Divisional Inquiry Report
815-09-01

INCIDENT INFORMATION

Vessel/Terminal Name: Spirit of Vancouver Island

Incident Type: Fire – Auxiliary Machinery Space

Incident Date: 9th Oct 2009

INVESTIGATION INFORMATION

Chair:

Darren Johnston, Director – Safety

Original Signed By	**28 Nov 2010**
(Chair's Signature)	*(Date)*

Panel Members:
- Master (SWB)
- Engineering Rep (BCFMWU)
- Director, Fleet Performance
- Director, Employee Relations (SWB)
- Director, Risk & Insurance

Interviews:
- Master
- Chief Engineer
- Chief Officer
- 1st Engineer (GY)
- 2nd Officer
- 2nd Steward
- 3rd Engineer (GY)
- 3rd Engineer (1)
- 3rd Engineer (2)
- 3rd Engineer (3)
- Deckhand (2)
- Deckhand (4)
- Deckhand (5)

Written Statements:
- Master

APPROVAL

- Convening Authority

Original Signed By	**17 Dec 2010**
(Convening Authority's Signature)	*(Date)*

Date of Incident: 9th Oct 2009

Location of Incident: Berth 1 – Swartz Bay Terminal

Type of Incident: Fire – Auxiliary Machinery Space

Section 1 - Incident Summary

1.1 An Auxiliary Machinery Space (AMS) fire onboard M/V Spirit of Vancouver Island (SOVI) on the morning of 9 October 2009 resulted in severe damage to the Standby Generator (SG) controls cabinet, external flex hoses, tubing, gauge lines and attached devices. There was also damage to cabling in wiring raceways adjacent to the engine. No fatalities or injuries resulted from this incident; however, the ship was rendered unserviceable for over one month whilst repairs were conducted.

1.2 The incident occurred onboard SOVI at the Swartz Bay Terminal (SWB) in Berth No.1 on a scheduled 'drill morning'. On drill mornings, the Engineering graveyard (GY) shift starts the plant while the incoming AM shift arrives early to participate in the drill. At the time of the incident the ship was the primary (No. 1) ship operating normal service on Route 1 between SWB on Vancouver Island and Tsawwassen Terminal in the Lower Mainland.

Section 2 – Incident Narrative

Sequence of Events

2.1 The ship berthed at 21:36 in the evening of 8th October. The GY shift took responsibility for the safety and security of the ship upon assuming their GY shift. During the GY shift a number of tasks were carried out including shutting down the main propulsion, conducting routine rounds of the ship, changing a bow door hydraulic ram (which took most of the shift) and resetting the Main Engine (ME) clutches. The GY shift is responsible for starting the transition from shore power to ship power each morning. The transition is done using the SG in parallel with shore power until the shaft generators are ready to take the ship's power load (see *Section 3: System Configuration*).

2.2 At approximately 05:20, the start up of the SG was initiated by the GY 1st Engineer. A pre-start walk around visual inspection was conducted and the SG was started and put on load at approximately 05:21.

2.3 After the SG was placed on load the GY 3rd Engineer did a complete walk around visual inspection of the engine and noticed nothing unusual. Upon completion of his rounds in the AMS, he left the compartment, closing the door to the AMS and proceeded through the Main Machinery Space (MMS) to the crew mess room.

2.4 At 05:29, heat detectors in the AMS triggered a fire alarm alerting the vessel crew. A fire burning intensely at the top of the SG was immediately visible on the CCTV monitor in the Machinery Control Room (MCR).

2.5 The GY 1st, located in the MCR and preparing for main engine start up, momentarily thought that the drill had started early. The GY 3rd, hearing the alarm from the crew mess room walked into the MCR and immediately saw the fire on top of the SG on the CCTV monitor at the machinery control console. The Chief Engineer (CE) of the AM shift, who had just arrived in the

MCR, assumed command of the incident. Over the phone to the Bridge he ordered the watertight door between the AMS and the MMS to be closed.

