Fire Investigation Summary

Cruise Ship Fire

Miami, Florida
July 20, 1998

A fire that began with an unsupervised cutting and welding operation resulted in serious damage to the mooring deck of a cruise ship within minutes after getting underway for a Caribbean cruise.

The failure to utilize proper cutting and welding procedures and the delayed discovery of the fire on the mooring deck led to damage throughout the aft portion of the ship. The prompt action of the ship’s fire brigade limited damage to a single vertical zone.
On July 20, 1998, a fire occurred on the passenger cruise ship “Ecstasy,” as the ship was beginning a four-day trip to Cozumel, Mexico from the Port of Miami, Florida. This fire resulted in injuries to 60 people, including both passengers and crewmembers. At the time of the incident the ship was carrying 2557 passengers and 920 crewmembers.

The ship was constructed in 1990 in Finland and refurbished in 1995. The ship was 260.6 m (855 ft) in length and 31.7 m (104 ft) wide with a draught of 8 m (26 ft). The ship’s gross tonnage was 62,827.7 metric tons (70,367 tons). The vessel had a top speed of 40.7 km/h (22 knots) and was powered by two diesel-electric engines.

The ship contained 10 accommodation and entertainment decks, which housed a combination of passenger cabins and entertainment areas (i.e., casinos, nightclubs), as well as numerous dining areas. Most mechanical spaces were located on the lower three decks of the ship, with equipment closets and chases scattered throughout the ship.

The aft mooring deck, where the majority of the fire damage occurred, was located on Deck 4 (Riviera Deck). There was a similar mooring area in the forward portion of the ship on Deck 6 (Upper Deck). The mooring decks contained the large electric winches that controlled several hundred feet of mooring lines. The mooring lines consisted of polypropylene rope of approximately 63.5 mm (2-1/2 in) diameter.

The laundry area, where the fire is reported to have started, is located on Deck 2, forward of the freshwater tanks.

The laundry area consisted of washing and drying machines and associated pressing and folding equipment.

While maintenance personnel were conducting repairs on a pressing and folding machine (referred to as a “mangle”) in the laundry room, an arc from a welding rod reportedly ignited combustible lint in and around the machine. Attempts to extinguish the initial fire were unsuccessful as personnel were driven from the laundry area by smoke. As personnel were exiting the area the laundry room manager activated the fire alarm.

Smoke began to spread to the decks above and below the laundry area. Reports and alarms were initially received for smoke on Deck Nos. 1 through 5. Upon investigation by fire brigade members, smoke and fire was discovered on the aft mooring deck (Deck 4).

The on-board fire brigade was called upon and began to deploy to the aft portion of the ship. The brigade members closed fire doors and monitored the conditions in the deck areas surrounding the laundry room and the mooring deck. An intense fire was discovered on the aft mooring deck, apparently fueled by pallets of polypropylene rope. As the fire on the mooring deck grew in intensity, thick black smoke was seen billowing from the rear of the ship. This smoke became visible to United States Coast Guard cameras at the Port of Miami as well as residents of the Miami Beach area. The Coast Guard contacted the ship’s captain at 5:30 p.m. and asked about the smoke condition. At that point the captain indicated that the crew was controlling the fire and they needed no
further assistance. Approximately 30 minutes later, the captain contacted the Coast Guard to request assistance.

Coast Guard and other fire-fighting vessels were dispatched to the ship’s location, now about five kilometers (2.7 miles) northeast of Miami Beach. In the meantime the ship had lost control of propulsion systems and began to drift northward. The Coast Guard and private assistance began arriving between 6:00 and 6:25 p.m.

The combination of the ship’s fire brigade and the fire-fighting vessels brought the fire under control around 7:15 p.m. The vessel was then towed back to the Port of Miami and arrived at 2:20 a.m. on July 21, 1998. Once in port, those passengers and crewmembers that required further medical attention were transported to local hospitals. The injuries included smoke inhalation and chest pains. Seven were hospitalized overnight and another two remained in the hospital for an additional day for observation.

Fire damage was centered on the aft mooring deck (4), the thruster equipment room on Deck 1, the dry goods storage area on Deck 3, and the aft portion of the Main deck (5). Smoke and water damage was experienced throughout the aft portion of the ship on all decks. Sprinklers activated on Decks 3 through 7.

The ship was moored in the Port of Miami for four days while the investigation was conducted. The ship left on Friday July 24, 1998, under its own power and sailed to Newport News, Virginia, where extensive repairs were completed. The ship was placed back into service on September 18, 1998.

On the basis of the fire investigation and analysis, the NFPA has determined that the following factors directly contributed to the fire:

- Cutting and welding without proper precautions
- Delay in discovery of the fire on the mooring deck
- Avenue of fire spread through ventilation ducts containing lint and dust accumulations

Photo showing damage on the port side of the ship, outside the mooring deck. The arrow shows the location of the bulkhead where the fire brigade held the fire’s spread. (NFPA)

Written by Robert Duval, Senior Fire Investigator
NFPA Fire Investigations Department

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July 20, 1998

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Cruise Ship Fire

Miami, Florida
July 20, 1998

Prepared by

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Abstract

On July 20, 1998, a fire occurred on the passenger cruise ship “Ecstasy,” as the ship was beginning a four-day trip to Cozumel, Mexico from the Port of Miami, Florida. This fire resulted in injuries to 60 people, including both passengers and crewmembers. At the time of the incident the ship was carrying 2557 passengers and 920 crewmembers.

The ship was constructed in 1990 in Finland and refurbished in 1995. The ship is 260.6 m (855 ft) in length and 31.7 m (104 ft) wide with a draught of 8 m (26 ft). The ship’s gross tonnage is 62,827.7 metric tons (70,367 tons). The vessel has a top speed of 40.7 km/h (22 knots) and is powered by two diesel- electric engines.

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rope. As the fire on the mooring deck grew in intensity, thick black smoke was seen billowing from the rear of the ship. This smoke became visible to United States Coast Guard cameras at the Port of Miami as well as residents of the Miami Beach area.

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Introduction

The National Fire Protection Association (NFPA) investigated the cruise ship fire in order to document and analyze significant factors that resulted in the ignition and spread of fire within the vessel.

The study was conducted by the NFPA as part of an ongoing program to investigate technically significant incidents. The NFPA’s Fire Investigations Department documents and analyzes incident details so that it can report lessons learned for life safety and property loss purposes.

The NFPA became aware of the Miami, Florida cruise ship incident the day it occurred. NFPA Chief Chemical and Marine Engineer Guy Colonna and Fire Investigator Robert Duval traveled to Florida to meet with investigators from: the National Transportation Safety Board; the Florida State Fire Marshal’s Office; the Metro-Dade County Fire Marshal’s Office and Police Department; the Bureau of Alcohol, Tobacco and Firearms; the United States Coast Guard; and Carnival Cruise Lines to view the scene and perform an on-site study of the incident. The information gathered during the on-site activities and subsequent analysis of that information are the basis for this report. Entry to the fire scene and access to the investigation reports were made possible through the cooperation of the National Transportation Safety Board, the United States Coast Guard, and Carnival Cruise Lines.

This report is another of NFPA’s studies of fires having particularly important educational or technical interest. All information and details regarding fire safety conditions are based on the best available data and observations made during the on-site data collection phase and on any additional information provided during the report development process. It is not NFPA’s intention that this report pass judgment on or fix liability for the loss of property resulting from the fire. Rather, the NFPA intends that its report present the findings of the NFPA data collection and analysis effort and highlight factors that contributed to the loss of life and property.

Where applicable, current NFPA codes and standards were used as criteria for this analysis so that conditions at the scene of the fire could be compared with state-of-the-art fire protection practices. It is recognized, however, that these codes and standards may not have been in effect during the ship’s construction. The NFPA has not analyzed this event regarding the compliance with the codes and standards that were in existence when the vessel was constructed or equipment was installed or during its operation.

The cooperation and assistance of all agencies involved in the investigation was greatly appreciated.

A special thanks goes to Andrew Grenier for his assistance in completing this report.
Background

The Ship

The cruise liner Ecstasy was constructed in the Kvaerner Masa Shipyard in Finland in 1990. The vessel entered service in June 1991 and was refurbished in 1995. The ship measured 260.6 m (855 ft) long and 31.7 m (104 ft) wide. The ship had a draught of 8 m (26 ft) and a gross tonnage of 62,827.7 metric tons (70,367 tons). The vessel had a top speed of 40.7 km/hr (22 knots) and was powered by two diesel-electric engines.

The vessel had 13 deck levels designated as follows (see Figure 1):

- Deck 0 – Mechanical Spaces
- Deck 1 – Storage/Mechanical Spaces
- Deck 2 – Storage/Mechanical Spaces/Crew Quarters and Laundry Area
- Deck 3 – Dry Goods Storage/Crew Quarters/Baggage Handling
- Deck 4 – Accommodations/Aft Mooring Deck (Riviera Deck)
- Deck 5 – Accommodations (Main Deck)
- Deck 6 – Accommodations/Forward Mooring Deck (Upper Deck)
- Deck 7 – Accommodations/Crew Recreation Areas (Empress Deck)
- Deck 8 – Entertainment Areas (Atlantic Deck)
- Deck 9 – Entertainment Areas (Promenade Deck)
- Deck 10 – Entertainment Areas/Wheel House/Officers Quarters (Lido Deck)
- Deck 11 – Deluxe Accommodations/Open Deck (Verandah Deck)
- Deck 12/13 – Recreation Areas (Sun and Sports Decks)

Interior stairwells and elevators connected Decks 4 through 11. Service elevators and stairwells connected Decks 2 through 11. The configuration of corridors, doorways, cabins, common areas, and utility and service areas varied per deck.

