightning	Fire extinguisher, water lines and foam lines; extinguishment
1975-??-??	Thailand		4			98		Crude oil	Lightning	
1975-??-??	Big Springs, Texas, USA		6							Boilover
1975-04-08			4	External floating roof	140			Low flash	Lightning	Fire extinguisher; extingtuishment
1975-06-19	Findlay, Ohio, USA		6	30 000 barrel capacity	90			Crude oil	Lightning	Tank extingusihed after about 19 hours of preburn and two minor and one major boil over. Most fuel consumed by the fire.

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1975-06-26	Richmond, Virg.USA	Oil terminal	6	Two tanks	about 70			Gasoline	Lightning	Preburn about 17 hours. Foam application started at 4:20 pm and control was achieved at 5:30 pm and the fire was declared out at 7:11 pm. Problem with reignition during foam attack due to two open valves. Total foam consumption approx. What NFPA 11 would
1975-06-29			4	External floating roof	135			Low flash	Lightning	Water lines; extinguishment
1975-08-17	Philadelphia, PA, USA		6	Four tanks				Crude oil	Overfilling	Vapours from overfilled internal floating roof crude storage tank travelled to boiler stack where they were ignited. Flashback to the tank resulted in large fire involving 4 tanks and other facilities
1976-??-??	Cartagena, Spain	REPSOL refinery	4			92,9		Crude oil	Lightning	Fixed foam, plus dry chem hand extinguishers
1976-??-??	Carribean		5	Cone roof tank	150			Low flash	Hot work	Intentional burn out; burned out; extensive damage
1976-01-04	Brooklyn, New York, USA	Oil terminal	6	Three tanks					Explosion	Explosion started a fire in three tanks. Foam applied by foam nozzle from a tower ladder. First tank achieved knockdown in 15 min. Second tank, some hour because of problems to reach all parts of tank. Third tank-no information.
1976-08-01	Big Springs, Texas, USA		6	Product tank				Light product		Fire spread to alkylation unit resulting in catastrophic loss of containment in light product tank
1977-??-??	UK		4			44		Gasoline	Flare carry over of cinders	Dry chemical hand extinguishers
1977-??-??	USA		4	180000 bbl external floating roof					Lightning	Foam lines; extinguishment
1977-??-??	USA		4	180000 bbl external floating roof				Low flash	Lightning	Foam lines; extinguishment
1977-02-01	Philadelphia, PA, USA		6	Two 10000 barrel tanks				Oil		Two 10000 barrel capacity tanks were involved in a fire with the loss of 3000 barrels oil
1977-09-07	Nanaimo, British Columbia, Canada		6	One tank						Fire erupted in one of four tanks near waterfront. Nearby homes evacuated and some vessels in harbour may have been damaged.
1977-09-24	Romeoville, Illinois, USA	Refinery	1	Three tanks	190; 180 and 100				Lightning	Spread by simultaneous ignition; Foam lines, over-the-top foam and subsurface foam; burned out; extensive damage
1977?	Chicago area, USA	Refinery	3	Tank type unknown	190			#2 fuel oil	Unknown	After 27 hours preburn, the fire was controlled in about 15 minutes using SSI single-point application at 0,116 gpm/sft. About 1% of fire area could not be extinguished and the tank became fully involved again. 42 hours after ignition, a second attempt wa
1978-??-??	Findley, Ohio, USA		6							Boilover
1978-??-??	USA		6					Naphtha		
1978-??-??	USA	Refinery	6	180000 bbl external floating roof				Low flash	Lightning	Foam lines; extinguishment
1978-??-??	USA	Refinery	6	120000 bbl; internal floating				Low flash	Lightning	Foam lines; burned out; extensive damage
1978-??-??	USA	Pipeline area	4	Floating roof tank	140			Crude oil	Lightning	Extinguishment
1978-02-01	Sanata Maria, California, USA		6	Four tanks				Crude oil		Four crude tanks became involved in a fire. Tanks ruptured and approx. 100 000 gallons of burning oil were retained in bund area. The fire took about 6 hours to control. One tank collapsed.
1978-02-21	Rialto, CA, USA	Tank farm	2	Solid steel roof and floating inner lid			15,2	Gasoline	Overfill	Extinguished by sub-surface injection
1978-06-22	Norco. Louisiana, USA		6	Two tanks				Caustic soda		Explosion ripped two caustic soda tanks each 80000 gallons. The blast curtailed production of premium unleaded gasoline.
1978-07-25	USA	Refinery	5	107000 bbl internal floating roof	144			Low flash	Lightning	Over-the-top foam; intensional burn out; extensive damage
1978-10-02?	Mississauga, Ontario		6	Tanks						
1978-10-22	Stockton, California, USA		6	Several tanks involved						Fires out within 8 hours. Tank size range of 155 000 to 600 000 gallons.
1978-12-01	Salisbury (Harare), Africa	Oil depots	6	Tank farm					Military rocket	Ignition by a RPG 7 rocket making a 75 mm hole in a gasoline tank. The fire lasted for five days and covered an area of about 40000 m2.
1979-??-??	Beira, Africa	Oil depot	6	Five tanks and about 5000m2 ground fire					Military rocket	Ignition by a rocket making a 75 mm hole in a tank and some 7-9 mm bullet holes. The fire lasted for about 40 hours and was extinguished within 2,5 hours after arrival of extinguishing equipment, foam and specialists from Angus
1979-??-??	UK		4			71,3		Crude oil	Lightning	Dry chemical hand extinguishers
1979-??-??	Malaysia		4			43,9		Crude oil	Lightning	Semi-fixed foam systems, plus foam hand lines
1979-??-??	USA	Refinery	6	180000 bbl external floating roof				Low flash	Lightning	Seal to surface fire; foam lines; extinguishment
1979-??-??	USA	Refinery	5	80000 bbl? Cone roof tank				Low flash	Debris from nearby explosion	Foam lines; burned out; extensive damage
1979-06-29?	Gibbstown, N.J., USA		6	Tank				Naptha		
1979-07-??	North America	Refinery	6	70000 bbl external floating roof	117			Low flash	Sunken floating roof	Over-the-top foam; extinguishment
1979-08-22	Ras Tanura, Saudi Arabia	Aramco refinery	6	One tank						Aramco refinery storage tank exploded. Fire spread and burned for one day. One tank, product lines, pumping station involved. 2 killed, 6 injured
1979-09-??			6	Internal floating	160			Low flash	Debris from nearby explosion	
1979-09-20	Heide, Germany	Texaco refinery	6	One tank						Tank explosion at W Germany's largest Texaco refinery. 1 fatality, 1 injured
1979-09-29	Amsterdam, Netherlands		6	One tank						2k tonne storage tank blew up-about 1/2 full when explosion occured in W Amsterdam port area. 1 fatality, 2 injured

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1979-10-01	Duisburg, Germany		6	17 tanks				Oil/gasoline	Human installation	Explosion followed by fire released 5,3 m of heating oil and gasoline into harbour. First 2 tanks exploded 10:00 hours. 150 firemen fought fire. 17 tanks affected, 34k tonnes oil/gasoline lost. Several buildings destroyed.
1979-10-25	Paris, France		6	Five tanks				Gasoline	Sabotage	Corsican Liberation Front bombed army gasoline dump. 5 of 8 tanks involved.
1979-11-11	Joliet, USA	Refinery	6	Three domed roof slop tanks	50				Pyrophoric action	Pyrophoric action started fire in first tank, impinging flames and heat started the other two tanks. All three tanks were a total loss. The fire was extinguished in about 4 hours.
1979-12-03	Torrance, USA	Refinery	5	External floating roof; two tanks	120			Gasoline	High vapor pressure product	Seal to multiple tanks, spread by radient heat; over-the-top foam and foam lines; burned out; extensive damage
1979-12-16?	Michigan, USA		6	1,2 million gallon tank				Gasoline		
1980-??-??	Africa	Refinery	6	LPG spheres 2-14 m, 3x3000 m3 tanks, 1x15000 m3	115				Limpets	Ignition by limpets, the three tanks in a single bund and the large tank in a separate bund. The fire started about midnight and was extinguished within about 8 hours.
1980-??-??	UK		4			43,5		Naphtha	Lightning	Foam handline, plus dry chemical hand extinguishers
1980-??-??	Martinique		4			75,3		Crude oil	Hot work on empty tank	
1980-??-??	Canada		4			45,7		Crude oil	Lightning	
1980-??-??	Scottsdale, Louisiana, USA		6							Boilover
1980-??-??	USA	Bulk plant / terminal	6	80000 bbl internal floating				Low flash	Ground fire	Seal to surface; Foam lines; extinguishment
1980-??-??			6	Internal floating	200			High flash	Iron sulfide deposits	Full surface at start; intentional burn out; extensive damage
1980-??-??	Honolulu, Hawaii, USA	Chevron Tank Terminal	2	Open top floating roof				Gasoline		Fire caused by overfilling and ignition of vapours. Instructive video produced highlighting the lessons learned
1980-03-20	Joliet, USA	Refinery	4	Open top floater, single deck potoon	128			Naphtha	Welding	Fire caused by hot slag falling to seal area from welding. 2500 gpm water used for cooling exterior of tank shell.
1980-05-??	USA	Bulk plant / terminal	4	Internal floating	170			Low flash	Ground fire	Water lines; extinguishment
1980-08-??	Lousiana, USA	Oil terminal	6	Three storage tanks, buildings				Gasoline	Overflow, tank truck engine	A tank overflowed during a fuel transfer from a tank truck. The vapours were ignited by the diesel engine. The fire quickly spread to two other tanks, a gasoline delivery truck and an office building.