2.6 Fuel supply to the AMS was immediately shut off and the engine stopped at 05:31. The GY 3rd recommended and received approval to commence boundary cooling by activating the main car deck sprinklers (Zones 10/11) directly above the AMS which he immediately did. Having ordered the remote shut off of fuel to the engine, the CE directed that the compartment be further sealed off by closing the dampers and ventilation.

2.7 The fire was localized on the free-end of the engine, fed initially by sprayed and pooled fuel at the engine top followed by prolonged combustion of spilled fuel at the base of the engine. Heat and smoke radiated upwards involving the entire compartment at the mezzanine level. There were no personnel in the compartment at the time.

2.8 At 05:32 the Bridge sounded the General Alarm, amplified by "this is not a drill". By 05:40 the BCF Operations & Security Centre was notified and confirmation was received from the SWB control tower that the North Saanich Fire Department was responding.

2.9 A CO2 System Fault alarmed momentarily at 05:34. It was noted that the 'CO2 available lights' to all machinery spaces (except bow thruster) were out. It was still assumed that the activation switches in the stairwells were available, however, at approximately 06:30 a team was dressed in fire fighting rig and sent to the shaft gland compartment to investigate. They discovered that the CO2 bottles in the CO2 room were leaking. The door was shut, the Incident Commander (CE) was notified and instructions were issued for all personnel to remain clear of the stairwell leading to the CO2 compartment lobby unless equipped with breathing apparatus.

2.10 Throughout the morning, the exact status of the CO2 system remained unknown until it was determined that the CO2 "A" valves had activated, charging the manifold up to the "B" valves. Accordingly, appropriate precautions were taken and regular air quality monitoring of the adjacent compartments was conducted throughout the day using PHD5 gas detectors. The CO2 system was fully discharged into the AMS later in the day to eliminate further risk from this compromised system.

2.11 The Chief Officer (CO) had arrived onboard early and was conducting upper deck rounds between 05:00-05:30 prior to the arrival of Deck Department personnel for drills. At the same time on the Bridge, the 2nd Officer was conducting pre-sail checks when the fire alarm sounded at 05:29. He immediately called the CO on the radio to report the location of the fire and then responded to a request from the MCR to activate the watertight doors.

2.12 The CO, conducting pre-sail rounds of the ship when the alarm was raised, immediately proceeded via the midships stairwell to lead the emergency response by establishing a staging area on the main car deck adjacent to the stairwell. He assembled a three person team consisting of Deckhand 1 and Deckhand 2 under the control of the AM 3rd Engineer 1. All were dressed in fire fighting rig and sent to the shaft gland compartment, aft of the AMS, to establish a boundary and take bulkhead temperature readings using the infra red heat detection device.

2.13 Although only limited recordings were taken of temperature readings observed, most reports were that bulkhead temperatures at approximately 05:45-05:50 (within 15-20 minutes of ignition) had peaked at around 70-80 degrees celsius and dropped to around 40 degrees celsius by approximately 06:10. After taking initial temperature readings and confirming that the fire was not spreading aft, two members of the team returned to the staging area leaving Deckhand 1 in position as the boundary cooler in the shaft gland space. The temperature on the car deck was checked by hand and found to be cool.

2.14 When they arrived at the staging area Deckhand 2 had no air remaining in his breathing apparatus so the CO assembled the AM 3rd Engineer 1 and Deckhand 3 as a team and dispatched them to the MMS in order to take bulkhead temperatures and establish a boundary forward of the AMS. Throughout this period of initial response the CO was in communication with the CE in the MCR.

2.15 The team sent to the MMS found bulkhead temperatures to be similar to those discovered on the aft bulkhead. The AM 3rd Engineer 1 left Deckhand 3 as the forward boundary cooler and returned to the staging area where AM 3rd Engineer 2 and two new Deckhands 4 & 5 were dressed and awaiting direction. Also present in support were two members of the North Saanich Fire Department, a Fire Chief and a Fire Fighter.