The accommodations on board included 1020 cabins, arranged as follows:

- 618 outside of corridor
- 402 inside of corridor
- 54 with balconies
- 20 to accommodate wheelchairs

During the cruise that departed July 20, 1998, there were reportedly 2557 passengers and 920 crewmembers on board the ship.
The Mooring Decks

The two mooring decks (forward and aft) contained the equipment to facilitate docking maneuvers. The equipment consisted of large, electric-powered winches and associated mechanical equipment. The ropes utilized in the mooring process were of laid polypropylene strand or nylon construction, approximately 50.8 mm – 63.5 mm (2 in. to 2-1/2 in.) in diameter. When the rope was not maintained on the winch spindles, it was coiled on pallets or in large open, metal-frame baskets located adjacent to the winch equipment. The forward mooring space contained four large capacity winches, while the aft mooring space contained three similar units. (See Figure 2)

The details on the mooring line stored on the aft mooring deck at the time of the fire is as follows (Photo 1):

- There were eight 220 m (726 ft) long lengths of mooring line (seven polypropylene and one nylon).
- Each length weighed approximately 405 kg (900 lb).
- One length was utilized on each of the three winches.
- The remaining five lengths were stored on pallets or in the metal frame baskets.
Figure 2 – Aft mooring deck and adjacent spaces

Photo 1 – View of Forward Mooring Deck showing one winch and polypropylene mooring line on a pallet. (NFPA)
The Laundry Area

The laundry area of the vessel [465 m² (5,000 ft²)] was located on Deck 2 ahead of the freshwater tanks in main vertical zone (MVZ) 2. The equipment in this area consisted of several washer and dryer machines, a pressing unit (mangle), folding equipment, storage lockers for soap and other supplies, and a small area for hand pressing or folding. (See Figure 3)
Shipboard Fire Protection

Construction Features

The construction features of a cruise ship include passive fire protection features such as structural assemblies that allow for the compartmentation of a fire. These construction features include thermally insulated structural steel assemblies (i.e., bulkheads and decks). These features are designed to slow the spread of fire from compartment to compartment and deck to deck for the time interval required to isolate and extinguish a fire or to allow for the safe evacuation of the vessel. Horizontal separation is provided by fire-rated bulkheads, which divide the decks into main vertical zones referred to as MVZs. The Safety of Life at Sea (SOLAS) regulations limit the size of the MVZs to a maximum of 40 m (131 feet) in length. The length of the MVZs on this ship ranged from 15 m (49.2 ft) to 32 m (105 ft).

The fire-rated bulkheads are designed to have a “A-Class” fire resistance rating. According to SOLAS 1974 – Chapter II-2, Regulation 3, - A-Class divisions are those divisions formed by bulkheads and decks that comply with the following:

- They shall be constructed of steel or other equivalent material.
- They shall be suitably stiffened.
- They shall be so constructed as to be capable of preventing the passage of smoke and flame to the end of the 1-hour standard fire test.
- They shall be insulated with approved non-combustible materials such that the average temperature on the unexposed side will not rise more than 140° C (284° F) above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 °C (356 °F) above the original temperature, within the following:
  
  A-60 – 60 minutes
  A-30 – 30 minutes
  A-15 – 15 minutes
  A-0   –  0 minutes

On the Ecstasy, interior stairwells and elevators connected all accommodation and entertainment decks (Decks 4 through 11). The lower (mechanical) decks were also connected with service stairwells and elevators, accessible only to the crew.

Deck plating consisted of steel of varying thickness, with carpeting and padding in accommodation or entertainment areas. Mechanical and service areas are typically painted or fitted with an appropriate deck tile material. Where insulation is required for thermal, acoustic, or fire protection purposes, the decks are typically covered with insulation on the underside. The deck plating and overhead areas in the aft mooring deck were of painted steel plate.
Sprinkler Protection

The Ecstasy was equipped with automatic sprinkler protection. A series of wet pipe sprinkler systems were located in passenger accommodation areas (i.e., cabins and corridors), mechanical areas and service areas (i.e., kitchen and laundry), as well as common areas such as restaurants and clubs. The design criterion of the systems in the aforementioned areas is outlined in SOLAS Regulation 12.

According to the SOLAS regulations, the sprinkler systems must be wet-pipe, except in exposed areas, where a dry-pipe-type installation has been determined to be a necessary precaution. The system must be maintained at an adequate pressure and shall have the provision of a continuous water supply. The system must be designed to operate at an average application rate of not less than 5 L/m²/min (0.125 gpm/ft²) over the nominal area protected by the sprinklers. Sprinklers shall be grouped in sections, each of which shall contain no more than 200 sprinkler heads. A section of sprinklers shall serve no more than two decks and shall not be situated in more than one main vertical zone (MVZ). The sprinkler systems must be resistant to corrosion due to sea air and water.

The system on board the Ecstasy was designed to provide 5 L/m²/min over a design area of 280 m² (0.125 gpm/ft² over 3014 ft²).

The sprinkler heads were 68 °C (155 °F) rated, 8mm orifice, glass bulb-type heads. Sprinkler heads adjacent to heat-producing equipment (i.e., laundry room) were rated at 93 °C (200 °F). The spacing per sprinkler varied with the area in which the heads were installed. The average sprinkler head spacing was 10 m² (107.6 ft²).

A manually operated deluge-type sprinkler protection system was located on the bridge area. This system was equipped with open sprinkler heads throughout the bridge area and is activated by a control valve located outside the bridge space in a corridor immediately adjacent to the bridge entrance.

A pressure tank located on Deck 2 supplied the sprinkler protection system.

The mooring decks were not required to be equipped with automatic sprinkler protection under the SOLAS regulations.

Fire Alarm Systems

The vessel was equipped with fire detection and alarm systems located throughout most of the ship. The detectors were arranged to sound an alarm on the bridge and the engineering control room.

Manual pull stations were located throughout the ship to allow passengers and crewmembers to manually report a fire.
Water flow alarms were installed within the automatic sprinkler system. The flow alarm indicators were arranged to sound on the bridge and in the engineering control room, as well.

The fire detection alarm panel was located on the bridge. The system annunciates the alarms by zones for automatic alarm activations and was equipped with an indicator light for each manual pull station throughout the vessel.

The mooring decks were not required to be equipped with fire detection systems under SOLAS regulations.

**Manual Fire Protection Equipment**

Cabinets containing manual fire protection equipment were located throughout the ship in corridors and mechanical areas. The cabinets contained a standpipe connection with a single jacketed hoseline (38 mm [1.5 in] diameter) and a 3.7 kg (10 lb) dry chemical, manual fire extinguisher for combating incipient stage fires. (See Photos Nos. 2 and 3) Other cabinets, located in service areas, were equipped with hand tools utilized by fire brigade members (i.e., axes, saws, and pry bars). (See Photo 4)
In the event of a fire each member of the crew had duties to perform. Certain crewmembers were assigned as fire fighters. Selected crewmembers were trained in shipboard fire-fighting techniques, which included use of the on-board fire-fighting equipment, self-contained breathing apparatus (SCBA), and the use of the passive fire protection features of the vessel to contain the fire to selected compartments and extinguish the fire.

It was the responsibility of the fire brigade members, upon activation of the ship’s fire alarm system, to respond to the fire area and surrounding zones, don protective clothing and SCBA, and attack the fire with suppression equipment available nearby. Should the fire be beyond the incipient stage, the brigade members could choose to isolate the fire location by use of bulkhead doors and MVZ barriers.

Carnival Cruise Lines requires fire brigade members to complete training in accordance with the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW-95) and the International Safety Management Code (ISM). The basic training consists of a five-day program in accordance with STCW Chapter VI, Tables A-VI/1-1 through 1-4. Two in-service training classes are also held for each ship annually.

**SOLAS**

The International Convention for the Safety of Life at Sea (SOLAS) was developed through the International Maritime Organization (IMO). IMO is a specialized agency of the United Nations devoted to maritime affairs. It has developed and promoted the adoption of more than 30 conventions and protocols as well as over 700 codes and recommendations dealing with such matters as maritime safety and the prevention of pollution at sea. The most important of the IMO requirements are
mandatory for all ships engaged in international trade, while even the recommendations often have widespread impact.

SOLAS was first adopted in 1914 following the sinking of the Titanic. Since then, four more versions of the convention have been developed and adopted, including the current version, SOLAS 1974, which entered into force in 1980. It applies to all ships that fly the flag of nations that are signatory to the convention.

Chapter II-2 contains the requirements for Construction – Fire Protection, Fire Detection and Fire Extinction. Part A contains general requirements applicable to all classes of vessels, while Part B applies to passenger vessels, Part C to cargo ships and Part D to tankers.

The main fire protection features covered in Chapter II-2 include the following:

- Main vertical zones (MVZ) – the structural/thermal boundaries of the ship
- The separation of accommodation spaces from other areas by structural and thermal boundaries
- Restricted use of combustible materials
- Fire detection/containment
- Means of egress
- Fire extinguishing equipment/systems

The regulations of the SOLAS 1974 document that were reviewed for this report include the following:

- Regulation 12 – Automatic sprinkler, fire detection and fire alarm systems
- Regulation 13 – Fixed fire detection and fire alarm systems
- Regulation 17 – Fireman’s outfit (Protection Clothing and Equipment)

The U.S. Coast Guard represents the interests of the United States in the IMO process and serves on the various committees that comprise the IMO and its agenda.

Weather

At the time of the fire the temperature was 28 °C (82°F), with the wind out of the east at 16 kph (10 mph). The relative humidity was 75%.
The Fire

Discovery

The ship departed the Port of Miami on the afternoon of July 20, 1998 at 4:42 p.m. for the first leg of a four-day cruise to Key West and Cozumel, Mexico. The vessel proceeded through Government Cut and headed out to sea at approximately 5:00 p.m. with 2557 passengers and 920 crewmembers on board.

On the aft mooring deck, the crew of 12 completed their duties associated with departure at 4:50 p.m. and remained on the deck for another 10 minutes completing assigned tasks until 5:00 p.m. The crewmembers with the exception of the first officer left the deck at this time to complete duties elsewhere on board. The first officer left the mooring area through the port aft passage between 5:00 and 5:10 p.m., locking the doors from the deck into the passenger corridor as he left. The first officer then reported to the bridge.