1980-08-05?	Sandwich, Mass., USA		6	Tank				Oil		
1980-08-27			4	External floating	196			Low flash	Lightning	Fire extinguisher; extinguishment
1980-09-07?	Albany, N.Y., USA		6	Two tanks						
1980-12-29?	El Dorado		6	Tanks						
1981-01-11	Montego Bay, Jamacia		6	Two tanks				Fuel	External fire	Valve on storage tank containing fuel was tampered with. Following explosions and fire attended by 150 firemen. Original tank and neigbour paraffin tank involved.
1981-03-01	Cork, Ireland		6						Operator sampling	Process upset allowed light-ends in tank. Operator sampling tank caused ignition. One fatality.
1981-02-??	California, USA	Bulk oil terminal	6	One tank and bund				Gasoline	Ground fire	18000 gal overflowed a tank and was ignited during a fuel transfer operation. Within 10 minutes after alarm a pump capacity of 13500 gpm and 80 men were on the scene. The fire was controlled but leaking valve flange gaskets made final extinguishment of di
1981-03-14	Chateauroux, France	Total Company	5	five tanks and most of the bund						6 gasoline storage tanks damaged. 20 hours to extinguish.
1981-04-18	Singapore		3			61		SR tops?	Lightning	Floating roof. Lightning ignited rim seal fire escalated to full surface fire and bund fire.
1981-07-23	Lousiana, USA		6	Tanks				Gasoline		Tank farm-gasoline tanks-details unknown.
1981-08-20	Shuaiba, Kuwait	Refinery	5	6 x 160000 bbl tanks; floating roof				Gasoline (low flash)	Ground fire	Floating roof. Leak from fractured meter. Wind driven flames caused collapse of unprotected pipe rack. Water curtain set up to protect process units nearby. Seven fatalities. Foam lines; extensive damage
1981-11-06?	Akron, N.Y., USA		6	Five tanks						
1981-11-??		Dome Petroleum	6	7 tanks				Crude oil		
1981-12-04			4	External floating	200			Crude oil		Foam lines; extinguishment
1982-??-??	USA	Bulk plant / terminal	6	120000 bbl external floating				Low flash		Foam lines; extinguishment
1982-??-??	USA	Pipeline area	6	120000 bbl external floating				Crude oil	Lightning	Foam lines; extinguishment
1982-04-21			6	118000 bbl external floating				Low flash	Lightning	Fire extinguisher; extinguishment
1982-05-28	Cotton Valley, Lousiana, USA		6	15 tanks involved						15 out of 40 product tanks destroyed. 5000 gallons of foam applied
1982-07-??	Hungary		3			72		Crude oil		Floating roof. Side-entry mixer fell off. Large bund fire escalated to rim seal fire.
1982-??-??	Lousiana, USA		5							Fire destruyed 15 tanks at refinery
1982-??-??	Beaumont, Texas, USA		5					Crude oil		Cone roof crude tank. 13 crude oil tanks and refinery affected by boilover.
1982-07-07	Panchevo, Yugoslavia		6							Vapour released from tank running too light material (high RVP) into tank. Process heater ignited release. Tank caught fire after explosion.
1982-09-??	Artesia, New Mexico, USA		3	Two tanks	80	24,384		Gasoline		
1982-09-06	Durban, South Africa		6	One tank					Lightning	Lightning hit a rv on storage tank. No other tanks involved.
1982-11-??		Navajo Refinery	2	Two tanks x 80 ft: Tank 1	80	24,384		Gasoline		
1982-11-??		Navajo Refinery	2	Tank 2	80	24,384		Gasoline		Hydro-Foam™ Technology with 3m ATC
1982-11-23	California, USA		6	One tank						The blaze took 7 hours to get under control with 115 firefighters at one stage. Only one tank was destroyed but many others were warped due to the intense heat. The quantity of water used to control the blaze resulted in the bund wall breaching and flushi

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1982-12-02	Nairobi, Kenya		6	Two tanks				Gasoline	Leakage	A small leak in a gasoline storage tank and a breakdown in a computer warning system, caused the fire. 1,5 million gallons of product lost. Fire spread to 2nd tank, lasted 54 hours.
1982-12-21	Bellville, Texas, USA	Oilfield	6	Three 16000 gallon? tanks					Welding	While preparing a 16000 gallon tank for use as temporary oilfield storage, a welding torch ignited vapours.
1982-12-08	Beira, Mozambique		6	30 tanks					Sabotage	30 tanks and feeder pipes to main Mozambique/Zimbabwe pipeline destroyed. RNM guerillas.
1982-12-19	Tacoa (near Caracas), Venezuela		3	Two tanks; cone roof		60	20	Heating oil (High flash)		Boil-over with a 450 m high fire ball. "Hot spots" or fire balls travelled 3000 m with the wind. Runninng fire.150 died (at least 30 fire men and 8 journalists). LASTFIRE: 2x55 m diameter heavy residual fuel oil fixed roof tank. Boilover killed more than
1982-12-23	Bogota, Columbia		6	Several tanks involved				gasoline/kerosene		Petrol tank containing 380k l caught fire. Firemen unable to prevent spread to gasoline and kerosene tanks. More than 3 tanks involved. 1 dead, 15 injured.
1983-07-30	Corinto, Nicaragua		6	Eight tanks					Maintenance	Oil tank explosion while repairing purification duct on top of tank. Explosive gas formed in duct igniting oil. 8 fuel tanks destroyed, 3 fatalities
1983-10-10	Corinto, Nicaragua		5	Eight tanks					Sabotage	Sandinista attack started blaze which engulfed oil depot.
1983-??-??	Massachussetts, USA		6					Fuel oil		1.6 million gal fuil oil lost.
1983-??-??	Philadelphia, USA		6					Naphtha		1.6 million gal tank.
1983-??-??	Texas, USA		5							Diesel engine ignited diesel vapours during cleaning. Fire spread to 6 tanks and 7 were severely damaged.
1983-??-??	Artesia, New Mexico, USA		6	2 tanks		24		Gasoline		Floating roof was blown off and ignited the fuel.
1983-??-??	USA		6	120000 bbl external floating				Low flash	Lightning	Foam lines; extinguishment
1983-01-06	Singapore	Pipeline area	5	187 ft, 120 ft and 80 ft fixed roof tanks with internal floating roofs					Overfill	Overfill leads to simultaneous ignition, tanks burned out; extensive damage
1983-01-07	Newark, New Jersey, USA		5	42000 barrel fixed roof gasoline tank with internal cover, plus 3 others	187			Gasoline	Overfill and external ignition	Overfilling led to about 1300 barrels of gasoline into the tank dike. The wind carried the developing vapor cloud about 1000 feet to a drum reconditioning plant, where an incinerator provided the ignition source. Although dikes contained the burning spill
1983-03-11	Ermelo, Johannesburg S. Africa	Mobil depot	6	Five tanks					Sabotage	Explosion at Mobil depot. Fire extinguished 8 hours after 1st blast. 5 storage tanks, 1 petrol tanker involved.
1983-04-25?	Cayuga, Texas, USA		6	Five tanks					Spark?	
1983-06-01	Havana, Cuba		6							Fire spread to adjacent tanks and no. 3 plant.
1983-08-30	Milford Heaven, UK	Amoco Refinery	1	600000 barrel external floating roof tank		78	20	Crude oil	Flare stack	Floating roof. Fire on roof from flare fall-out. Ignited by incandescent carbon particles discharged from the top of a 250-foot-high refinery flare stack situated 350 feet from the tank. The tank had a single mechanical seal and was equipped with a 12-inc
1983-08-31	Chalmette, Louisiana, USA	Tenneco Refinery; production	1	External floating	150	45,72	12	Gasoline	External ignition	At that time the largest fully involved tank fire extinguished in history. The floating roof sunk after the start of the fire. First use of Prototype 1000 GPM Hydro-Foam™ (Dual jets on 180 degree peripheral inside wall). Foam streams directed towards one
1983-10-03	Benjamin Zeladon, Nicaragua	Petroleum depot	6	Two tanks				Gasoline/diesel	Sabotage	Rebels sabotaged main Caribbean petroleum depot supplying Atlantic coast. One 308k gal petrol gasoline tank and one 62k gal diesel tank involved.
1983-10-05	Philadelpia, USA		6	45000 bbl tank				Naphtha	Explosion	Fire started by explosion in 45000 bbl naphta tank. Brought under control in 6 hrs.Four hours later an explosion followed at a reformer unit some 900 feet from the original tank fire. Fire out within 1 hour. Naphtha tank reignited burning 4 workers. Fire
1983-12-25?	Lima, Ohio, USA		6	Four tanks involved				Crude oil	Rupture in cold weather	200 000 bbl crude lost due to tank rupture in cold weather. Tidal Wave over bund. Four tanks involved.
1983-12-01		Mid-Valley Pipeline	6	1x120, 2x140				Crude oil		Hydro-Foam™ Technology with 3m ATC
1983-12-21	Naples, Italy		5						Overfilling	Twenty-four of the 32 storage tanks at a large government owned marine petroleum products terminal were destroyed by a fire began with a tank overfill. About 715000 barrels of gasoline and fuel oil were being off-loaded into tanks which were reportedly eq
1984-01-09	Banias, Syria		6	One tank				Oil	Lightning	Lightning strike damaged oil tank
1984-??-??	Milford Heaven, UK	Amoco Refinery	4	Open top floating roof						Tank fitted with fixed foam pourers
1984-03-08	Cochin, India		6	Several tanks involved				Naphtha	Explosion	4+ tanks damaged, 3 naphtha tanks destroyed, 4 fatalities. 100 tn tank exploded and fire spread to 4000 tn naphtha tank about 100 yds away. Several other tanks (6500 tns) engulfed. Cooling tower destroyed and major damage to turbo generating building. Gla
1984	Herne, Germany	Chemical factory	2	Fixed roof tank, 10000 m3				IPA	Lightning	Chemische Werke Huls AG, Herne. Tank ignited during heavy thunderstorm
maj-85	Cologne, Germany		6	Several tanks involved						28 truckloads of firefighters fought for several hours to control blaze sparked by the explosion of several oil tanks at 3am. 2nd explosion at 6am, area evacuated.