2.16 At approximately 08:11 the North Saanich Fire Fighter proceeded to the MMS with the AM 3rd Engineer 2 and Deckhands 4 & 5 in order to assess the bulkhead temperatures using the North Saanich thermal imaging camera (TIC) while the Fire Chief joined the CE in the MCR. Shortly thereafter a report was passed from the team in the MMS that they had entered the AMS and determined the fire to be out. This report surprised both the CE and the Fire Chief, neither of whom had given direction to enter the AMS. Orders were given by the CE to exit the AMS.

2.17 The AM 3rd Engineer 1 and the Fire Fighter reported their findings to the MCR, specifically that the fire was out and that they had heard the sound of running machinery inside the AMS. Shortly before 10:00 the CE directed the AM 3rd Engineer 1, accompanied by the Fire Fighter, to proceed back into the AMS via the MMS to shut down a running compressor.

2.18 At approximately 10:00 a planned entry into the AMS via the Deck 1 stairwell took place and it was confirmed that the fire was out and no hot spots were present. The fire was overhauled and by 11:30 the team had exited the space.

2.19 Throughout the incident the Master exercised overall vessel command from the Bridge. His primary objective was the safety of all personnel, specifically accounting for personnel. This was not a straight forward task due to the timing of the event, occurring during an overlap between the GY and AM shifts. Although unable to conclusively determine who was onboard and who was not, through good communication with the MCR, it was established that there were no personnel in the AMS.

2.20 The Catering Department provided critical support throughout the incident. One cashier made several PA announcements to assist in the effort to account for personnel. The ship's Occupational First Aid attendants monitored for smoke inhalation and heat exhaustion and, importantly, a steady supply of water and food was provided to fire fighting teams.

2.21 Terminal Operations ashore provided support in liaising with civilian agencies, assisting with the provision of spare fire fighting equipment from adjacent vessels and security access on and off the vessel after the incident.

Post Incident

2.22 The vessel was quickly declared unfit for operational service and at approximately 14:00 the ship was moved cold by tugs to Berth 3 – bow in. At 15:40, as immediate post incident inspections were taking place, there was a small flare up in some smoldering air filters which was quickly extinguished. Finally, at 18:20 a controlled discharge of the CO2 system was executed into the AMS.

Section 3: Technical Overview

System Configuration

3.1 The electrical power generation plant includes two shaft driven generators, the SG and the emergency generator. Under normal route operating conditions, the shaft driven generators provide all electrical power for the vessel. During night tie-up, the vessel is powered from shore.

3.2 Each morning, the SG is started and electrical load is transferred from shore power. Once the main propulsion engines are started and the shaft generators are put on load, the SG is disconnected and shutdown. Typical runtime is about 45 to 60 minutes. At the end of the operating day the electrical load is transferred directly from a shaft generator to shore power.

3.3 The SG is located in the AMS, one compartment aft of the MMS. Prior to the incident the SG had been started and put on load. The emergency bus was connected to the starboard bus and the emergency generator was in auto-start mode.

3.4 The top end of the SG is continuously visible in the view field of CCTV camera 'Boiler Flats' located at the deckhead, mezzanine level in the starboard aft corner of the AMS. This camera recording showed a light smoke haze rising from the vicinity of the #2 cylinder head of the engine several minutes before flash ignition.

3.5 A review of the CCTV recording from 24 hours previous showed a very light haze rising above the same position on the SG.

Maintenance and Repair History

3.6 The SG engine has a Planned Maintenance (PM) job schedule in Maximo matching Caterpillar recommended service intervals at 250, 1000, and 2000 hrs. There is also a maintenance inspection Job Plan 3150-CAT3606-M-2 to "Check for leaks, loose fittings and bolts/fasteners" each 30 days.

3.7 The maintenance inspection PM created work orders as follows:

SVI.17071 reported July 9, 2009; completed July 9, 2009.
SVI.25353 reported Sept 28, 2009; completed Oct 5, 2009.

Note: There is a gap in the generation of PM work orders in August due to the application upgrade from Maximo 4.1 to Maximo 7.1.