Meanwhile, in the laundry room, repairs were underway on the piece of equipment referred to as a “mangle,” which presses linen materials and prepares them to be folded. Two galley fitters were making adjustments to the mangle when a roller adjustment bolt broke. A decision was made to weld this bolt back in place and reassemble the machine. A welding unit was brought into the laundry room and activated. As the fitters prepared to begin welding, they reported that the electrode swung free after being placed over the side of the mangle machine. As it swung out, it struck the grounding strap and an arc was developed. Shortly thereafter, the fitters reported seeing flames under a roller on the machine. As they attempted to extinguish the fire under the roller by throwing water on it they noticed a fire overhead in an exhaust duct above the machine. As burning materials from the duct fell onto the mangle machine, small fires were started in lint on the rollers of the machine.

The fitters attempted to extinguish the fire using manual fire extinguishers. As the fitters were combating the fire, a steward who was picking up linens smelled smoke, entered the laundry area, saw the fire, and activated a manual fire alarm station (Station 2202) outside the room. The laundry manager, who was in the laundry room galley adjacent to the laundry room while the fitters were repairing the mangle, also went to investigate an odor of smoke. As he entered the corridor he saw the laundry room filled with smoke. He activated the manual fire alarm station in the corridor outside the laundry room (Station 2201). The assistant laundry room manager joined the manager in the corridor and closed the watertight doors leading from the laundry room, after ensuring that the passageway was clear.

A smoke detector signal was received on the bridge from the laundry room area at approximately 5:10 p.m. Other detector signals were received in quick succession (within a minute) from the thruster room on Deck 1, Deck 5 aft, Cabin 421 on the Riviera Deck, and the steering gear room (portside) on Deck 3.
Fire Brigade Response

The fire brigade muster signal was sounded at approximately 5:12 p.m. Brigade members began to gather at their assigned muster points.

Brigade members responded to the numerous muster locations within the ship and began closing fire doors and monitoring conditions in corridors and mechanical spaces.

Fire brigade personnel responded to the area of the laundry room to investigate the initial alarm activation in that area. They were confronted with heavy black smoke and moderate heat, but no visible fire. Brigade members then examined the mechanical area below the laundry room (thruster area) for fire and smoke conditions. The smoke was reported to be heavy with a moderate heat condition, but no visible fire. The decks above the laundry room (Deck 4) were checked by brigade members for fire extension and smoke conditions. Hoses were deployed at the bulkhead doors on these decks in the event that the fire began to spread upward through the compartments above the laundry and mooring areas.

Fire hoses were deployed to the bulkhead doors (MVZ 1) at the mooring deck. Attempts were made to enter the mooring deck through these doors. Due to the heavy fire and smoke conditions, brigade members held positions in the corridor outside the mooring area on Deck 4.

Water was applied to the bulkhead doors on the port and starboard side corridors of Deck 4 to maintain the integrity of the doors as the intense fire burned behind them on the mooring deck.

At this point, the Coast Guard vessels and private tugs were arriving and began applying water to combat the fire from the rear of the ship.

Eventually fire brigade teams were able to access the aft mooring deck, via the starboard door, to examine the extent of the fire and attempt to combat it. Brigade members reported that fire was seen exiting the exhaust ducts at the forward wall of the mooring space. Fire was also seen involving pallets of the polypropylene rope lines. On their first entry attempt, the teams were pushed back by the extreme heat and smoke conditions.

The combination of the exterior application of water by the Coast Guard and the tugs and the interior hose streams applied by the fire brigade brought the fire under control by 7:15 p.m. and the fire was extinguished by 9:00 p.m.

Water application for the cooling of the decks and bulkheads continued until the ship arrived in port the next morning at 2:20 a.m.
Outside Assistance

When the ship captain requested assistance at 6:00 p.m., the Coast Guard had already dispatched a single vessel to the scene. This 12-½ m (41 ft) rescue craft arrived at about 5:40 p.m. Additional units were dispatched upon the captain’s request. This assistance consisted of three 12-½ m (41 ft) rescue boats from Miami Beach and Fort Lauderdale stations, two 25 m (82 ft) patrol boats from Fort Pierce and Fort Lauderdale, three 33-½ m (110 ft) patrol boats from Miami Beach, two rescue helicopters from Clearwater air station and one helicopter from the Miami air station. Four private tugboats also responded to the call for assistance. Rescue personnel from the Miami Beach and Metro-Dade Fire Departments also responded. All units had arrived at the scene by 6:25 p.m.

Coast Guard personnel and fire and medical personnel from the Metro-Dade and Miami Beach Fire Department boarded the ship to assess the fire conditions and assist in the treatment of the injured. These personnel stayed on board until the ship docked early the next morning. The injured were treated on board until the ship docked at the Port of Miami, where those needing to be transported to hospitals were taken by ambulance.
## Time Line

<table>
<thead>
<tr>
<th>Time (Elapsed)</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:42 p.m. (0)</td>
<td>Ship departed Port of Miami.</td>
</tr>
<tr>
<td>4:50 p.m. (8 minutes)</td>
<td>Aft mooring deck crew completed departure tasks.</td>
</tr>
<tr>
<td>5:00 p.m. (18 minutes)</td>
<td>Aft mooring deck crew departed mooring deck.</td>
</tr>
<tr>
<td>Approximately 5:00 p.m.</td>
<td>Fitters began work on “mangle unit” in Laundry Room on Deck # 2.</td>
</tr>
<tr>
<td>5:10 p.m. (28 minutes)</td>
<td>First Officer locked mooring deck doors as he departed for bridge.</td>
</tr>
<tr>
<td>Approximately 5:10 p.m.</td>
<td>Fitters attempted to weld broken bolt on mangle unit. Noticed fire beneath the unit and in the ventilation duct work above.</td>
</tr>
<tr>
<td>5:10 p.m.</td>
<td>Smoke Detector and Manual Pull Station alarm were received on bridge from the Laundry room.</td>
</tr>
<tr>
<td>5:10 p.m.</td>
<td>Additional alarms received from thruster room (Deck 1), Deck 5 aft section, Cabin 421(Riveria Deck), and the steering gear room (portside- Deck 3).</td>
</tr>
<tr>
<td>Approximately 5:12 p.m. (30 minutes)</td>
<td>Fire Brigade mustered to points to locate seat of fire.</td>
</tr>
<tr>
<td>Time (Elapsed)</td>
<td>Event</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5:12 to 5:30 p.m.</td>
<td>Smoke from aft section noticed by people on land and by US Coast Guard cameras. USCG unit dispatched. Ship’s Captain is contacted, indicated that on-board resources would handle the situation and no further assistance was required</td>
</tr>
<tr>
<td>5:40 p.m. (58 minutes)</td>
<td>First USCG vessel arrived.</td>
</tr>
<tr>
<td>6:00 p.m. (1 hour 18 minutes)</td>
<td>Ship’s Captain requested assistance from USCG.</td>
</tr>
<tr>
<td>6:25 p.m. (1 hour 43 minutes)</td>
<td>USCG and private fire-fighting vessels arrived at scene.</td>
</tr>
<tr>
<td>7:15 to 9:00 (2 hours 33 minutes – 4 hours 18 minutes)</td>
<td>Ship’s propulsion lost. Fire on mooring deck brought under control and extinguished.</td>
</tr>
<tr>
<td>2:20 a.m. (9 hours 38 minutes)</td>
<td>Ship Arrived at Port of Miami under tow.</td>
</tr>
</tbody>
</table>
Analysis

Damage

The damage on the mooring deck was extensive. The deck plates (floor and ceiling) were warped from the intense heat. Nearly all of the combustible materials on the mooring deck were consumed by the fire. Only melted piles of nylon or polypropylene rope remained. Most mooring line contained on the winch spools or in piles on pallets or in the metal frame baskets was destroyed. All rubber hoses or plastic covering on cabling was melted in the fire. (See Photo Nos. 5 - 6)

Photo 5 – Damage on the aft mooring deck (NFPA)

Photo No. 6 – Damaged winch on aft mooring deck (NFPA)
The heat damage extended into the bulkhead passageways and into the corridors (port and starboard sides) adjacent to the aft mooring space. These spaces also contained water damage from hoseline and sprinkler operation.

The mechanical space on Deck 1, known as the stern thruster equipment area, was also damaged by heat and smoke. Rubber and plastic covering on wiring and other control devices was melted. All ventilation duct work connecting to the aft mooring space showed signs of heat damage.

The accommodation spaces adjacent to and above the aft mooring deck showed signs of smoke, water, and heat damage.

The aft exterior surfaces of the ship showed signs of serious heat and flame exposure. Soot staining and oxidation reached the upper surfaces of the rear portions of the ship. The location of the MVZ 1 is clearly evident in photographs as a line of demarcation between damaged and undamaged exterior surfaces. (See Photo Nos. 8 and 9)

Approximately 60 sprinkler heads activated as a result of this fire. The activated sprinkler heads were located in the port side corridor and stairways adjacent to the aft mooring deck and in passenger accommodations and adjacent corridors on Deck 5 above the aft mooring deck, as well as in the Deck 3 dry goods storage area. Sprinkler heads were found to have activated in isolated areas on Decks 6 and 7, near ventilation ducts that apparently were heated during the fire. Additional sprinkler heads may have activated in passenger rooms, but several rooms on Deck 5 were secured and access could not be gained. None of the sprinkler heads in the laundry room area were activated.

With an average per head spacing of 10 m² (107.6 ft²), sprinklers heads opened over a 600 m² (6458.3 ft²) area, over twice the design area.
Photo 8 – Exterior heat damage to the port side of the ship. (Note: The point where the discoloration ends, denoting the location of MVZ 1 in the left-center of the photo.) (NFPA)

Photo 9 – Exterior damage to the stern surface of the ship (NFPA)
Cutting and Welding (Hot Work) Permitting System

Carnival Cruise Lines has a cutting and welding permit procedure that involves supervisory personnel examining a potential hot work project for several factors prior to the beginning of any work. A permit is then issued if the project can be completed safely. It appears in this case the procedure was not followed.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work* (1999 edition), is the standard providing guidance for persons, including outside contractors and property managers, who manage, supervise, and perform hot work.