1985-??-??	Naples, Italy		5						Overfilling	Tank overfilling resulted in vapour ignition from unknown source. 24 of 31 tanks destroyed. Fire covered 3.7 acres. Severe damage to nearby industrial and residential areas. Extinction after 3.5 days. 5 deaths and 170 injuries. Estimated loss $50.9M.
aug-85	Philadelphia, Pennsylvania USA		6					Crude oil	Overfilling	Tank overfilling, overpressure, flashback and piping failures caused explosion in crude oil tank.
okt-85	Honolulu, Hawaii, USA	Pearl City Peninsula Naval fuel depot	1	Floating roof		36		Aviation gasoline	Static charge	Floating roof sank due to rain. Roof foamed while emptying tank. 3 days later foam blanket was almost dissipated when fuel ignited. Extinction in 2.5 hours.
jun-85	San Juan, Havana, Cuba	Refinery	6							Involved at least three tanks
1985-??-??	Jacksonville, Florida, USA		5				18,3	Gasoline	Lightning	Internal floating roof. Lightning ignited tank and triggered an explosion. Tank puncured and fuel spilt out. Eventually it collapsed.

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1985-??-??	Italy		6			30,5		Leaded gasoline	Lightning	
1985-??-??	USA		4			36,6		Recovered rerun from brine deoiler	High v. P. Material put in tank. Ignition of vapour from furnace 76 m away.	C3 and C4 was allowed to burn off. The extinguished from 4 foam towers
1985-04-19	Norco, Louisiana, USA		6					Crude oil	Explosion	Tank containing 2 000 000 bbl crude oil exploded. Fire lasted 2 hours.
1985-05-21	Pretoria, South Africa	Sasol plant	6					Petrol		3 hrs after fire broke out, tank exploded (02:00 hrs). Fire under control at 07:00 hrs. 3 firemen killed and 7 injured.
1985-08-24			4	External floating	144			Low flash	Lightning	Foam lines; extinguishment
1985-09-04	USA	Refinery	6		120				Lightning	Extinguishment
1985-09-07			6	External floating	196			Crude oil	Lightning	Over-the-top foam; extinguishment
1985-10-24	Lousiana, USA		6	Four tanks				Crude oil	Lightning	Lightning ignited vapours. 3 other tanks burned.
1985-12-21	Neapel, Italy	AGIP Tankfarm	5	24 tanks				Various petroleum-products	Explosion	Tank farm with several tanks containing various qualities of petrol, fueloil, diesel, kerosine. About 20 tanks ignited shortly after intitial explosion. Fire area about 15000 m2. The fire was extinguished at 17:00 on Dec 24. 24 of 31 tanks destroyed by fi
1986-??-??	Pembroke, UK	Texaco	4	Open top floating roof tank				Crude oil	Lightning	About two thirds of the circumfence had been involved in the fire. About 7000 l of foam used for extinguishment, the rest for "top-up" operations
1986-02-24	Thessaloniki, Greece		5	Multiple tank types, including 40 m and 80 m diameter.				Crude oil		Floating roof tanks. Fires in 10 out of 12 tanks. Boilover in 40 m diameter floating roof crude tank.
1986-04-08?	Chicago area?, USA		6	Three 20 000 gallon tanks						
1986-06-13			6	Internal floating	120					
1986-08-09	Bayonne, New Jersey, USA		5	Four tanks involved				Gasoline		Gasoline tank explosion. 4 tanks destroyed, 8 others damaged. Fire spread to nearby canal.
1986-08-12	Tampico, Mexico	Pemex Cuidad Madero refinery	6	One tank				Oil		Oil storage tank exploded and burned. No other damage.
1986-10-01	Newport, Ohio, USA	Ohio Pil Gathering Corporation	1		95	28,956	8,5	Crude oil	Lightning	Wooden roof
1986-12-23?	Chicago area?, USA	Refinery	6	Tank				Gasoline	Explosion	One fatality
1987-??-??	South Carolina, USA		5	Floating roof tank			12	Gasoline	Lightning	Tank destroyed.
1987-??-??	Pennsylvania, USA		6					Gasoline		1.1 million gal gasoline lost.
1987-??-??	Lyon, France		5	Multiple tank types				Diesel		14 tanks destroyed. Diesel tank boiled over. 2 fatalities.
1987-??-??	Castellon, Spain	BP Oil refinery	4	Geodesic		23		Naphtha	Lightning	6 fixed foam chambers
1987-??-??	USA	Pipeline area	4	Floating roof	115			Crude oil	Lightning	Foam lines; extinguishment
1987-04-01	Cleveland, Ohio, USA		6	100 000 gallon tank					Explosion	Explosion followed by fire. Explosion ripped bottom seal of 100 000 gallon tank spilling contents over surrounding area.
1987-05-01	Madero, Mexico		6	Tank				Gasoil	Lightning	Gasoil tank exploded following a lightning strike.
1987-06-02	Edouard Herriot Port, near Lyons, France	Shell Oil	5	Several storage tanks						
1987-06-20	USA	Bulk plant / terminal	5	External floating	150			Low flash	Lightning	Over-the-top foam; burned out; extensive damage
1987-07-26	Newport, Ohio, USA	Ohio Pil Gathering Corporation	1		95	28,956	8,5	Crude oil	Lightning	
1987-08-10	Philadelphia, Pennsylvania USA		5	100000 bbl cone roof tank with internal floating cover				Gasoline	Lightning	2 other tanks in same bund kept cool by water. Floating deck jammed under roof and hindered foam application. Disconnection of inlet lines allowed foam injection direct to tank. 2 days duration.
1987-08-26			4	External floating	210			Crude oil	Lightning	Fire extinguisher; water lines; extinguishment
1987-09-14	Chicago area?		6	900 000 gallon tank				Fuel	Explosion	Two fatalities, three injured
1987-09-24	Romeoville, Illinois, USA		5	Cone roof tank	190	57,912		Diesel	Lightning	Lightning struck tank. Debris struck three nearby gasoline tanks. 2 tanks destroyed, 2 others involved.
1988-??-??	Minneapolis, USA	Ashland oil	1			36,6			Explosion	"Cracking tower" containing 8000 m^3.
1988-??-??	Borger, USA		3	Floating roof tank				Gasoline	Foam application	Heavy rains tilted roof. As foam was applied, the gasoline ignited.
1988-03-01	Puerto Rosales, Argentina		6						Lightning	Lightning strike. Fire brought under control by 300 firemen.
1988	Port Arthur, Texas, USA		5	4x18000 bbl fixed roof tanks with internal floating roofs				Gasoline		1 tank ruptured sending flames 200 ft high. 8 deaths and 8 injuries.
1988-??-??	Massa, Italy		6					Cyclohexane		

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1988-??-??	USA		4	External floating				Low flash	Overfill	Over-the-top foam; extinguishment
1988-03-13	Pueblo Rosales, South America	Bulk plant / terminal	5	188.7 mbbl				Crude oil	Lightning	Burned out; extensive damage. Crude oil tank exploded during storm. 2 vessels shifted to safe distance. 300 fire men controlled fire next day.
1988-04-06?	Los Angeles area?, USA	Oil field	6	Tank				Crude oil	Welding?	
1988-04-11	USA	Refinery	3		120					Over-the-top foam; extinguishment
1988-05-24	Chihuahua City, Mexico	Pemex	6	Floating roof tank				Gasoline	Lightning	Lightning struck tank, which exploded. Blaze raged nearly 7 hours and was controlled by firefighters
1988-06-17	Memphis, USA	MAPCO	1		112	34,1376	12	Heating oil	Explosion (reparations)	
1988-06-23	Guadalupe, Mexico	Pemex Guadalope plant	6	Three tanks				Gasoline	Maintenance	Gasoline spilled during filling and vapours ignited by sparks from maintenance work. 1,3 mill gallon gasoline tank exploded. Fire spread to two smaller tanks-all three exploded in quick succession. Blaze lated 3,5 hours and was controlled by 200 firefight
1988-06-27	Sines, Portugal		6	One tank					Maintenance	1 of 3 fuel tanks completely destroyed. Firefighting control unit struck by tank roof. When explosion occured in fuel/slop tank 2 men were killed outright. 3 others hospitalised.
1988-06-??	Port Arthur, Texas, USA	Chevron	5	3 tanks + major piping manifolds						Presurised fires; Hired Gun™ , Hydro-Foam
1988-07-08?	Houston, Texas, USA	Phillips refinery	6	80 000 gallon tank				Gasoline	Lightning	
1988-10-25	Palau Merlimau, Singapore	Singapore Refining Company (SRC)	5	Three 160000 bbl external floating roof tanks		41		Naphtha	Electrostatic discharge? Sunken floating roof	Ignition of partially sunk roof of one tank. Escalation by radiant heating to two identical tanks.
1988-11-09	Mahul, Bombay, India		6	Six tanks and bund area				Naphtha	Pipeline burst	A pipeline burst with the result that spilled naphtha burst into flames all over the tank farm.Six tanks had their roofs blown off. The fire took more than 12 hours to control.