3.8 The engine had 13,359 hours of total run time at the time of the incident.

3.9 The last major maintenance work was a 1000 hr service in February 2009. This job was combined with the replacement of several cam lobes. The work did not necessitate the removal of the fuel supply tubes to the cylinder heads. The work was conducted by Finning with assistance from vessel crew.

3.10 The fuel supply tubes are not a maintenance item. They are removed every couple of years for the top end overhaul of the engine. The location of the compression fitting between the cylinder head rocker boxes is awkward for tightening with a regular combination wrench. The last top end overhaul of the engine was done in April 2008.

Section 4: Findings & Conclusions

Summary of Technical Findings

4.1 Primary Failure: Engine Fuel Delivery Component: Loss of containment and resulting vaporization, ignition and sustained combustion of diesel fuel.

Failure Mode/Causes:
4.1 (a) Loss of containment at fuel supply tube fitting into cylinder head #2 (engine free-end side).
Cause: O-ring face seal (ORFS) fitting nut backed off the fitting threads. (See Appendix A)
Root Cause: Incorrect assembly of the compression fitting. No seal ring fitted. The nut machine thread holding force is solely dependent on a hard metal to metal compression without the additional resilient strain of seal ring crush.
(i) **Recommendation #1:** Examine all the same fuel supply fittings on the 3606 Caterpillar engine for presence and condition of the O-ring seal.

(ii) **Status:** Complete.

4.1 (b) Fault with ORFS fitting was not recognized and remedied.
Cause: Early signs of fitting failure (e.g., fuel drip) most likely corrected by tightening the fitting nut.
Root Cause: Corrective procedures for fuel fitting defects.
(i) **Recommendation #2:** Discuss corrective procedures for fuel fitting defects at five minute safety briefings.

(ii) **Status:** Complete.

4.1 (c) Impingement of fuel on a heated surface exceeding 220 deg C created a fuel vapour that subsequently ignited.
Cause: Insufficient barriers between fuel leak source and nearby heated surfaces.
Root Cause: Original installation did not include spray containment features.
(i) **Recommendation #3:** Spray tape to be applied to fuel line fittings subject to fuel pressure (ref: Technical Guide BCFE 0602 Vessel Fire Safety – Flammable Liquid Systems.)

(ii) **Status:** Complete.

4.2 Secondary Failure: CO2 Fire Suppression System: Un-commanded activation of "A" solenoid valves and loss of CO2 gas containment.

Failure Mode/Causes:
4.2 (a) Un-commanded activation of "A" solenoid valves.
Cause: Fire and heat damage to control cabling in wireways adjacent to the SG.
Root Cause: Original outfitting of the vessel.

4.2 (b) CO2 bottle manifold leaked CO2 gas.
Cause: Thermal contraction of components, a result of prolonged presence of CO2 under pressure following un-commanded "A" valve activation.
Root Cause: Abnormal operation of the fitted system
(i) **Recommendation #4:** Control cabling to be re-routed away from fuel burning equipment.

(ii) **Status:** SOVI complete; SOBC control cable not re-routed but insulated.

Summary of Technical Conclusions

4.3 The cause of the fire is summarized as follows:

a) During a previous maintenance action on the SG engine, the O-ring face seal fitting was reassembled and tightened without the O-ring. Without seal ring compression, very little energy was necessary to tighten the joint.

b) The metal to metal joint achieved sufficient annular contact to establish a complete seal or to allow very minute leakage at operating pressure of 100 psi.

c) Tool markings on the failed end of fuel tube suggest that it was worked more often than the opposite end, i.e., for reasons other than removing or refitting the fuel tube, such as tightening to stop a leak. This supposition, however, is not corroborated by work log records or by crew interviews.

d) Video evidence shows a very light smoke haze over the fitting location when the SG engine was run the previous morning (24 hours earlier) suggesting presence of fuel on a heated engine surface. The quantity was likely small and easily evaporated.

e) On the morning of the fire, engine vibration overcame the remaining joint energy in the fitting and the nut became loose on the machine threads. Vibration was sufficient to turn the nut up the threads in a short period of time. Once the face seal was fully parted, mass fuel flow from the joint could be as much as several kilograms per minute, providing ample energy for the intense localized fuel fire.