It appears that no hot work procedures were considered by the two workers. Fundamental requirements of such procedures would involve a hazard assessment of the fuel source, the ignition source, and the oxygen source. Since the oxygen necessary for the combustion to occur was derived from the ambient air, it is not a factor. Likewise, once the workers determined that welding the damaged bolt was the best course of action, the ignition source was determined. The only remaining factor left to be established was the fuel source. Due to the presence of lint below the mangle equipment from the recently operated machine, a ready fuel source existed.

Hot work safe practices require that consideration first be given to moving the hot work to a location where no risk of fire exists (like a specially designated work area or machine shop). In this case, it was impractical due to the size of the equipment and location of the damaged bolt to move the hot work location. Therefore, safe practices require that the area be made safe by moving combustibles to a safe distance [NFPA 51B requires at least 10.7 m (35 ft)]. Again, it was unlikely that all the lint could actually be cleaned sufficiently to not pose a fuel risk given a viable ignition source.

The next step in the hazard analysis would have been to isolate the ignition source and fuel source by shielding, guarding, or protecting with some appropriate fire retardant barrier. The area below the mangle (and below the intended hot work location) should have been covered in this manner so that no sparks could fall to the floor and contact the accumulated lint. Safe practices also caution against work in areas adjacent to pipelines, conveyors, or ventilation ducts – anything that could convey a spark or heat to a distant fuel source. In this instance, immediately above the mangle were exhaust ports that apparently collected a spark from the arcing electrode and carried it to an area of accumulated lint within the ventilation system for the laundry area, which was linked to other parts of the ventilation system for the vessel. Safe practices require covering openings (doors, windows, hatches, scuttles, ventilation ducts) when hot work is to be conducted in the vicinity [again a typical distance is 10.7 m (35 ft.)].

A fire watch is an important part of the hot work permit system. A fire watch is a person that monitors the hot work and whose sole responsibility is to watch for fires started by the open flame, sparks, or hot slag from the work being completed. A fire
extinguisher or charged hose line should be in place for use in case of a fire during the completion of the work. Additionally, a fire watch is required to maintain the watch for 30 minutes after the hot work is completed to check and protect against smouldering fires.

Workers need to be trained on the importance of hot work procedures and precautions. Understanding the fundamental risks associated with hot work is an important part of this training. Undertaking work without authorization and proper permits can lead to unforeseen problems or even a major fire.

Had the proper hot work procedures been undertaken in this case, which should have included an assessment and authorization by someone other than the two maintenance workers, the repair work on the mangle equipment may not have been initiated without further precautions being taken.

Fire Brigade Actions

Shipboard fire fighting differs greatly from fire fighting conducted on land. While some tactics may be similar, the methods in which they are carried out must be adapted to the environment on board a ship. One of the major differences is that once all of the resources are utilized (personnel, equipment, etc.) additional resources could be hours away. NFPA 1405, Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires (1996 edition), covers the differing aspects of these two forms of fire fighting.

This guide identifies the elements of a comprehensive marine fire-fighting response program including, but not limited to, vessel familiarization, training considerations, pre-fire planning, and special hazards that enable land-based fire fighters to extinguish vessel fires safely and efficiently. In general, the practices recommended in this publication apply to vessels that call at United States ports or that are signatory to the SOLAS agreement.

There are many aspects of marine fire fighting that warrant special attention because of the unique environment encountered aboard a vessel. Ships often are compared to high-rise buildings. This is not an altogether inappropriate comparison. However, the ventilation of a vessel fire can be more difficult to achieve and the spread of a fire more difficult to check. The fire fighter’s natural response when confronted with a structure fire is to act immediately. This is because most structure fires exhibit similar characteristics that have been encountered before and thus provide a source of knowledge and experience from which to draw. However, a major fire aboard a ship seldom occurs, and very few fire fighters have experienced such a fire. Therefore, fires aboard ship should be approached in a quick but safe and prudent manner. Fire fighters have come to realize that, when approaching hazardous material incidents, it is preferable to proceed slowly rather than to react too quickly, thus increasing risks and jeopardizing success. This is also true when fighting vessel fires.
Unlike structure fires, hazardous material incidents, and many other fireground operations for which there is extensive written material available for fire service personnel to study, there is relatively little information available to land-based fire fighters concerning the management of a fire aboard a vessel. The absence of this type of information often leads fire fighters to apply strategies and tactics associated with structure fires to fires aboard vessels. Although these strategies and tactics are similar, it is important to recognize that there are distinct differences in the two types of fires.

To address this major void in knowledge and understanding of vessel fire-fighting procedures, the NFPA, at the request of, and in cooperation with, the United States Coast Guard (USCG) and with the assistance of the fire service and maritime communities, has undertaken the task of developing this guide for use by local fire-fighting organizations that could be confronted with a fire aboard a vessel.¹

In this incident, the ship’s fire brigade was notified of the fire by automatic alarms, initially from the laundry space and then from other adjoining areas where smoke and heat had spread. Brigade members and officers checked each of the locations, eventually finding the main body of fire on the aft mooring deck. Due to the amount of heat and smoke on the mooring deck, it was decided that the brigade would hold their positions at the bulkhead doors of MVZ# 1 and cool the wall at that location to prevent the fire from spreading out of the mooring deck. Other groups of brigade members were staged on the decks above and below the mooring deck to check for extension of the fire, and smoke spread and to provide or maintain the fire boundaries by cooling the surfaces being effected by the heat.

The efficient manner in which the brigade responded to and fought the mooring deck fire resulted in the localization of fire and smoke damage to the spaces immediately adjacent to the mooring deck. The outside assistance provided by the US Coast Guard and the private tugboats succeeded in cooling the metal surfaces on the stern of the ship and inside the mooring deck.

**NFPA 301**

NFPA 301, *Code for Safety to Life from Fire on Merchant Vessels* (1998 edition), takes the same approach to fire and life safety aboard merchant vessels as that derived from SOLAS requirements.

First, NFPA 301 was developed following the premise that through a combination of methods, both passive and active, a fire will be limited to the space or deck of origin.

The primary objective is to provide through various means, 100 percent self-sufficiency in extinguishing or controlling fires, thus protecting lives and property. Recognizing the unique operating environment, NFPA 301 utilizes various features of fire protection.¹

The Ecstasy fire highlighted the value of this approach. Even though the fire occurred shortly after the vessel got under way so that the vessel was still close to port, the additional response assistance that was provided only augmented the fire protection; it was not essential to the safety of the vessel or the passengers.

NFPA 301 limits the use of combustible finishes and requires the installation of fire detection and alarm systems throughout the vessel to protect accommodation, service, and storage spaces.

NFPA 301 also relies on the development of protective boundaries that limit the spread of fire. In SOLAS that is accomplished with the MVZ. In NFPA 301, this protective boundary is referred to as the horizontal exit.

In NFPA 301, the horizontal exit has been defined as an exit between adjacent areas on the same deck that passes through an A-60 Class boundary that is contiguous from side shell to side shell or to other A-60 Class boundaries.”

Horizontal exits provide protection against serious fire for a long period of time in addition to providing immediate protection from smoke. They are similar to MVZ but do not have the restrictions in length.

The cruise ship industry and U.S. Coast Guard are working with the International Maritime Organization to evaluate the classification of the mooring decks and to determine if further fire protection measures (i.e., automatic sprinkler protection and fire detection) are warranted.

NFPA 301 recognizes the importance of the human element in the overall protection scheme – the need for crew training and passenger instruction. The fire brigade’s response and ability to control the fire demonstrates their preperation.
Conclusion

The fire on the cruise ship Ecstasy resulted from an unsupervised cutting and welding operation and failure to follow established “hot work” guidelines.

Due to the prompt actions of the on-board fire brigade and the structural fire protection features of the vessel’s construction, the fire damage was limited to the aft mooring deck and adjacent vertical spaces. Due to the presence of the main vertical zone barrier, the fire did not spread beyond MVZ 1, limiting horizontal damage to that zone. Main vertical zones act as fire walls do in structures on land, compartmentizing a fire to limit damage and allow automatic suppression or manual fire fighting to control and extinguish the fire.

The activation of automatic sprinklers in the adjoining corridors, passenger accommodations, and common areas also assisted in limiting fire damage and controlling the spread of fire.

Shipboard fires, while somewhat similar to fires of similar products on land, must be fought in a different manner by the sole fire fighting force on board the ship. Additional resources can be miles and therefore hours away. The ship’s design and the tactics used by the brigade isolate the fire to allow for the extinguishment by automatic suppression and/or manual means such as extinguishers and hoselines.

Vessels are constructed with features that are designed to confine the fire within a compartment or a MVZ, allowing the fire brigade to control the fire within this limited area. SOLAS regulations outline these construction features.

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Limiting the use of combustible finishes and requiring the installation of fire detection and alarm systems throughout the vessel works to protect accommodation, service, and storage spaces.

The cruise ship industry and U.S. Coast Guard are working with the International Maritime Organization to evaluate the classification of the mooring decks and to
determine if further fire protection measures (i.e., automatic sprinkler protection and fire detection) are warranted.

NFPA 301 recognizes the importance of the human element in the overall protection scheme – the need for crew training and passenger instruction. The fire brigade’s response and ability to control the fire demonstrates their preparation.

A combination of built-in construction features and fire brigade actions of holding the fire in place while the construction features slowed and stopped the fire spread confined fire damage to a relatively small portion of the ship.
### NFPA Documents

<table>
<thead>
<tr>
<th>NFPA 301, Code for Safety to Life from Fire on Merchant Vessels, (shall be known as the Merchant Vessel Code)</th>
<th>The purpose of this code is to provide minimum requirements, with due regard to function, for the design, operation, and maintenance of merchant vessels for safety to life from fire and similar emergencies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFPA 1405, Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires</td>
<td>This guide identifies the elements of a comprehensive marine fire-fighting response program including, but not limited to, vessel familiarization, training considerations, pre-fire planning, and special hazards that enable land-based fire fighters to extinguish vessel fires safely and efficiently. In general, the practices recommended in this publication apply to vessels that call at United States ports or that are signatory to the Safety of Life at Sea (SOLAS) agreement.</td>
</tr>
<tr>
<td>NFPA 51B, Standard for Fire Prevention During Welding, Cutting, and Other Hot Work</td>
<td>This standard shall provide guidance for persons, including outside contractors and property managers, who manage, supervise, and perform hot work. This standard shall cover provisions to prevent loss of life and property from fire or explosion as a result of hot work in institutional, commercial, and industrial operations.</td>
</tr>
</tbody>
</table>
Figure 1: Location of Fire Outbreaks

Using information of reported fires and explosions on ships, from 1982 until the end of 1996, entered into Lloyd’s Register’s (LR) Casualty Database.