1988-11-19?	Suffolk	Oil tank farm	6							
1988-12-14	Bogota, Columbia		6	Three tanks				Gasoline		A gasoline tank containing 380 000 litres of gasoline caught fire and spread to two adjacent tanks.
1989-08-12	Qingdao, China	Oil depot	5	Six tanks				Crude oil	Lightning	Lightning ignited 40000 tonne crude oli tank. Fire spread to 5 more similar tanks. 16 deaths and 70 injuries.
1989-??-??	Batum, Georgia		5					Oil		The fire spread to another tank. A boilover occurred.
1989-??-??	Sanwich, Mass?		5	Two tanks				Fuel oil	Maintenance	Explosion occurred during maintanence. Possible spillage into bund.
1989-??-??	Mumbai, India	BPCL	6	Three tanks						Three tanks burned out
1989-03-22	Sullom Voe, Shetland, UK		4	Open top floating roof				Crude oil	Lightning	Severe electrical storm resulted in lightning strike causing rim fire on Ninian crude tank. Alarm at 9:56 hours and the fire extinguished by terminal's fire brigade at 10:17 hours.
1989-03-23	Porvoo, Finland	Neste OY	1	Floating roof tank		52	14	Iso-hexane		Ignition whilst pumping product off roof. Fire on roof rapidly extinguished. Then foam layer decayed. During reapplication of foam second ignition occurred. Fire escilated to full surface and destroyed tank.
1989-06-??	El Dorado, Arkansas, USA	Lion Oil	7							Sunken roof on floating roof tank; tank safed with stabilized foam: 3M ATC and FS 7000.
1989-06-??	Port Arthur, Texas, USA	Texaco Chemical	7							Sunken roof on floating roof tank; tank safed with stabilized foam: 3M ATC and FS 7000.
1989-08-05	Sandwich, Mass, USA		6	Two tanks				Fuel oil	Maintenance	Explosion/fire occured as workmen installed insulation on 7,7 m gal fuel oil tank. 1 feeder tank blew up, another deteriorated due to heat. Possible oil spillage. 2 injured.
1989-08-12	Huang Dao, China		6	Concrete tank 72 x 48 m, 23000 m3				Crude oil	Lightning	Half sub-floor rectangilar reinforced concrete tank, 72m x 48 m, 23000 m3. The tank was filled to 70%. Boilover occured?. Fire fighting using fixed foam extinguishment with water sprinkler system, 3000 l/s.The fire extinguished at 17:00 on aug 16. 2204 fi
1989-08-26	Bahrain		6							Maintenace work at the storage tank caused leaks from a pipeline leading to the tank.
1989-12-24	Baton Rouge, Louisiana, USA	Exxon Refinery	1	15 storage tanks (16 enligt LASTFIRE & Devonshire); cone roof	Two 134			Diesel and lubrication oil	Debris from nearby explosion	15 storage tanks (Two tanks were 134 ft in diameter with manifold fires and the dikes completely involved in fire), 4 API separators, and 2 pipebands involving approximately a quarter of a million sq. Ft. Of fire area. All fire extinguished in 14 hours an
1989-12-31	Dar Es Salaam	Tanzanian/ Zambian Pipeline Company	4	Floating roof tank	180	54,864		Crude oil	Lightning	Tank struck by lightning on New Year's Eve. 360 degree rim seal fire burnt for five days. Extinguished by experts on the 7th Jan. 1200 tonnes of crude oil consumed, 12000 saved.
1990-??-??	Holland	Afvalstoffen Terminal Moerdijk (ATM)	5					Waste chemicals (toluene, paraffin, furnace oil and acetic acid)		Toluene, acetic acid, paraffin, and furnace oil. May have been caused by sudden mixture of chemical vapours in a valve connected to an exhaust and filtration unit near the tank. Tank exploded and was totally destroyed.
1990-??-??	Oklahoma, USA	Storage	5	3 tanks					Worker using a lighter ignited	3 tanks severely damaged, 3 deaths.
1990-??-??	Western Siberia		5					Oil	Lightning	Lightning struck a storage tank containing 5000 T oil. The fire spread, 3 other tanks destroyed.
1990-??-??	Africa	Bulk plant / terminal	4	External floating	180			Crude oil	Lightning	Foam lines; extinguishment
1990-01-19	Cadereyta, Mexico		6	200 000 bbls tank				Oil	Spark from welding	Fire probably caused by spark from welding torch. About 8000 bbls of oil burnt. Storage tank capacity 200 000 bbls.

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1990-02-??	El Tablazo, Venezuela	Petro-chemical complex	6	Tank				Tetramer of propylene		A fire in a tank containing a tetramer of propylene. 2:30 hours after the fire started, 5500 gallons of AFFF were brought to the scene and the fire was controlled and extinguished.
1990-02-09?	Arkansas?, USA	Fuel storage	6	Tanks				Fuel		
1990-03-17	Lemont, Illinois, USA		6	60 000 bbls tank				Gas oil	Heater malfunction	Fire burned for 12 hours destroying a 60 000 bbls gas oil tank. Cause possibly a heater mal function. About 30 000 bbls of oil in the dike was burning which resulted in failure of the roof and the wall. Fire fighting was initially hampered by lack of wate
1990-04-??	Port of Tampa. Florida, USA	Citgo gasoline	6	Tank				Gasoline	Explosion	An employee of Port of Tampa was killed when a Citgo gasoline tank exploded.
1990 04 27	Houston, Texas, USA	Petro-chemical company	4	Open top floating roof	200			Gasoline	Lightning	The fire was contained in the tank's seal area and was extinguished by a semi-fixed system using CNF Universal 3x6. The tank had 9 months before been equipped with 8 MCS-55 CNF Foam Chambers sized for full-involvement
1990-06-21?	Siberia, Russia	Oil field	6	Four tanks				Fuel	Lightning	
1990-07-06?	Houston area?, Texas, USA		6	Two tanks				Waste water and tank run off?	Explosion	17 fatalities, 5 injured
1990-07-11	USA	Refinery	6	80000 bbl tank				LowFlash	Static electricity	Extinguishment
1990-08-25		Refinery	4	External floating roof	150			LowFlash	Lightning	Foam lines; extinguishment
1990-09-24	Tampa, Florida, USA	Port of Tampa	6	114 000 gallon tank	30		12,2 (40 ft)	Isopropyl alcohol	Explosion	A 114000 gallons tank containing 35000 gallons of IPA exploded at about 16:00 when a construction worker was sandblasting its roof. The 30 foot lid was blown away and the worker killed and the subsequent fire crushed the 40 foot high tank. Two crash truck
1990-09-30	USA	Bulk plant / terminal	4	Floating roof; 80000 bbl	117			Crude oil	Lightning	Water lines; extinguishment
1990-11-25	Denver, Colorado, USA	Stapleton Internationa l Airport	5	Two tanks (LASTFIRE: multiple tank types)				Jet fuel	Leak from damaged pump ignited by the electric motor for the pump	Manifold fires presented biggest problems during this fire. 7 of the farm's twelve tanks destroyed. More than 1.6 million gallons of jet fuel was consumed. As the fire contimued to grow, coupling gaskets in the piping deteriorated and more fuel flowed out
1990-12-07	USA	Refinery	4	714000 bbl external floating roof	345			Crude oil	Lightning	Fixed foam; extinguishment
1991-??-??	Kuwait		5	Multiple tank types				Crude oil	War actions	Fires during Iraqi occupation of Kuwait. Several tank farm facilities were set on fire. Due to the war situation only some fires were fought while others were allowed to burn out. Although the unusual circumstances, a lot of important information has been
1991-??-??			5	Several fixed roof tanks				Gasoline		Large gasoline depot fire
1991-??-??	USA		4			35,8		Crude oil	Lightning	Foam hand lines from wind girder, plus water cooling outside shell
1991-??-??		United Kingdom oil refinery	8	Floating roof tank		15				
1991-??-??	Middle East		5	Cone roof	100				Sabotage	Intentional burn out; extensive damage
1991-??-??	Middle East		5	235.9 mbbl; 3 tanks, external floating	258			Crude oil	Sabotage	Spread by boil over; intentional burn out; fixed foam; extensive damage
1991-??-??	Middle East		5	220.1 mbbl; cone roof	196			High flash	Sabotage	Fixed water spray; intentional burn out; extensive damage
1991-??-??	Middle East		6	100.6 mbbl;				Low flash	Sabotage	
1991-??-??	USA	Pipeline area	4	Floating	120			Low flash	Lightning	Fixed foam; Extinguishment
1991-??-??	USA	Pipeline area	4	Floating	144			Crude oil	Lightning	Foam lines; extinguishment
1991-??-??	Middle East	Refinery	5	350 000 bbl; cone roof;	200					Fixed water spray; intentional burn out; extensive damage
1991-??-??	Middle East	Refinery	6	Cone roof	120			High flash		Over-the-top foam; extinguishment
1991-02-26	Coryton, Essex		3	Floating roof tank		31,5		Naphtha		Roof had sunk on its legs. During vapour suppression the tank was being emptied. After 17 days fire broke out through the foam blanket, crippling the tank.
1991-04-04	Pasadena, Texas, USA		4	100 000 barrel tank					Lightning	100 000 barrel tank caught fire from lightning strike. Fire broke out at rime seal area and extinguished in 1 hr. Minimal damage.
1991-05-29	HPCL, Visakh, India	Refinery	4	Floating roof tank				Naptha	Lightning	Due to a lightning strike at a naptha tank, vapour at rim seal area ignited. A fixed halon 1211-system was released and extinguished part of the fire but two third of peripherical sections remained burning. Foam through fixed foam pourers extinguished mos
1991-06-25	Tampa, Florida, USA		4	4 million gallon tank					Lightning	Lightning struck 4m-gallon tank in port Tampa. Seal fire extinguished in just over an hour. Neoprene seal damage only.