Summary of Findings & Recommendations into the Emergency Response

Start-up Routine

4.4 The SG start up was conducted in accordance with the approved procedure contained in the checklist at Article 7.2.1 of the SOVI - Vessel Specific Manual. At no time during the post start walk around visual inspection was there any detection of a fuel leak on the SG.

Initial Response

4.5 The watchkeeping practices in both MCR and on the Bridge were professional and the quick reaction to alarms enabled the fire to be extinguished quickly. Some personnel were initially confused as to whether the incident was real or the scheduled drill was starting early. This was effectively resolved through radio and PA communications. The Incident Commander did not have an accurate accounting of all personnel during the initial response to the incident and therefore the decision not to deploy CO2 was correct.

Accounting of Personnel

4.6 Control and accounting of personnel during the incident was not effective. Many crew members were arriving early for the scheduled drill and walked onboard the ship through the Zone 10/11 drencher on the main car deck and then used the elevator to proceed to various stations. Others were immediately called upon to carry out important tasks in support of those already involved in the response before they could be accounted for. Later during the damage assessment phase there was a lack of access control on the ship which meant that shore based personnel were onboard and not accounted for.

(i) **Recommendation #5*:*** Review and improve protocols for the accounting of personnel. This should include the requirement for a quartermaster at the gangway (where appropriate), a clearly defined assembly area ashore and a log in/out register.

(ii) **Status*:*** Ongoing (as part of the policy component of the BCF fire fighting doctrine review)

Fire Boundaries (Boundary Cooling)

4.7 The establishment of effective boundaries was critical to the containment of the fire. In this case the doors, dampers and ventilation were shut and drenchers were promptly activated above the fire. As soon as teams in the correct rig were available they were despatched as boundaries forward and aft of the fire to check temperatures and ensure that breaches into adjacent compartments did not occur.

Smoke Boundaries

4.8 Although ventilation was quickly shut down and there were actions taken to prevent personnel not dressed in breathing apparatus from entering the smoke filled zone, there was no formal establishment of 'smoke boundaries' (a defensive layer around the immediately affected compartments within which personnel may only enter if dressed in breathing apparatus) and this is not currently part of the BC Ferries fire fighting doctrine.

(i) **Recommendation #6*:*** Develop and implement protocols for the use of smoke boundaries.

(ii) **Status*:*** Ongoing (as part of the training component of the BCF fire fighting doctrine review)

Fire Fighting Equipment and Procedures

4.9 The Fire Party was well lead by the CO who worked closely with the CE to ensure that appropriately briefed and equipped attack teams were despatched to the correct locations in a timely manner. These teams were in turn well lead by individuals who applied all of the correct procedures when advancing into adjacent compartments and ultimately into the AMS. There were several reported instances of personnel misidentification (when dressed in fire fighting rig) which led to confusion when briefing and despatching personnel as attack team and boundary party members. There were also several reported instances of difficulty communicating over the radio between personnel wearing breathing apparatus and remote stations.

(i) **Recommendation #7:** Investigate the use of 'velcro' name tags that could be quickly fixed on a fire suit to assist in the identification of personnel.

(ii) **Status*:*** Ongoing (as part of the equipment component of the BCF fire fighting doctrine review)

(i) **Recommendation #8*:*** Investigate the use of in mask radio communication transmitters.