REGULATORY REQUIREMENTS - DO THESE ADEQUATELY REFLECT ACTUAL FIRE EXPERIENCE? By P. Mather and T.D.D. Strang, Lloyd’s Register of Shipping – Used with Permission
### Fire Integrity of Bulkheads Separating Adjacent Spaces

Table 3: Fire Integrity of Bulkheads Separating Adjacent Spaces

() Fire integrity of bulkheads separating adjacent spaces (cargo ships SOLAS Table 44.1)
(1) Fire integrity of bulkheads separating adjacent spaces (passenger ships SOLAS Table 27.1)
(1) Fire integrity of bulkheads separating adjacent spaces (LR SSC Rules)

<table>
<thead>
<tr>
<th>SPACES</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tr>
<td>Corridors</td>
<td>(2)</td>
<td>(C)</td>
<td>(B-0)</td>
<td>(B-0/A-0)</td>
<td>(B-0)</td>
<td>(A-60)</td>
<td>(A-60)</td>
<td>(A-60)</td>
<td>(A-60)</td>
<td>[A-10/A-20]</td>
<td>(A-15)</td>
</tr>
<tr>
<td>Open decks</td>
<td>(10)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ro-Ro cargo spaces</td>
<td>(11)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special category spaces</td>
<td>(12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Categories 1 to 10 for passenger ships are the same as for cargo ships, except as shown.
2. Categories 1 to 7 for LR SSC are the same as for cargo ships, except as shown.
3. (*) Where an asterisk appears in the table, the division is required to be of steel or other equivalent material but is not required to be of "A" class standard.
4. Alternative materials (for LR SSC [1]), sprinkler system to be provided - notes have not been included.

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**Fire Integrity of Bulkhead Separating Adjacent Spaces According to SOLAS Requirements**

**REGULATORY REQUIREMENTS - DO THESE ADEQUATELY REFLECT ACTUAL FIRE EXPERIENCE?** By P. Mather and T.D.D. Strang, Lloyd’s Register of Shipping – Used with Permission
REGULATORY REQUIREMENTS - DO THESE ADEQUATELY REFLECT ACTUAL FIRE EXPERIENCE?

P. Mather and T.D.D. Strang, Lloyd's Register of Shipping

SUMMARY

Using information of reported fires and explosions on ships, from 1982 until the end of 1996, entered into Lloyd’s Register’s (LR) Casualty Database, the relationship between actual fires and the measures prescribed in the standards for fire protection, detection, and extinction have been examined. The data is limited to LR’s classed fleet. Nevertheless, because of its size it is considered to provide a reasonable representation of the world fleet and, therefore, may be extended to other vessels. Any extrapolation of the data should take into account the vessels’ unique features, such as, layout, service, materials and construction. By comparing Rule requirements with the incidence of reported fires, with respect to whether the ship was at sea or in port, the location of the fire, source and contributory factors, the extinguishing medium used, and finally the severity of the fire, it has been possible to concluded that the various Rule and Regulation requirements do address the most frequently reported occurrences of marine fires. However, this should not be a signal for complacency. It is not intended to be an unqualified endorsement of marine fire regulations. Reference to Rules or Regulations or both may be read as meaning either LR classification, administration, of international requirements, unless it is specifically stated which requirements are being discussed. The limits of the investigation are acknowledged, in so far as the majority of the
ships in the database are, Safety of Life at Sea (SOLAS) 1974 Convention type ships \( \text{Ref. 1} \) although not exclusively. Also, the data was extracted from reports compiled by non-fire specialists. Therefore, a degree of caution was exercised when arriving at the conclusions expressed in the paper. Additionally, the validity of the conclusions may be challenged when extending those conclusions to other vessel types. However, the data and the statistical analysis show clearly those areas most exposed to one of the most feared hazards at sea, namely fire.
AUTHORS BIOGRAPHIES

Paul Mather is presently in charge of the Fire Group at Lloyd’s Register. His experience includes the offshore and shipping industries. Before joining Lloyd’s Register in 1980 he was a Naval Architect at Smith’s Dock Company Limited, Middlesbrough.

Thomas D D Strang is currently a senior surveyor within the Passenger Safety Group of Lloyd’s Register. Before joining the Passenger Group in 1994 he worked in Japan and the USA where he was mainly involved in surveying cruise ships. Prior to joining LR in 1984 he was with V.S.E.L.
1. INTRODUCTION

The standards give prescriptive requirements for passive fire resistance ratings, fire detection and extinction systems. The objective of this paper is to ask the question: do these prescriptive requirements adequately address the incidence of actual fires experienced on board ships?

In the Statistics section of the paper, an attempt has been made to answer the question raised above by analysing LR’s Casualty Database. A statistical analysis was carried out covering all vessel ship types in the database. This examined all the reported cases of fire. Each ship type was then examined. There were variations in the type of information that was available for each recorded fire, but the information has been conveniently grouped.

In the Fires Versus Prescriptive Standards section, the results of the reported fires are compared to the fire protection arrangements as required by the various standards. The fire safety requirements of SOLAS, LR’s Special Service Craft (SSC) Rules Ref. 2} and the High Speed Craft (HSC) Code Ref. 3} are compared.

Alternative fire protection solutions are considered in the Equivalency section. By examining the results and extrapolating for use on other vessel types we may consider fire safety arrangements alternative to those advocated by the Rules compromising safety. Additionally, LR’s SSC Rules and the IMO HSC Code have been considered.
Finally, the **Conclusion** section discusses the problems with prescriptive standards. As an alternative, consideration is given to a safety case approach because of the increase in vessel types and the wide range of construction materials. Nevertheless, it is concluded that the standards are addressing the most frequent occurrence of fires on ships.
2. STATISTICS

The LR Ship Casualty Database contains details of any reported fires and explosions (inter alia) that occur on LR classed vessels. In the majority of cases the actual raw data is obtained directly from the surveyors in the field, via the classification reporting system. Press articles and casualty returns, reported in Lloyd’s List and similar publications, are scanned as a secondary source of information.

As a condition of classification owners are required to inform LR of any damage that is sustained by their vessels, including damage caused by fire. Regrettably, not all fires are reported by the owners and details of these fires (of course) are not entered into the database. However, its is likely these fires are small and do not affect the overall results of the analysis.

Once an owner reports a fire, an LR surveyor is required to survey the vessel and report on the extent of damage caused by the fire, including details of the cause of the fire (if known). On receipt of the surveyor’s report, the data is then entered into the Casualty Database.

Surveyors are instructed to report fires and explosions, and to report the extent of damage and repairs. The surveyor’s report should include a completed standard data form, detailing the following information that will be entered into the Casualty Database:

(a) Date of incident.
(b) Incident type:
e.g. fire, explosion followed by fire, etc.

(c) Motion of ship:
   e.g. underway, anchored, alongside, etc.

(d) State of ship:
   e.g. in ballast, empty, loaded, etc.

(e) Ship operation:
   e.g. ballasting, bunkering, gas freeing, etc.

(f) Ship location:
   e.g. dry-dock, at sea, canal, in port, etc.

(g) Loss of life / number dead:
   e.g. yes or no / number.

(h) Pollution type:
   e.g. cargo oil, fuel, none, etc.

(i) Effect on ship:
   e.g. abandoned, temporarily disabled, towed, etc.

(j) Total loss type:
   e.g. sank at sea, grounded, wrecked, etc.

(k) Fire containment:
   e.g. extinguished, not contained, etc.

(l) Assistance required:
   e.g. none, fire pump, fire brigade, etc.

(m) Extinguishing method:
   e.g. hose, sprinkler system, hand extinguisher, etc.

(n) Extinguishing material:
   e.g. CO₂, water, halon, etc.

(o) Extinguishing time:
   e.g. less than 1 hour, 1-5 hours, 5-24 hours, etc.

(p) Heat source type:
e.g. spontaneous combustion, hot surface, lightning, etc.

(q) Contributory factor:
e.g. collision, sabotage, negligence, etc.

(r) Operation:
e.g. smoking, welding, gas cutting, etc.

(s) Combustible material:
e.g. fuel oil, soot, cargo oil, paper, etc.

(t) Material movement:
e.g. fuel oil overflow, cargo spillage, etc.

(u) Fault type:
e.g. short circuit, hydraulic oil leak, burst, etc.

(v) Fault location:
e.g. electrical equipment, hydraulic oil pump, cargo hose, etc.

(w) Fault case:
e.g. water leak, governor failure overspeed, etc.

(x) Seat of incident - hull:
e.g. accommodation, engine room, hold, etc.

(y) Seat of incident - machinery:
e.g. windings, crankcase, tube nest, etc.

(z) Machinery component:
e.g. port generator, main engine, starboard EGE, etc.

(aa) Damage degree:
e.g. minor, major, burnt out, etc.

(bb) Comments:
e.g. describe spread of fire, another comments or opinions, etc.

In order to compare the effect of the most recent fire safety standards on the incidence of fires, and to include as wide a range of experience as possible,
the input parameters for the interrogation of the database were as broad as possible with respect to vessel types. Additionally, there was no restriction placed on the service of the vessels. The following search criteria limits were applied:

- **Fires:**
  
  The database search was limited to fires. Only if an explosion was followed by a fire does the incidence of the explosion result in an entry in the data.

- **Vessels built between 1 January 1982, and 31 December 1996.**
  
  The range of dates was chosen to provide a large enough sample of vessels, and ensured the analysis was carried out on fires where the vessels were constructed to current fire safety standards.

All vessels, regardless of type or service, brought into class since 1 January 1982 have been included in the search. In addition to the SOLAS type ships, for example, tankers and general cargo ships, vessels such as yachts, pilot launches, tugs, fishing vessels, and semi-submersibles are also represented.