1991-07-11	CTF of Mehsana (Gujarat) India		6	10 000 m3 fixed roof tank				Crude oil	Lightning	A 10000 m3 fixed roof tank was hit by lightning and the roof blew off and the shell of the tank was badly damaged. The tank contained 500m3 and was extinguished in 2,5 hours. No damage to humans or adjoining tanks.
1991-07-24	USA	Bulk plant / terminal	4	Floating	265				Lightning	Extinguishment

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1991-08-20	Melbourne, Australia	Coode Island petrochemical bulk storage facility	5	200 tanks				chemicals	Arson	A 400 m3 cone roof tank rocketed. Fire spread to bund. 21 tanks destroyed, 35 damaged. Tanks contained acylonitrile, benzene, methyl isobutyl/ethyl ketone, phenol and butanol. $24 million property damage
1992-??-??	New Orleans, Louisiana, USA		5					Crude oil		Debris from oil treatment explosion ignited crude oil storage tank. 200 T oil spilt, 2 deaths.
1992-??-??	Texas, USA		6							Partying people ignited vapours on a storage tank. Explosion and fire severely damage tank. 1 death and 4 injures. Fire controlled in one hour.
1992-??-??	Santos, Brazil		5	2 tanks				Acrylonitrile	Lightning	2 tanks struck by lightning. 1 destroyed.
1992-06-08	Wyoming, USA	Frontier Refining	5	More than 100 tanks						A fire in a tank containing 20000 gallons of naphta was extinguished early in the afternoon. A 250000 gallons tank of raw, unleaded gasoline was left to burn out. Firefighters hosed down oil tanks as a precaution. Four workers were taken to the hospital w
1992-06-23?	Easr Bay Plant, San Francisco?		6	Tanks						
1992-07-17			4	External floating roof	196				Lightning	Over-the-top foam; extinguishment
1992-08-07	Hereford, UK	Bulmers Cider	5	900 tonne tank				Diesel		The tank exploded in a vast fireball of burning fuel. The tank was propelled 70 metres into the air.
1992-12-25	Castellon, Spain	Refinery	4	Floating roof tank		92,2	21,8	Crude	Lightning	Fixed foam system used but some foam chambers blocked and final extinguishment achieved with protable extinguishers
1993-??-??	USA		4	260000 bbl; external floating					Lightning	Fixed foam; Extinguishment
1993-01-02	Jacksonville, Florida, USA	Steuart Petroleum	2	50000 gallons fixed roof tank with internal floating roof	100	30,48		Gasoline	Explosion (overfilling)	Extinguishment of the largest internal floating roof tank in history. Overfilling ignited by worker driving car into bund. The potential ignition sources included the operator's vehicle, the mechanical action of the internal floating pan being forced by t
1993-01-28?	Houston, Texas, USA		6	Tank				Sodium sulfide	Explosion	
1993-06-14	Buras, Lousiana, USA		6						Lightning	Fire extinguished with foam in 3 hours
1993-01-28	outside Houston, USA	Khempak Industries at Collingsworth and Cherry	6						Explosion (welding)	Two men welding on a storage tank apparently touched off an explosion that resulted in the death of one worker at the scene. The explosion blew the cone-shaped roof off the tank and stated a fire that threatened other tanks in the diked storage yard. Most
1993-06-16?	Chevron?		6	280000 barrel tank				Crude oil	Lightning	
1993-08-14	Kanash, Chuvash rep, Russia		6	Three 1000 tonnes tanks						At least 3 tanks destroyed each containing 1000 tonnes
1993-09-??	USA	Bulk plant / terminal	4	External floating roof	120			Crude oil	Hot work	Foam lines; over-the-top foam; extinguishment
1993-09-16?	Florida distilleries, Lake Alfred		6	At least a dozen tanks						
1993-10-??	South America	Refinery	4	External floating roof	220			Crude oil	Lightning	Fire extinguisher; extinguishment
1993-10-09?	Shell plant, Martinez		6	Tank						
1993-10-14	Kurnell Austr.	Refinery	6	Fixed roof tank				Caustic soda and diesel "sponge" on top	Pyrolytic action	The caustic was used for cleaning of pipelines andother systems. An explosion blow off the lid into the bund area. 3 ground monitors used for cooling and 4 for foam application using FP-foam. The fire was controlled but not extinguished. A "Skyjet" telesc
1993-10-21	Nanjing, China		6	10 000 m3 tank				Gasoline	Overfill	Overfilling of a 10 000 m3 tank, resulting in spill into an adjacent drain channel. Vapours ignited by passing tractor, 2 workers killed. Fire involved at least 100 tons of gasoline. Fire took 17 hours to control.
1994-??-??	Canada		6			36,6		Gasoline	Lightning	
1994-??-??	Phillipines	Refinery	4	External floating roof	300			Crude oil	Overfill	Fixed foam; extinguishment
1994-01-02	USA	Bulk plant / terminal	3	Internal floating	100			Low flash	Overfill	Over-the-top foam; subsurface foam; extinguishment
1994-01-08	South America	Refinery	6	94000 bbl				High flash	Lightning	Water lines; foam lines; extinguishment
1994-02-03	Fredericia, Denmark	Refinery	4	External floating roof, 33100 m3				Crude oil	Welding	Fire started during welding operation and caused a rim seal fire of about 250 degrees. Ground monitors used for cooling of tank. Foam attack by handlines from the stairway.
1994-02-14	Ndola, Zambia	Indeni Petroleum Refinery	4	External floating roof	138	42		Crude oil		Floating roof; rimseal foam pourers fixed to the tank; extinguishment
1994-03-22	Rio de Janerio, Brazil		6	14 000 m3 alcohol tank				Sugarcane alcohol	Lightning	Lightning ignited alcohol in a 14 000 m3 storage tank for sugarcane alcohol used as motor fuel. Cooling prevented spread to 8 other tanks.
1994-04-03	Mina Al, Ahmadi, Kuwait		6	Tank						Fire in tank 836 contained after 15 minutes
1994-05-27	Belpre, Ohio, USA	Shell Chemical Co	6	Tank				Hydrocarbons	Explosion in process unit	An explosion occured in the K-1 unit at about 6:30 on Friday where a thermoplastic rubber was manufactured. The fire spread to a nearby tank which ruptured and collapsed. Foam was used to fight the fire and it was put out sometime between 15:00 and 16:00
1994-06-04	Yemen	Aden Refinery	5	4 fixed roof tanks		20 35		Crude oil, Naphtha, Kerosene	Missile attack	
1994-07-03	USA	Refinery	3	153000 bbl and 122000 bbl external floating	140 and 120			Different	Lightning	Spread by simultaneous ignition; foam lines; extinguishment

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1994-07-13	Midland, Texas, USA	Chevron	4	80000 bbl capacity floating roof tank				Crude oil	Lightning	At 2340 lightning strike lead to 360 degree rim seal fire. No wind girder so not possible to extinguish fire from tank top. No fire equipment was available until 0030 hours the following day , the fire department were busy responding to a fire at a compet
1994-07-13	USA		3	Fixed roof tank with internal floating roof		34,9		Naphtha	Lightning	1 ft vapour space under roof. Full surface fire for 3.5 hours. Extinguished by mobile attack from ground.
1994-07-24	UK	Refinery	4	External floating	240			Crude oil	Lightning	Fixed foam; extinguishment
1994-07-17	Kaucuk, Czech Rep		6	30 000 t tank					Lightning	An oil fire in a 30 000 te holing tank was extinguished in less than 2 hours. The tank was 90% full. The fire was caused by a lightning strike. Only minor damage.
1994-07-22	Delaware, City, USA		6	Two tanks				oil/watermix	Lightning	Lightning struck a fuel tank and the subsequent fire destroyed both the first tank and a second tank that caught fire quickly. The tanks contained a total of 4500 bbl of an oil/watermix. Six firefighters injured.
1994-09-??	South America	Refinery	4	External floating	220			Crude oil	Lightning	Fire extinguisher; extinguishment
1994-10-??	Baytown, Texas, USA	GATX	7	3 tanks				Gasoline		Protect and safe area with three sunken roofs on gasoline storage tanks
1994-10-??	South America	Refinery	4	External floating	220			Crude oil	Lightning	Fire extinguisher; extinguishment
1994-10-11	Ueda, Nagano, Japan		5	4 floating roof tanks				Gasoline		A petrol tank exploded and ignited three other storage tanks. One fatality.
1994-11-07	France		2	Floating roof tank		36		Platformate		Roof sunk during rainstorm. Ignition nest day during another thunderstorm. Extinguished within an hour.
1994-11-14	Groznyy, Russia		6	2000 m3 oil tank					Terror attack	A 2000 m3 tank destroyed by plastic explosives. No injuries.
1995-02-09	Puente Hierro, Sucre, Venezuela		6	700 m3 tank				Oil		Fire at a 700 m3 oil tank within a naval port area
1995-03-??	USA	Refinery	3	Cone roof	150			High flash		Full surface at start; frothed over with water; extinguishment
1995-03-08	Freeport, Grand Bahama Island		5	500 000 bbl floating roof tank				Diesel	Lightning	Lightning ignited a rim seal fire, lasted 56 hours. Tank allowed to burn down. See also Lloyds List 15/3/95 p15.