(ii) **Status*:*** Ongoing (as part of the equipment component of the BCF fire fighting doctrine review)

Command, Control & Communication (C3)

4.10 The three departments onboard and Terminal Operations ashore worked well together. In particular the Incident Commander (CE) reacted very well to a major threat and this ensured that the fire was contained within the first 5 minutes of ignition. The Master, by allowing the CE to focus on the fire, in turn was able to focus on personnel safety. His emphasis on accounting for personnel was very appropriate given the circumstances of the incident. Notwithstanding, the MCR was never formally established as the incident command post and at one stage the Master had difficulty contacting the CE to discuss the CO2 situation. Liaison with the civilian fire department was satisfactory with the one exception of the entry into the AMS which was not authorised by the Incident Commander. There was no coordinated effort to record information (e.g. the times of entry into compartments, temperature readings on bulkheads etc)

(i) **Recommendation #9*:*** Review and improve protocols for the establishment, roles and responsibilities of an incident command post. Included in the resource requirements for effective C3, should be a method of capturing and recording real time information (e.g. a scribe on the Bridge or at the incident command post) to ensure that decision makers have immediate access to accurate information.

(ii) **Status*:*** Ongoing (as part of the policy component of the BCF fire fighting doctrine review)

(i) **Recommendation #10*:*** Establish clear guidelines with respect to incident management responsibility and authority with civilian fire departments.

(ii) **Status*:*** Ongoing (as part of the policy component of the BCF fire fighting doctrine review)

Post Incident De-briefing

4.11 Although various post incident de-briefs did take place by department, there was no formally initiated critical incident stress de-brief.

(i) **Recommendation #11*:*** Establish clear requirements with respect to critical incident stress management post incident.

(ii) **Status*:*** Complete.

Summary of Emergency Response Conclusions

4.12 Overall the response to this serious event was good and met the key objective of ensuring the safety of personnel. The professionalism of the crew in fighting and containing the fire ensured that nobody was injured and damage was limited to the AMS. As already highlighted, it was significant that the immediate reaction by those on watch when the fire started was swift and precise. This, above all else, ensured that the hazard to personnel and assets was minimised to as low as reasonably practicable.

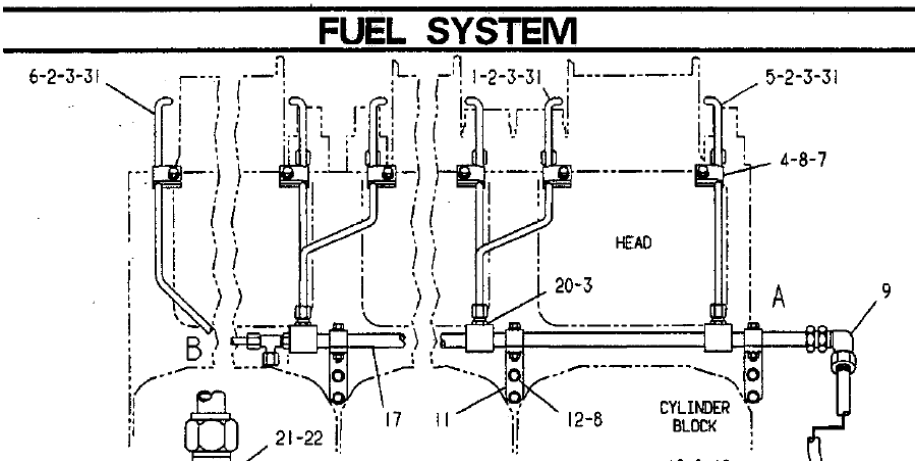
4.13 The most important lesson for all involved is the need for a quick and accurate response to the first indication of any fire, in particular, a fire that is fed by fuel. It is important that the lessons learned from this incident are incorporated into formal BC Ferries policy as part of the ongoing fire fighting doctrine review that is looking specifically at policy, procedures, equipment, training and drills. Continuous improvement will serve to enhance our ability to meet this type of threat successfully again in the future.