Because of the wide variety of vessel types it was decided to group together ship types whose function, and thus standard of safety was similar. This grouping provided a better population for the statistical analysis. The vessel types and vessel groupings chosen for the analysis are as follows:

1. Bulk Carrier
2. Cable
3. Cement Carrier
4. Chemical / Oil & Chemical / Gas Tanker
5. Container
6. Dock Ship
7. Ferry: Train/Vehicle/Passenger
8. Fishing Vessel: Stern Trawler
9. General Cargo / Refrigerated / Vehicle carrier
10. OBO Carrier
11. Offshore Supply Vessel / Tug / Fire Fighting
12. Oil / Caustic Soda Tanker
13. Oil Tanker / Asphalt / Bitumen
14. Passenger
15. Pilot / Patrol Launch
16. Research Ship
17. Ro-Ro / Container
18. Semi-submersible
19. Yacht
20. Air Cushion Vehicle / Hydrofoil
21. Barges / Pontoons
22. Dredges
23. Naval Vessels
24. Oil Storage Tanker

It should be noted not all vessel types experienced a reported fire incident, and therefore do not appear in Table 1, Reports of fires.

From the database, data entries have been conveniently grouped and reviewed, for each ship type and individual case, to provide wherever possible the following information:

(a) The ship motion:
   e.g. underway, port, anchored, etc.

(b) The location of the fire outbreak:
   e.g. accommodation, galley, etc.

(c) The heat source that initiated the fire:
   e.g. electrical, spontaneous combustion, etc.

(d) Any contributory factors that influence the fire:
   e.g. negligence, collision, sabotage, etc.
(e) The primary fire extinguishing medium (it being noted that in most fire situations a variety of hand held means will be utilised in addition to any fixed installation):
e.g. fire main, fixed gas system, etc.

(f) Fire containment:
e.g. additional help provided by either shore based organisations or water borne means, spread of the fire, etc.

(g) Any recorded loss of life or injury:

(h) The severity or degree of the fire. Data based upon a subjective assessment of the damage by the surveyor at the scene:
e.g. major, serious, sank at sea, etc.

Before analysing the information contained in the database, the limitations of the collected data should be clarified. The population is limited to LR classed vessels but, in view of the size of the LR classed fleet (see Table 2 Annual ship completions (LR classed)), they may be considered to be a reasonable representation of the world fleet. High speed craft are one notable exception in the data. Because the increase in the number of high speed craft has been relatively recent, not enough data is available for such craft. Therefore, the newly introduced HSC Code will not be represented in any data collected. The majority of ships examined are constructed of steel and are SOLAS Convention compliant.

It should be appreciated, for all the standard reporting procedures, that the information contained in classification reports for various reasons varies enormously. Also the consistency of the reporting may be open to question. Again there are many reasons for this. In some cases the reports are extremely detailed and it is possible to identify the source of the incident, reasons for its
occurrence, the extinguishing medium known, whether the fire was contained, etc. In another case the report might only contain a statement such as “fire occurred alongside in cargo hold and extinguished”. Data entry into the database will consequently be limited. Often this is because of the delay between the occurrence of the fire and the information reaching LR, and it may be sometime after the fire before a surveyor is able to report on that specific incident. In such cases, gathering information is extremely difficult, especially when the ship has already left the port where the incident occurred, and details are available only via agents etc.

Not all fires are recorded. The recorded fires tend to be only the major incidents. It is the author’s experience that the vast majority of minor fires that occur on ships (i.e. fires that cause only a very small amount of damage and no one is injured), are quickly extinguished, and never reported to either the insurers or the authorities. In deed, when the vessel is in port, practically the only time the incident is reported to the press is when the fire brigade or other shore based facilities are used. This appears to be supported by the reported incidence of use of portable extinguishers which would be expected to be used in nearly all cases for immediate first aid. This situation may change in the future as the introduction of the International Safety Management (ISM) Code {Ref. 4}and the implementation of shipboard safety management procedures will require any incident to be logged and reported.

It would be reasonable to expect more than the four reported fires in a galley. However, because the galley is manned when the main hazard is present, during cooking, any fire is quickly detected and extinguished. Also the galley is well equipped with fire extinguishing facilities.
Similarly, relatively few accommodation fires have been reported, 26 in total. Clearly the accommodation has a higher fire risk; it is where personnel are concentrated owing to work and recreational activities, including smoking. Additionally, there are many combustible materials in these spaces. However, because the accommodation is a manned area, detection and extinction of a fire is usually quickly dealt with, thus preventing any escalation of a fire. It is suspected that the majority of galley and accommodation fires are quickly detected and extinguished with relatively little damage and hence never reported.

Also the surveyors attending the ship after a fire are not fire specialists. Establishing the cause of a fire may be difficult for an expert let alone a non-specialist. Attributing a cause, especially if negligence is suspected, presents the surveyor with a potential problem. What is the evidence and can the evidence be substantiated? Consequently, this probably accounts for the relatively small number of reported cases where the heat source contributory factor to the fire is reported. Nevertheless, 29 cases were attributed to negligence and one case to sabotage. Soot deposits, fuel and lubricating oil from burst pipes and leaking joints accounted for 65 and 63 cases respectively. Under the circumstances this probably represents a reasonable return when establishing contributory factors.
From the data obtained from the Casualty Database, the following tables and figures have been complied:

- **Table 1: Reports of Fires;** shows the distribution of incidents by ship type, giving specific details of the locations of the fire, and where known the extinguishing medium used. The temptation to add to the data sets to provide a more comprehensive picture in Table 1 has rightly been resisted. Only information that has actually been supplied by the attending surveyor has been recorded in the database.

- **Figure 1: Location of Fire Outbreaks;** shows the distribution of fire locations for all ship types.

- **Figure 2: Heat Source;** shows the distribution of heat sources.

- **Figure 3: Contributory Sources;** shows some contributory factors in the causes of fires.

- **Table 2: Annual Ship Completions (LR Classed);** shows a breakdown of the yearly completions of ships in the date range of the search of the database. Also, for each ship type, the table contains; total completions for the range dates, total ship years, total recorded fires, percentage of fires per ship type, and finally the incidence of fires per ship year.

- **Figure 4: Percentage Incidence of Fire per Ship Year**

The analysis clearly indicates that the area where the most fires can be expected are the machinery spaces, despite the numerous fire safety measures.
provided in these spaces. From the data it can be seen that some 71% of the reported fires occur in the machinery spaces. In order to further examine the fire incidence in machinery spaces, and try to be more specific with the actual locations within the space, a further examination of the records was carried out, and the following breakdowns made.

Of the fires recorded as having occurred in engine rooms and machinery spaces, 102 were actually Boiler Fires (including economisers). Of these, 22 were reported to be caused by hot surfaces, one by Spontaneous Combustion, 8 by overheating of which 7 were attributed to water shortage, 5 due to FO leakage, including 3 pipe breakages, and most significantly 60 due to soot deposits.

There were 108 fires in main engine rooms, of which 57 were attributed to hot surfaces and 20 to electrical causes. There are 48 recorded incidents of FO/LO leakage having a contributory effect of which 40 were directly linked to pipe failure.

Of the remaining spaces that make up the machinery space group, for example pump rooms and auxiliary machinery spaces such as steering gear rooms, some 13 incidents were recorded. These consisted of 2 fires due to overheating of a pump bearing, 4 caused by electrical faults, one by welding, and with 3 recorded incidents of FO/LO leakage being a contributory factor.

From this analysis it can be seen that the majority of boiler and economiser fires can be attributed to soot build up, and 56 machinery space fires can be attributed to oil leaks, and in particular pipe and joint failures.

Whilst standards exist to regulate the design and installation of oil fuel, (e.g. SOLAS Chapter II-2 Regulation 15; Arrangements for oil fuel, lubricating oil
and other flammable oils), there are no specific standards that address soot build up. Possibly this is an area for a suitable standard to be developed.

Electrical fires are identified as being directly responsible for 33 fires. While in port, the crew levels onboard vessels tends to be reduced and the observance of safety procedures that would be observed at sea are possibly more relaxed. Welding and gas cutting equipment used during repairs, carried out in port, account for 18 fires. Therefore, it is no surprise that 31% of all fires reported occur in port. Fire was directly the cause of one fatality and 2 serious injuries.

The assessment as to the intensity or degree of a fire, as reported, should be treated with some caution, as the basis of assessment to a certain extent is subjective. However, it is interesting to note that in only two cases has a vessel’s sinking been as a result of a fire. The significant number of ships that were temporarily disabled corresponds closely to those incidents where the engine room fixed gas installation was activated.

Examining Figure 4, in order to determine whether any type of ship is more prone to fire than any other, it can be seen that the only vessel type that appears more prone to fire is the semi-submersible. Further examination of the facts reveals that only three semi-submersibles have been constructed within the time frame examined and that between them they have experienced 5 fires. Ignoring the semi-submersibles, each of the remaining ship groups reveal an incidence of fires per ship of less than 4%. Further, when OBO’s, oil and caustic soda tankers, ships with small populations, are ignored the incidence of fires per ship is less than 2%. For all ships the incidence of fire per ship year is 0.81%.
3. FIRES VERSUS PRESCRIPTIVE STANDARDS

Before making the comparison of actual fires and the requirements of the standards, the different rules have been compared to see if there is any consensus with respect to fire protection. Table 3, Fire integrity of bulkheads separating adjacent spaces, compares a selection of the different standards. It is not the intent of this paper to analyse in detail the various rule requirements; comparison is made merely to establish if there are any major philosophical approach differences to fire protection between the standards. A review of Table 3 shows that there are no major differences in approach between the standards considered. For example, all the standards identify engine rooms, and galleys as requiring A60 and A0 class ratings respectively. The rules, with the notable exception of the HSC Code, identify the category of the space and then the adjacent category space and establish a rating for the divisions, regardless of which side the fire is from. An example of this would be a machinery space to an accommodation space requiring an A-60 class division. That is, the A-60 class division is to be maintained whether the fire is in the accommodation space or the machinery space. The HSC Code, however, takes a different approach to the same configuration as just described, and requires 60 and 30 minutes structural fire protection times for the separating bulkhead. That is to say, the bulkhead is to afford 60 minutes protection from the effects of fire in the machinery space, but need only be capable of providing 30 minutes protection should the fire source be within the accommodation space. Such a distinction would not be so important to an A-60 class certified (without restrictions) steel and mineral fibre “standard type SOLAS bulkhead”. However, it may have an important influence on, say, an aluminium core type bulkhead that is suitably insulated on both faces to withstand different fire load exposures. One face, the machinery side, is
required to provide 60 minutes fire protection and the other face, the accommodation, would afford 30 minutes fire protection. Additionally, regardless from which side the fire exposure is from, the aluminium core temperature is required not to rise more than 200 degrees C above the ambient temperature in accordance with the fire resistance duration.