1995-03-17?	New Jersey?	Gasoline terminal	6	Tank						
1995-03-30	Wilmington, California, USA	Ultramar Refinery	2	Cone roof insulated vacuum residue tank	156	47,5488		Residue fuel		Fuel was heated to 149-204˚C. Process upset caused overpressurisation of tank, which split, throwing out a cloud of vapour and a flood of oil. The ensuing fire took two days to cool the product and extinguish the fire. A loud rumble was followed by a clo
1995-04-04	Novorossisk, Black Sea, Russia	Oil terminal	6	Tank						A tank caught fire in one of the oil storage areas. The fire was extinguished by port workers within 15 minutes and caused only slight damage.
1995-04-10	Savannah, Georgia, USA	Powell Duffryn storage terminal	6	400 000 gallon tank				Crude sulfate terpentine	Explosion	The blaze began on Monday when a storage tank containing 400000 gallons of crude sulfate turpentine exploded. The fire then spread to other tanks. Fire fighters planned to let the fire burn but due to a windshift on Wednesday, they decided to use foam to
1995-04-??	Toronto, Canada	Shell Oil	7		160	48,768		Gasoline		Sunken roof
1995-04-26	Sri Racha, Thailand	Refinery	4	600000 bbl external floating				Crude oil	Lightning	Foam lines; extinguishment
1995-04-??	Toronto, Canada	Shell Oil	7		160			Gasoline		Sunken roof
1995-05-??	Norco, Louisiana, USA	Shell Oil	7		234	71,3232		Naphtha		Sunken roof
1995-05-15	Groznyy, Russia		6	Five tanks				Oil	Terror attack	Oil terminal attacked with grenade launchers. Five tanks were damaged and fire destroyed 15 000 tonnes of oil.
1995-05-16?	Kansas City, USA		6	Tank				Oil	Lightning	
1995-06-11	Addington, Oklahoma, USA		5	55 000 bbl cone roof crude tank				Crude oil	Lightning	Lightning struck tank and blew off roof during the afternoon. No attempts to fight fire. Oil slopped over between 10 and 11 pm. At 1 am a large eruption of oil out of the tank ran down hill and engulfed a P19 crash apparatus, killing two. Two fire-fighter
1995-06-26	USA	Refinery	3	80000 bbl	110			High flash	Lightning	Full surface at start; over-the-top foam; extinguishment
1995-07-01	Russia	Yaroslavl oil refinery	6	Four tanks					Spark, maintenance work	The fire probably occured because of a spark during maintenance work. Three out of four tanks were destroyed and the fourth was expected to burn out shortly afterwards. Firefighters were unable to extinguish the fire for safety reasons.
1995-07-12	Tampa, Florida, USA		6	250 000 gallon tank				Methanol	Lightning	Lightning struck a tank 250 000 metanol tank holding about 40 000 gallons. About 25 000 gallons left after fire. One nearby tank filled with solvent blew its lid but the blaze was contained.
1995-08-04	IOCL, Baroda, Gujarat, India		6	Two 5000 m3 floating roof tanks		24	12	Motor spirit	Overfilling, vapour ignition by car	Overfilling of one tank in common bund. Vapours ignited by a car resulting in a fire in both tanks. Nearby tanks cooled by water curtains. The burning tanks were cooled by handlines and monitors.Foam applied through fixed foam makers but this was not effe
1995-08-17	Perm refinery, Russia?		6	Tank				Residue oil		
1995-08-22	Kucove, Albania		5	A 400 tonne tank				Crude oil	Lightning	When the fire seemed to be under control a second 1000 tonne crude oil tank exploded, killing one fireman. The fire was extinguished after 33 hours and three tanks with 1600 tonnes of crude destroyed.
1995-10-??	Baytown, Texas, USA	TEPPCO	3		110	33,528		Gasoline		Internal floater (not completely sunk), vents
1995-08-22	Cilacap, Indonesia		5	Multiple tank types				Kerosene, avtur, naphtha	Lightning	Total capacity 169 380 m3. Stock before incident was 33 778 m3. Lightning struck kerosene tank and lead to fire on seven tanks at refinery, including avtur and naphtha floating roof tank(s). Fire burnt for more than 19 hours. At least three tanks destroye
1995-08-20	Port Arthur, Texas, USA		6	Tank vent				Hot coker		The fire was confined to a vent on a tank filled with hot coker feed in the refinery's farm. The fire which lasted for about 1 hour had no impact on refinery operations.
1995-08-25	Fort Lauderdale, USA		6	35 ft high tank						
1995-09-20	Houston, Texas, USA	Refinery	6	168 000 bbl tank				Crude oil	Lightning	The fire started when lightning struck a 168 000 bbl crude oil tank. There were no interruption to refinery operation.
1995-10-20	Kolonnawa, Sri Lanka	Oil terminal	5	Six tanks and bund area					Terror attack	Tanks were attacked using penetrating weaponary and explosives to open up the top of the tanks. Six tanks and bund area involved in fire, several tanks severly exposed. Due to the extreme situation, the bund fire was controlled/extinguished while the tank

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
1995-11-30	Woods Cross, Salt Lake City, USA		6	Tank						Firefighters pumped foam into 20% full tank to douse blaze. Fire contained within the tank.
1995-12-??	Tacoma, Washington, USA	U.S. Oil	7		120	36,576		Gasoline		Sunken roof
1996-01-02	Alberta, Canada		6	Tank						
1996-??-??	Mexico, Mexico City		3	Floating roof tank with geodesic dome		40			Lightning	Lightning struck geodesic dome. Dome collapsed and sank roof. Full surface fire ensued.
1996-??-??	UK		4			44		Spirit	Hot work on empty tank	Dry chemical hand extinuishers
1996-??-??	Saudi Arabia		4			80		Naphtha	Lightning	Fixed foam system failed. Dry chemical used instead
1996-??-??	Italy		4			97		Crude oil	Lightning	
1996-??-??	USA		6	Floating roof		43,3		Gasoline	Lightning	A small fire from a lightning strike occured on a roof vent of a floating roof gasoline tank. The 6 inch vent fire burned for 30 minutes without escalation and was extingusihed with a hand foam line.
1996-01-09	Vado Ligure, Italy		6	Tank						Fire quickly brought under control following explosion and deformation of tank roof.
1996-??-??	Visakh, India	HPCL refinery	6	11 tanks						Eleven tanks burned out
1996 06 04	Texas City, Texas, USA	Amoco Refining	1	Open floating	135	41,148	14,6	MTBE	Lightning	Lightning caused ignition to the 41 m tank filled with neat MTBE and the roof sunk. Two trailer-mounted monitors, 7600 l/min each were used and supplied with two brands of AFFF-AR at 3% and 6%, resp. Knockdown was achieved within 20-30 minutes while compl
1996-06-11	Woodbridge Township, N.J., USA	Shell Oil	1	Fixed roof tank with internal floating roof	140	42,672		Gasoline	Lightning	Its steel external roof, flipped by the explosion, lay to one side inside the burning tank. The internal floating roof sank to the bottom of the tank. ;Double wiper seal pan type floating roof landed on legs regularly to change product, vapour space forme
1996-07-19	Sarnia, Ontario, Canada	Sonoco Refining	1		140	42,672	15	Raffinate	Lightning	The tank contained three million gallons of gasoline. Firefighters worked the night pouring water on the blaze and nearby storage tanks.; the plans was to let the gasoline burn itself out and then pour foam into the storage tank.
1996 07 01	Sarnia, Canada	Petro-Canada	7		120	36,576		Crude oil		Sunken roof, protected for over 10 days. Using 6% foam proportioning, the foam blanket lasted for about two days
1996-11-11	San Juanico, Mexico		5	100 000 bbl gasoline in two tanks				Gasoline		Faulty valve. Burned out of control for 36 hours. 5000 evacuated, $5 M loss of product. Two storage tanks destroyed. Initially municipal fire fighters tried to douse flames with water. Only spread the fire. 4 deaths.
1996-12-??	Pascaguola, Mississippi, USA	Chevron	4		180	54,864				Internal floater, seal fire
1996-12-03	Woodbridge, N.J., USA	Shell Oil	5					Gasoline	Lightning	The tank contained three million gallons of gasoline. Firefighters worked the night pouring water on the blaze and nearby storage tanks.; the plans was to let the gasoline burn itself out and then pour foam into the storage tank.
1997-01-??	Harris County, USA		6	535 000 gallon tank						
1997-02-??	Gulf of Mexico	Samadan Drilling	6	Collection tank				Crude oil		
1997-04-09	Castleford, UK		6					Diesel		
1997-05-??	Corpus Christi, Texas, USA		5							A refinery plant explosion ripped through the facility, igniting fires in at least two tanks.
1997-06-25	Richland Township, USA	Atlas Roofing Corp.	6	Insulated asphalt tank	30			Liquid asphalt	Overheating	An asphalt tank caught fire, probably due to overheating. The 30 feet tank contained several thousand gallons of liquid asphalt and fire fighters battled the fire using foam and by cooling the outside of the tank with water. More than 100 firefighters fou
1997-07-30	Cobb County, USA	Colonial Pipeline Co	4	7 million gallon open top floating roof tank				Gasoline	Lightning	The fire began shortly before 18:00 during a strong thunderstorm. The 7 million gasoline tank was holding about 6,1 million gallons.The fire fighters were on the scene within 6 six minutes and started to apply foam. The fire was brought under control abou
1997-07-31	30 Miles south of Venice, Louisiana, USA	Texaco	4		160	48,768		Crude oil		Louisiana sweet crude oil; seal fire; 3M ATC3-603AR
1997-09-??	Hyderabad, India		5	Fifteen storage tanks				LPG, kerosene, petroleum		An oil refinery explosion left 34 people dead and injured at least 100 others. Fifteen storage tanks also continued to burn for two days.
1997-11-??	Israel		5							One worker died when a refinery's plant diesel fuel storage tank blew up, sending a towering cloud of smoke into the sky.