Appendices:

Appendix A – Arrangement Diagrams

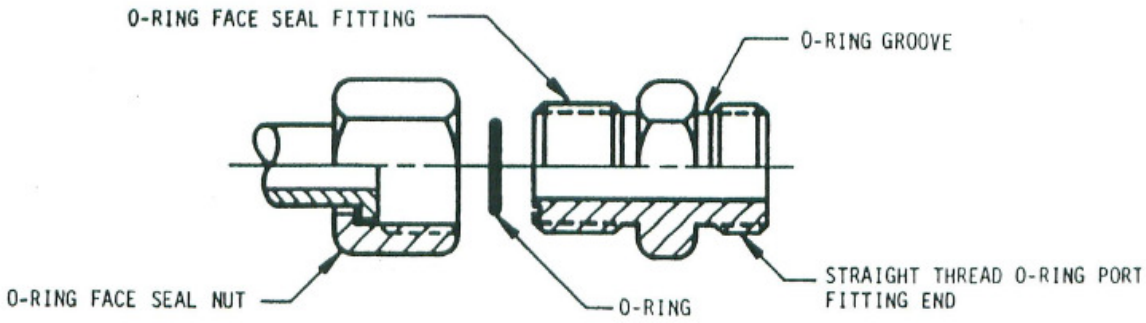
Engine Fuel Supply

The fuel supply tube is shown in the arrangement below as third tube from the right hand side.



Fuel Tube Fitting Style

The fitting is an O-ring face seal design shown in the diagram below. The same fitting type is found at both ends of the fuel tube. No O-ring was found in the fitting or in the near vicinity on the engine upon inspection after the incident.



Appendix B – Root Cause Analysis

The goal of the root cause analysis ("RCA") is to determine the underlying or effective causes of the failures that led to the incident. The applied RCA methodology is presented in a cause and effect flow chart.

	B	C	D	E	F	G	H	I	J
3	**Vessel suffered systems and equipment damage from an engine fuel fire**	caused by	Ignition of fuel vapour from the Standby Generator engine	caused by	Fuel leaking from a loose compression fitting at the engine cylinder head #2	caused by	Compression fitting nut backed off the fitting threads	caused by	Incorrect assembly of the compression fitting not identified
4			and		and		and		
5					Fuel contact with surface heated in excess of 220' C	caused by	Insufficient barriers between fuel leak source and heated surfaces	caused by	equipment and component design
6									
7			Sufficient volume of fuel available for sustained high energy combusition	caused by	0.375" diameter tube spraying fuel radially across the engine from a parted fitting at 100 psi (a mass flow rate of up to 3 kg per minute)	caused by	equipment and component design		
8			and						
9			Prolonged high heat combustion of spilled fuel as fire burned down.	caused by	No immediately available safe means to directly extinguish combustion	caused by	Whereabouts of personnel could not be immediately confirmed.	caused by	Personnel arriving onto site for start of work day, shift change, and drill preparation. Personnel not yet fitted out for normal watch communications
10							and		
11							Potential lethal effects of CO2 for persons in the vicinity of a discharge	caused by	Inherent risk with CO2 fire suppression system

Appendix C – Pictures

Pic-1 Standby Generator

Top deck view of fire damage to the 3606 Caterpillar Standby Generator.

Pic-2 Generator Control Panel

Extensive fire, heat and smoke damage to the panel components, cabling and gauges.

Pic-3 Auxiliary Machinery Space Mezzanine Deck

Extensive heat and smoke damage on the mezzanine deck of the Auxiliary Machinery Space.

Pic-4 Auxiliary Machinery Space Grating Deck

Fire, heat and smoke damage is much more localized on the grating deck level. The electrical end of the generator is relatively clean.

The wire raceways through the compartment pass to the outboard side of the SG. Cabling in these wireways suffered damage near the forward end of the SG.

Pic-5 Found condition of the fuel tube compression fitting

The nut was found to be completely backed of the fitting threads.

Pic-6 Cylinder Head #2 (engine free-end)

The vicinity of the fuel leak was found clean, believed to be the result of a washing action from the fuel spray pattern (down and radial).

Pic-7 Feb 2009 Nut Condition

During the February 2009 cam replacement job, the same fitting was captured in a photograph of the work. (See bottom left corner of image)

The working marks on the nut faces are evident in this photograph.