The HSC Code approach is more precise in categorising the fire hazard in only one space than the other rules. Nevertheless the Code then goes a further step than the other rules by stating a particular fire rating for that hazard. This approach in effect acknowledges the potential range of different material that may be used in the construction of craft.

From the analysis of the data it can be seen that the incidence of fire is indeed addressed by the prescriptive standards for all vessels.
4. EQUIVALENCY

What are the criteria for equivalency? It may be considered an arrangement that offers the same or very similar level of fire protection. What does this really mean in practice? Does it mean, for example, in the case of a rule requirement for A60 class, a system that provides 60 minutes integrity protection, and on the unexposed side a temperature that does not exceed 140 degrees C. for 60 minutes due to the insulation protection provide (A60 class definition). In this case the “equivalency” means the A60 class may be achieved by various fire resistance systems. Alternatively, a water spray system of sufficient flow rate to provide sufficient cooling to the bulkheads and decks, or a combination of passive fire protection and water spray, may be used.

What the authors mean by “equivalency” is: providing a level of fire resistance commensurate with the fire hazard. Before defining further this rather nebulous statement, the idea of a fire safety concept has been expanded upon. Fire safety, in this context, means providing a level of protection from the effects of a fire sufficient to permit a course of action by the craft’s crew or the crew and passengers. The action taken by the crew may be fighting the fire with a view to containment and eventual extinction of the fire. In this case adequate fire detection, alarm and fire fighting arrangements would be required.

Alternatively, the appropriate action may be abandonment of the craft by crew, or crew and passengers. In this particular case adequate passive fire protection would be required for a suitable duration and extent to permit safe mustering, entering into lifeboats, and abandonment of the mother craft.
Suitable detection and alarm systems would need to be provided in such cases. Additionally, careful consideration would need to be given to the layout of the escape routes.

Safety measures for high speed craft, adopted by the 1994 SOLAS Conference (May 1994), make the HSC Code mandatory. This Code entered into force, 1 January 1996, and applies to high-speed craft built on or after that date.

The HSC Code has been prepared in recognition of the growth, in size, types, and number of high-speed craft and is intended to facilitate the future research and development of fast sea transportation while maintaining a high degree of safety for passengers and crew. The traditional method of regulating ships should not be accepted as being the only possible way of providing an appropriate level of safety, nor should it be assumed that another approach using different criteria could not be applied. Numerous new designs of marine vehicles have been developed and put in to service; while these do not fully comply with the standards for steel ships, they have demonstrated an ability to operate at an equivalent level of safety when engaged on restricted voyages under restricted operational weather conditions and with approved maintenance and supervision schedules. The Code recognised that safety levels can be significantly enhanced by the infrastructure associated with regular service on a particular route, whereas the conventional ship safety philosophy relies on the ship being self-sustaining with all necessary emergency equipment being carried on board. The safety philosophy of the Code is based on the management and reduction of risk as well as the traditional philosophy of passive protection in the event of an accident. Management of risk through accommodation arrangement, active safety systems, restricted operation, quality management and human factors
engineering should be considered in evaluating safety equivalent to current conventions. Application of mathematical analysis should be encouraged to assess risk and determine the validity of safety measures. Taking into account that a high-speed craft is of light displacement, the HSC Code allows for the use of non-conventional shipbuilding materials. Similarly, LR’s SSC Rules make provisions for alternative materials (to steel and mineral wool), provided the standard of fire safety is not compromised.
5. CONCLUSIONS

This paper deals primarily with fire safety standards that are laid down in various Rules and Regulations. These standards are prescriptive. The problem with prescriptive standards is that they tend to inhibit innovation and are slow to respond to developments. They require a level of safety that is the same for all situations and for all vessels because they are influenced by past experience. No account is taken of specific, and indeed what may be unique features, of any one vessel. Further, this uniformity is extended when comparing the requirements of the different standards. That is to say, there is very little difference in the fire safety standards laid out in the SOLAS Convention, the HSC Code, and those of LR’s SSC Rules. Not unreasonably, the standards primarily require fire safety for high risk areas such as engine rooms to be protected by structural fire resisting divisions, detection and extinguishing systems. Furthermore, the importance of human actions is not generally considered in the standards, although this aspect will be addressed to a certain extent by the ISM Code.

The standards generally divide the fire safety requirements in three main parts. First the design requirements for fire extinguishing and detection systems that can apply to any vessel type. For example, engine room fire extinction and detection systems are basically similar, and not dependant on vessel type, construction, or service. Secondly, structural fire protection divisions are assigned a fire resistant rating that is based on the potential fire risk of the adjacent spaces. Section 3 has shown, that despite minor differences, the assessment of risk assumed by the different sets of standards is consistent for similar spaces on different ship types. Finally there are requirements for cargo area fire extinction and detection that are ship type specific. Typically these
will consist of fixed gas installations on cargo ships, automatic sprinkler systems on passenger vessels, and inert gas and deck foam systems on tankers, together with any required detection system.

Examination of the statistics shows that the assessment of the hazards and their associated risk, assumed by the standards, is reflected in the actual fire experience, see Figure 1. Indeed, historically the development of the prescriptive fire requirements contained within the rules and regulations tends to follow major maritime incidents. Regrettably, these are usually those where a significant level of mortality has occurred. It is, therefore, concluded that presently the current prescriptive standards available do, by their very nature, reflect actual fire experience and this is well supported by the evidence from the LR Fire and Explosion Casualty Database presented here. This is particularly true for conventional ships in compliance with SOLAS or Classification Rules. It is not possible to make a similar conclusion for craft built in compliance with the HSC Code because the Code has not been in force long enough. The same can be said of craft built for compliance with LR’s own SSC Rules. It is, however, not unreasonable to assume that the trends that are indicated from the study will be repeated on these types of craft. Further, this assumption is supported by the fact that the experience gained from conventional vessels, i.e. SOLAS compliant, has been extrapolated to the standards that cover other vessel and craft type for example, the IMO, HSC Code, the Marine Safety Agency (MSA) Megayacht Rules Ref. 5 and LR’s SSC Rules. The human element also has a part to play in fire safety in both conventional vessels and less conventional craft. After all, the personnel and companies operating the less conventional craft are often the same as those who operate conventional ships. Crew training has an important part in ensuring safe operations. In this respect it is too early to
see whether the ISM Code, which is compulsory for HSC and will shortly be for all vessels, will have any effect on improving fire safety. To reiterate, it has been concluded that, in the main based on the available data, the various standards do in fact address the potential fire hazards that may be encountered on a vessel. However, as has been previously stated, this is not a reason for self congratulation or complacency. Too many fires still occur, and the potential for a major disaster remains ever present. Harvey (Ref. 6) noted that, despite significant changes to statutory regulations over the years (usually regarded as improvements), the occurrence of fires in ships and the resultant financial losses incurred has increased and not decreased as might be expected. It is interesting to note that from the population examined in this study that after showing an initial increase in the fires per year, the incidence of fires has recently begun to decrease, see Figure 5, Fires per år. The data reveals that the age of ships does not effect the incidence of fire. It is important to note that there are many recorded incidents of brand new ships suffering fires within a few months of entering service - perhaps not enough crew familiarity with the equipment?

The basic premise of all the standards is the same: they are all based on past experience. Is there anything wrong in this approach? The results, admittedly primarily of SOLAS convention type ships, would suggest not. After all it is reasonable to make the assumption that, if engine rooms are the most hazardous place on a 100,000 tonne dead-weight tanker, what is so different on an 80 metre yacht, other than scale? Therefore, taking the assumption further, it seems reasonable that rule makers should extrapolate their experience to all vessel types and sizes.
60 Minutes fire protection for a tanker engine room is an accepted standard, but for a yacht it may be reasonably argued, for example, that 15 minutes fire protection is more than adequate, because of the size of the yacht, the reduced numbers of personnel, and easier communication.

That is all well and good. However, by definition non conventional craft are different. They are made of non conventional shipbuilding materials. Their layouts vary. The number of crew are small. Having sited, very generally, some of the differences, is the likelihood of fire on such a craft any less? The answer must be no. In fact, because of the materials that are being used, the effects of a fire are more likely to be catastrophic than with a conventional ship and conventional shipbuilding materials. An escalation of a fire on a small craft would give the crew or personnel no alternative but to abandon the craft. This of course is the main argument offered by builders and designers of smaller craft. That is to say, if a fire cannot be extinguished by a portable fire extinguisher, the only course of action is to abandon the craft.

The authors’ view is that any vessel regardless of size or service should be provided with a reasonable level of fire safety. The problem is to decide what is a reasonable level of fire safety. Service limits in the context of fire safety generally would not justify any relaxation of the fire safety requirements for that craft. Except when a service restriction would allow the craft quickly to reach a place of refuge in order to evacuate the craft or obtain assistance.

While it is not the intention of this paper to provide details of individual fire cases, because of confidentiality issues, there are some important questions raised by examining the records in more detail.