1997-12-25	Sarawak, East Malaysia	Malaysian Shell plant	6	Two tanks				Gas oil, kerosene	Explosion	An explosion occured at 22:50 involving two tanks containg gasoil and kerosene in fire. Foam was applied to the burning tank and nearby tanks were cooled with water. The fire was extinguished almost 18 hours after the explosion. 12 people were injured by
1998-??-??	Singapore		5	3 tanks				Naphtha		
1998-02-05	Cinderford, UK		3	50 tonne tank + surrounding bund				Bitumen		
1998-02-18	Bergen op Zoom, The Netherlands	Nedalco	2	1.2 million L storage tank				Ethanol		Europé's biggest alcohol production plant.
apr-98	Pascaguola, Mississippi, USA	Chevron	3	3 tanks x 95 ft	95	28,956		Gasoline		Tanks involved internal floaters, two were fished mouthed.
1998-04-08	South Claiborne Parish		6	oil tank battery				Oil	Lightning	Lightning blew off roor from two tanks which started to burn. Firefighters used one deluge gun stream and several handlines incl AFFF to extinguish.
1998-08-??	Kapotnya, Moscow, Russia	Moscow oil refinery	6	2000 m3 tank				Diesel fuel		The fire started at 11:05 after an explosion blowing off the roof, causing diesel oil to spill out causing a burning area of 500 m2. Nearby tanks were cooled using 25 water guns and the situation was under control. After about six hours the tank was succe
sep-98	Taft, Louisiana, USA	Union Carbide	7		234	71,3232		Naphtha		Sunken roof; BigFoot™

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
sep-98	Belle Chase, Louisiana, USA	BP Alliance	7		200	60,96		Crude oil		Sunken roof
1998-09-20	Jiangyou, China		6							Twenty tons of crude oil burned when a storage tank caught fire. No injuries were reported.
okt-98	Pascaguola, Mississippi, USA	Chevron	7		202	61,5696		Crude oil		Sunken roof
okt-98	Texas City, Texas, USA	Amoco Refining	7		345	105,156		Crude oil		Sunken roof
1998-10-16	Trainer Borough, Pennsylvania, USA	Bayway Refining Co's Tosco Trainer Refinery	6					Jet fuel		An explosion in a storage containing jet fuel rocked an oil refinery. Only minor injuries were reported.
1998-10-17	Igoumenitsa, Greece		6							Two seamen suffered minor injuries in an explosion and fire in a petroleum storage tank at a coastal port. The explosion happened after a tanker finished unloading gasoline at the port.
1998-12-10	Islington, New Zealand		6					Bitumen		A 100-ton bitumen storage tank was blasted off its foundation in an early morning explosion.
jan-99	Belle Chase, Louisiana, USA	BP Alliance	4		120	36,576		Hot oil		
1999-02-26	Daggett, CA, USA		6	900000-gallon tank				Hydraulic fluid		A 900000-gallon storage tank containing hydraulic fluid located at a solar power plant exploded. No injuries were reported.
1999-03-15	Stockport, UK		6	9000 L tank				Diesel		
1999-04-29	Yugoslavia		6							
maj-99	Franklin, Louisiana, USA	Philips Services Corp	5	Multiple storage tanks				Crude oil		largest tank 75 ft; Frothed over three times; Hot zone formation; Hydro-Foam™ technology
1999-05-15	Abidjan, Ivory coast (Africa)		6					Gasoline		
1999-05-30	Mount Zion		6					Oil	Lightning	
1999-07-??	Serbia			Thirty oil tanks				Oil	Bomb fallout	
1999-07-07	Chicago, IL, USA		3		24	7,3152		Asphalt		A 24-foot diameter asphalt tank exploded and burned
1999-08-09	Hub Oil Co, Calgary, Canada	Oil recycling plant	5	Several storage tanks				Oil, diesel fuel, jet fuel, propane, sulphuric acid		The fire began about 11:30 on Monday and blasts rocked the site throughout the day. Firefighters began advancing the blaze at 20:30 using water and fire fighting foam. The fire was contained within the one-acre site due to modearte winds. Two men were fea
1999-08-17	Turkey	Izmit oil refinery	5	Three naphta tanks and a crude oil tower.					Earthquake	An earthquake that killed many thousands triggered a fire at state-owned refinery that burned for three days. Three naphta tanks and a crude oil tower were involved.
1999-10-18	West Feliciana, USA	Probe Offshore LLC	6	Several storage tanks				Crude oil	Cutting torch	The fire occured in an abandoned oil facility. A 1000 barrel crude oil tank was to be removed and a worker using a cutting torch caused an explosion. The fire spred to two more tanks. The fire department allowed most fuel to burn out for about 45 minutes
1999-10-28	Ponca City, Oklahoma, USA	Conoco	1	Insulated cone roof tank	198	60,3504	14,64	Gas-oil (about the thickness of motor oil)	A spark from maintenance work	The 80000 barrel tank contained about 50000 barrels of gas-oil about as thick as motor oil. (2238600 gallons); enligt IFJ 2002: "Tank #118 was a 48' high 198' diameter insulated cone roof tank containing approximetely 2900000 gallons of gasoil. The explos
1999-12-03	Laem Chabang, Thailand	Thai Oil Company refinery in the Sri Racha district of Chonburi Province	6							
2000-01-??	Wood River	Equilon Refining Co.	6	Tank				Asphalt		Similar fire to Granite City fires in 2001
2000-03-15	Samara region, Russia	Samaraneft egaz	6	Several storage tanks				Oil		Fire in several oil storage tanks. The fire started on Wednesday at 18:10 Moscow time when oil "boiled up" and was discharged out of tank no 6. Tank 5 and 7 were ablaze on Thursday afternoon and firefighters tried to extinguish with foam.
2000-04-06	Anchorage, AK, USA	Williams Petroleum tank farm	6					Naphtha (jet fuel)	Tank cleaning	Naphtha trapped in the seal ignited. Fifteen fire engines responded to a fire at a tank fire that ignited 2000 gallons of jet fuel.
2000-05-15	Blaine, Washington, USA	Arco Cherry Point Refinery	7		150	45,72		Ligth Naphtha		Sunken roof
2000-07-23	Sealy, Texas, USA	TEPPCO Crude Oil, LLC	4		100	30,48		Crude oil		Internal floater
2000-08-14	West Deptford, MD, USA		6					Asphalt	Lightning	Lightning struck a storage tank at an asphalt plant with flames showing from the vent.
2000-11-07	Kingston, Jamaica		6							An empty storage tank at an oil refinery exploded, igniting a fire that spread to two tanks filled with gasoline.
2000-11-30	Samara Metal Works, Russia		6	Several storage tanks				Kerosene		
2001-02-08	Memphis, TN, USA		6	50000 gallon tank				Dicyclopentadiene		A 50000 gallon tank of dicyclopentadiene at a chemical plant caught fire, an explosion blowing the tank roof off.
2001-02-25	Wayne Township, Indianapolis, USA	Riley Industries	6					Non-toxic chemicals	Lightning	Contained 100000 gallons of chemicals.
2001-03-04	Port of Santos, Brazil		5							At least two storage tanks each containing more than 26000 gallons of fuel oil ruptured and spilled into the sea
2001-03-23		BHP,s port						Acid		
2001-04-25	Sukhodol, Russia		3							Fire broke out in a 3000 ton tank at an oil storage refinery. Firefighters extinguished the blaze in four hours.

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
2001-05-11	Seminole, Texas, USA	Exxon Mobil Corp	3		120	36,576		Crude oil		
2001-05-29	Oklahoma		6					Crude oil	Lightning	
2001-05-31	New Chapel Hill, TX, USA		5					Crude oil		Firefighters chose to let a crude oli storage tank fire burn itself out. A line to a truck being used to heat and recirculate the crude ruptured, igniting the fire. There was no water available at the site for firefighting efforts.
2001-06-07	Norco, Louisiana, USA	St Charles Parish plant; Orion Refinery	1		270	82,296	9,75	Gasoline	Lightning	Largest storage tank ever extinguished.The roof had partly sunk (due to a 15-inch rainfall) on Tank 325-4, a tank containing about 300000 barrels of gasoline. "I've been told that there were more than 14 roof sunk between here and Texas. In Louisiana alon
2001-06-24	Luling, Texas, USA	TEPPCO Crude Oil, LLC	6					Crude oil?		
2001-07-01	Nederland, Texas, USA	Unocal	6					Crude oil?		
2001-07-03	Port Arthur, Texas, USA	Motiva Enterprises LLC	4		197	60,0456		Crude oil?		
2001-07-09	Martinsville, Illinois, USA	Marathon Ashland Pipe Line LLC	7		200	60,96		Gasoline		Partially sunken roof
2001-07-10	Granite City, IL, USA	Petroleum Fuel and Terminal Co	2	4,2 million gallon tank			24,4	Asphalt	Explosion, Cause not determined	An 80-foot high, 4,2 million gallon capacity tank containing 400000 gallons of liquid asphalt caught fire. No injuries were reported. The primary intention was to let it burn out to aviod the risk of biol over but when they realized that it would take day
2001-08-08	PanCanadian, Weyburn, Canada?	Oilfield production plant	6	20000 barrel oil tank				Oil	Lightning	Lightning struck an inactive 20000 barrel tank, blowing of the fibre glass roof. There was only a minimal amount of fuel in the tank. Adjacent tanks were cooled until the tank had burnt down so it could be extinguished with foam.