(1) Negligence:
Care must be taken when attributing the cause of a fire. A negligent act would only be reported when there is supporting evidence that may be substantiated. There are few (29 of 308) cases where negligence has been reported as being a contributory factor in the start of a fire. This is because of the nature of the classification reporting system which deals only in facts as reported to the surveyor or directly witnessed by him. Blame is not attributed as this often requires a subjective judgement to be made about an individual or organisation, and has obvious legal implications. However it can reasonably be assumed that negligence is the reason for many more fires. Negligence manifests itself not just in the form of the obvious discarded cigarette but also in the form of poor maintenance. The significant occurrence of fires due to oil leaks and soot deposits indicates that maintenance needs to be improved. This is not something that has been traditionally regulated from a fire perspective, but the introduction of the ISM code and the Seafarers’ Training, Certification and Watchkeeping (STCW) Code [Ref. 7] should both have an impact on these incidents.

(2) Detection:
Few reports detail how the fire was initially detected, therefore it is difficult to judge the effectiveness of any fire detection system fitted. However, as the majority of fires occurred in engine rooms, many of these rooms are fitted with fire detection systems to allow for the notation UMS (Unmanned Machinery Space), and, as in nearly all cases the fires were extinguished in reasonable time, it is concluded that the detection systems were effective.

(3) Soot Deposits:
Of the 220 fires recorded as starting in Engine rooms, some 102 were actually boiler or economiser fires. Of these, in 60 cases soot deposits were reported to have either been the cause or a contributory factor. Although most fires of
this type can be contained by the boiler/economiser enclosure and allowed to burn out, this is not always so. This is a case where the standards could be improved, either in the design or maintenance of the installations particularly when you consider the financial aspects of loss and replacement of equipment.

The proposition and the title of the presentation is “Regulatory Requirements: Do These Adequately Reflect Actual Fire Experience?”. The evidence would suggest that statutory standards do address the hazard of fire on SOLAS type ships. There is insufficient data to support one way or the other an argument for other vessel or craft types. However, it is a reasonable to conclude that similar standards as those applied to SOLAS type ships when extrapolated to smaller ships would be more than adequate for those other craft types and some would argue are much too onerous. There is an argument for moving towards more of a safety case regime. However, regulators should be cautious of this approach because, as the analysis has shown existing standards are addressing those areas where fires frequently occur on ships. It is possibly the level of fire protection that needs further consideration.

This section started by discussing the problems with prescriptive standards. Notwithstanding those problems, the conclusion is that prescriptive Rules and Regulations do address the most frequent occurrences of fire. Nevertheless, regulators are faced with the difficulty of ensuring that the standards are effective and relevant, particularly with the proliferation of different vessel types and materials used in their construction. Hence, the argument for a safety case approach becomes ever more relevant. Provided that vessel safety can be enhanced by adopting the safety case approach, then there must be a place for such a procedure.
ACKNOWLEDGEMENTS

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REFERENCES

2. Lloyd’s Register’s Rules and Regulations for the Classification of Special Service Craft.
<table>
<thead>
<tr>
<th>Table 1: Reports of Fires</th>
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</thead>
<tbody>
<tr>
<td><strong>Ship motion:</strong></td>
</tr>
<tr>
<td>Under way</td>
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<tr>
<td>Port</td>
</tr>
<tr>
<td>Anchored</td>
</tr>
<tr>
<td>New Construction</td>
</tr>
<tr>
<td><strong>Location of fire outbreaks:</strong></td>
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<tr>
<td>Accommodation</td>
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<tr>
<td>Galley</td>
</tr>
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<td>Machinery spaces / pump room</td>
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<tr>
<td>Electrical installations</td>
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<tr>
<td>Funnels and uptakes</td>
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<td>Stores</td>
</tr>
<tr>
<td>Oil tanks</td>
</tr>
<tr>
<td>Cargo space</td>
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<td>Deck Area</td>
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<td><strong>Heat source:</strong></td>
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<tr>
<td>Hot surface</td>
</tr>
<tr>
<td>Scavenge space</td>
</tr>
<tr>
<td>Repairs/cutting/welding</td>
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<tr>
<td>Cigarette/Match</td>
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<td>Cargo/Coal</td>
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<td><strong>Heat source contributory factor:</strong></td>
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<td>Negligence</td>
</tr>
<tr>
<td>Collision</td>
</tr>
<tr>
<td>Sabotage</td>
</tr>
<tr>
<td>Soot deposits</td>
</tr>
<tr>
<td>F.O./L.O. (burst pipes, joints etc)</td>
</tr>
<tr>
<td><strong>Fire extinguishing:</strong></td>
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<td>Allowed to burn</td>
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<td>Fixed water - main/sprinkler</td>
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<tr>
<td>Fixed gas</td>
</tr>
<tr>
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</tr>
<tr>
<td>Fixed dry powder</td>
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<td>Major/serious</td>
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<tr>
<td>Sink at sea</td>
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<tr>
<td>Temporarily Disabled</td>
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<tr>
<td>Totals</td>
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Table 2: Annual Ship Completions (LR Classed)

<table>
<thead>
<tr>
<th>Year</th>
<th>Bulk Carrier</th>
<th>Cable</th>
<th>Cement Carrier</th>
<th>Chemical Tanker/Oil/Chem. Tanker</th>
<th>Container</th>
<th>Dock Ship/Deck Cargo</th>
<th>Fishing Vessels, Stern Trawler</th>
<th>General Cargo/Refrigerated/Vehicle carrier</th>
<th>LCT/Combi Stow Carrier</th>
<th>Offshore Supply Vessel/Fire Fighting</th>
<th>Oil/Caustic Soda Tanker</th>
<th>Oil Tanker/Asphalt/Bitumen</th>
<th>Passenger</th>
<th>Pilots/Passenger Launch</th>
<th>Research Ship</th>
<th>Ro-Ro/Container</th>
<th>Tugs</th>
<th>Semi-submersible</th>
<th>Yacht</th>
<th>Air Cushion Vehicle/Hydrofoil</th>
<th>Barges/Pontoons</th>
<th>Dredgers</th>
<th>Naval Vessels</th>
<th>Oil Storage Tanker</th>
<th>Annual Totals</th>
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Total Completions: 535, 10, 13, 244, 180, 32, 177, 254, 573, 28, 851, 14, 380, 88, 283, 38, 79, 3, 49, 46, 320, 58, 4, 24, 4283

Total Ship Years: 551, 10, 13, 244, 180, 32, 177, 254, 573, 28, 851, 14, 380, 88, 283, 38, 79, 3, 49, 46, 320, 58, 4, 24, 4283

Total recorded fires: 551, 60, 135, 181, 117, 308, 1552, 2072, 4876, 303, 777, 126, 527, 525, 2590, 360, 761, 41, 171, 537, 3502, 404, 32, 170, 57808

Percentage fires per ship: 10.64%, 10.06%, 9.02%, 11.67%, 9.38%, 4.52%, 2.76%, 13.61%, 32.14%, 1.41%, 28.57%, 13.68%, 10.23%, 0.71%, 2.63%, 15.19%, 166.67%, 2.04%, 2.17%, 0.60%, 0.00%, 0.00%, 0.00%, 0.00%, 0.00%, 7.19%

Incidence of fire per ship year: 1.05%, 1.21%, 1.79%, 0.97%, 0.52%, 0.34%, 1.60%, 2.97%, 0.15%, 3.17%, 1.59%, 1.71%, 0.48%, 0.28%, 1.57%, 12.20%, 0.58%, 0.19%, 0.00%, 0.00%, 0.00%, 0.00%, 0.81%
Table 3: Fire Integrity of Bulkheads Separating Adjacent Spaces

- Fire integrity of bulkheads separating adjacent spaces (cargo ships SOLAS Table 44.1)
- Fire integrity of bulkheads separating adjacent spaces (passenger ships carrying not more than 36 passengers SOLAS Table 27.1)
- Fire integrity of bulkheads separating adjacent spaces (LR SSC Rules)

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Notes:
1. Categories 1 to 10 for passenger ships are the same as for cargo ships, except as shown.
2. Categories 1 to 7 for LR SSC are the same as for cargo ships, except as shown.
3. (*) Where an asterisk appears in the table, the division is required to be of steel or other equivalent material but is not required to be of A-class standard.
4. Alternative materials (for LR SSC [], sprinkler system to be provided - notes have not been included.
Figure 1: Location of Fire Outbreaks

No. of Incidents

Location

- Deck Area: 5
- Cargo space: 47
- Oil tanks: 2
- Stores: 0
- Funnels and uptakes: 9
- Electrical installations: 7
- Machinery spaces / pump room: 220
- Galley: 4
- Accommodation: 26
Figure 2: Heat Source

Heat Source

- Outside the ship: 4 incidents
- Cargo/Coal: 8 incidents
- Cigarette/Match: 3 incidents
- Repairs/cutting/welding: 18 incidents
- Scavenge space: 11 incidents
- Spontaneous combustion: 15 incidents
- Electrical: 33 incidents

Recorded No. of Incidents
Figure 4: Percentage Incidence of Fire Per Ship Year

- Oil Storage Tanker: 12.20%
- Naval Vessels: 0.58%
- Dredgers: 0.28%
- Barges / Pontoons: 0.08%
- Air Cushion Vehicle/Hydrofoil: 1.57%
- Yacht: 1.71%
- Semi-submersible: 1.59%
- Ro-Ro/Container: 3.17%
- Research Ship: 2.97%
- Pilot/Patrol Launch: 1.60%
- Passenger: 0.97%
- Oil Tanker/Asphalt/Bitumen: 0.34%
- Oil/Caustic Soda Tanker: 0.52%
- Offshore Supply Vessel/Tug/Fire Fighting: 0.97%
- OBO Carrier: 1.79%
- General Cargo/Refrigerated/Vehicle carrier: 1.71%
- Fishing Vessels: Stern Trawler: 1.21%
- Ferry: Train/Vehicle/Passenger: 1.48%
- Dock Ship / Deck Cargo: 1.52%
- Container: 1.05%
- Chemical Tanker / Oil & Chem. Tanker
- Cement Carrier
- Cable
- Bulk Carrier
Figure 5: Fires per Year

The graph shows the number of fires per year from 1980 to 1998. The number of fires fluctuates over these years, with peaks in 1992 and 1994, and a significant drop in 1996 and 1998. The number of fires ranges from 5 in 1980 to 39 in 1994.