2001-08-15	Granite City, IL, USA	Petroleum Fuel and Terminal Co	2	4,2 million gallon tank				Asphalt	Explosion, Cause not determined	Fire broke out once again in an asphalt storage tank that caught fire on July 10. The asphalt had cooled and solidified since the previous fire and reheating had started about one week ago to be able to pump it from the damaged tank. The fire broke out on
2001-08-21	Florence, Kansas, USA		5					Oil	Lightning	A total of five tanks caught fire
2001-09-04	Tonganoxide, KS, USA		6							A worker checking the level in a large oil tank at night struck a match. He was killed in the resulting blast.
2001-10-02	Magnolia, AR, USA		5							A 15000 gallon fuel tank blew up, spreading fire to three other tanks
2001-11-30	Duson, LA, USA	Central Crude Storage Inc.	6	Oil storage tank				Crude oil	Explosion, cause not determined	A 14-year-old boy suffered third degree burns in a crude oil storage tank explosion. The tank holding about 2200 barrels were full at the explosion. The tank was burning for several hours and was then extinguished with foam by Lafayette Regional Airport f
2001-12-10	Dartmouth, Nova Scotia		6							An explosion at an oil refinery sent a 1400 barrel fuel storage tank flying. The tank was only one-tenth full at the time
2002-01-07	Superior, WI, USA		6					Gasoline	Ignited during inspection	A fire that ignited during an inspection destroyed an almost empty oil refinery gasoline storage tank. The tank was nearly empty at the time
2002-01-24	Greenville, OH, USA		6					Gasoline		A gasoline storage tank exploded, causing minor injuries to two workers and damage to three homes
2002-02-08	Coffeyville, KS, USA		6							A mid-sized storage tank on the west side of a refinery complex exploded and burned. No injuries were reported by plant officials
2002-03-19	Ra'al-Unuf, Libya		6							The country's largest oil refinery caught fire and burned nearly three days. An explosion in an ethylene tank triggered the blaze.
2002-03-20	Pasadena, TX, USA		6							A tank damaged in an explosion last January at a chemical plant erupted again in flames.
2002-05-01	Pearland, Texas, USA	Third Coast Packaging facility	5	Petrochemical plant: many aboveground storage tanks (91 ASTs) 2500000 gallons totally				antifreeze, transmission fluid, motor oils, mineral oils		Due to a lack of fire hydrants in the area and an inability to transport large volumes of water to the site, the fire was allowed to burn through the early morning hours and it was not completely extinguished.
2002-05-05	Malopolska region in Poland	Trzebinia Refinery	1	10000 m3 cone roof with internal floating roof				Crude oil	Lightning	Tank ignited by lightning at 16:10. Semi-fixed system damaged and could not be used. At about 18:35, tank is starting to leak into bund area. At about 18:40-19:00, an attack was initiated towards the bund area and at 20:30 the tank was attacked. Knockdown
2002-05-17	Portland, OR, USA		6				10	Asphalt		A 32-foot-tall asphalt tank being heated exploded and burned. No injuries were reported.
2002-05-21		El Paso Energy	4		110	33,528		Light crude		21/5-3/6
2002-05-21	Mamou, LA, USA		5							An environmental emergency was declared after three oil storage tanks erupted in flames, creating a moat of crude oil and salt water that threatened nearby homes
2002-01-06	Lafayette, Lousiana, USA	Chevron-Texaco pipeline terminal		Open top floating roof (110ft), cone roof (20 ft)	110, 3x20					A dike fire involved one floating roof tanks and three cone roof tanks. The dike fire was extinguished with a 400 gpm HydroFoam nozzle and the 3D-fires with Hydro-Chem. The rim seal fire was then extinguished within 5 minutes using a wand. One of the smal
2002-06-05	Jacksonville, Florida, USA		6							An explosion at a company that treats oily wastewater blew the top off a fuel tank, throwing it nearly 500 feet.
2002-06-07	Dexter, KS, USA		5					oil		One man was treated after an explosion involving two storage tanks, one containing 1000 barrels of oil.
2002-07-07	Shuaiba, Kuwait		6					water-oil wastewater		A small fire broke out in a refinery storage tank used for water-oil wastewater.
2002-07-20	Nigeria	Chevron-Texaco Escravos oil terminal	6	Floating roof; 180000 bbl				Crude oil	Lightning	This incident started as a seal fire and for some reason the fire department was unable to extinguish this.
2002-07-28	Turkey	Akcagaz	6	At least eight LPG-tanks, 150-180 m3 each				LPG		The fire involved the 1700 m2 facility area and completely destroyed 9 LPG-tanks. 5000 people were evacuated. The fire was controlled after three hours aided by airplanes and helicopters dropping water and foam onto the fire. No information if other petro
2002-08-11	Port a la Heche, LA, USA	Forest Oil Corporation	5	3 tanks				Crude oil	Lightning	
2002-08-18	Houston Texas, USA	Houston Fuel Oil Terminal	2	30 000 gal tank				Residual fuel oil	Rupture of expansion joint	The largest black oil facility on the US Gulf coast. A pipe carrying fuel from shipping docks to storage tanks ruptured, igniting the tank. Subsurface foam was injected.
2002-09-01	Refugio, TX, USA		5	10000 gal tank					Lightning	A 10000 gallon oil tank struck by lightning caught fire, spreading flames to two other tanks and two tanker trucks.

Date	Location	Object	Rating	Description	Tank diameter (ft)	Tank diameter (m)	Height (m)	Fuel	Ignition source	Comments
2002-10-04	Sydney, Australia		6					Hexane		Workers were evacuated from a factory when a small storage tank containing hexane caught fire
2002-10-13	Pascogola, Mississippi, USA		5					Paranitrotoluene		A chemical plant tank containing nitrotoluene exploded, rupturing a neighboring tank of paranitrotoluene which ignited
2002-10-17	Dunbar, South Africa		6							A fuel storage tank at a bitumen factory exploded, killing one worker and injuring six others
2002-10-19	Banten, West Java	Chemical plant	6	10 chemical storage tanks						The fire involved 10 of the 13 tanks on the chemical plant. One person injured.
2002-10-21	Olympic Dam Australia	Mine	6	Tank				Kerosene	Static electricity	
2002-12-08	Cabras Island, USA	Mobil tank farm	6	Several tanks involved				Gasoline, jet fuel, diesel	Supertyphoon Pongsona	Fire occured in a tank of jet fuel and then a tank of diesel fuel. The fire was extinguishe 5 days after ignition due to limited water supplies and was extinguished at 14:00 on Dec 13.
2003-03-07	Guwahati, India	Digboi Refinery	2	5000 m3 tank				Petrol	Mortar attack	One of 13 tanks in the tank farm hit by the mortar attack
2003-04-08	Glennpool, Oklahoma, USA	Tank farm	6	75000 barrel tank				Diesel	Static electricity	A 75000 barrel tank had taken in about 8000 barrel of diesel when it burst into flames.The explosion occured during transfre from on tank to another and was probably caused by static electricity. During the fire, a power line fell into some spilled fuel i
2003-05-03	Gdansk, Poland	Refinery	1	Tank 20 000 m3				Gasoline	Mobile telephone?	Ignition occurred when a fuel sample was taken from top of tank full of gasoline. An explosion occured and three men on the tank top were killed. The explosion occured at 15:00 at the fire was extinguished at 02:00 on May 4.
2003-06-04	Brisbane, Australia	Oil refinery	4	Foating roof tank				Crude	Lightning	Lightning strike ignited a fire between the between floating roof and a side wall of a crude oil tank. No injuries reported
2003-07-09	Moss Landing, CA, USA	Duke Power Plant	6	Tank				Fuel-oil		
2003-08-14	Puertollano, Spain	Repsol refinery	3	Tank						An explosion in Repsol-YPF refinery killed three people and injured seven others. Gasoline tank on fire
2003-09-26	Hokkaido, Japan	Idemitsu Kosan Co Ltd refinery	3	Tank (no 30006)		42,7	24,39	Crude-oil	Major earthquake	The refinery had 105 tanks and 29 tanks had structural damage or leaks. One tank on fire, extinguished within 7 hours
2003-09-28	Hokkaido, Japan	Idemitsu Kosan Co Ltd refinery	3	Tank (no 30063)		42,7	24,39	Naptha	Aftershocks from major earthquake	Fire broke out following an aftershock in a tank about 100 m from the first tank fire. Strong winds hampered the fire extinguishing operations and and adjacent tanks were cooled to prevent escalation. The tank burned for more than 29 hours and was severel

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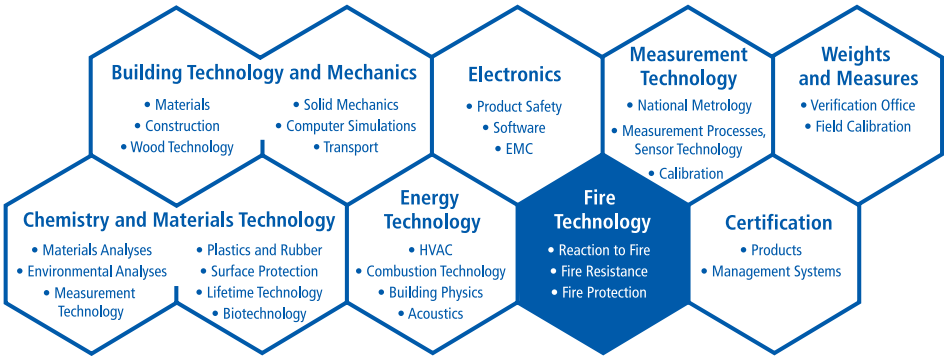

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SP Swedish National Testing and Research Institute
Box 857
SE-501 15 BORÅS, SWEDEN
Telephone: + 46 33 16 50 00, Telefax: +46 33 13 55 02
E-mail: info@sp.se, Internet: www.sp.se