SECTION H
Tab 1

HOLYROOD THERMAL GENERATING STATION

FIRE PROTECTION UPGRADE ASSESSMENT

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Prepared By:
John Mallam, P. Eng.
Generation Engineering
Production Division
Newfoundland and Labrador Hydro

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Introduction

Stage 1 (Units 1 and 2) of the Holyrood Thermal Generating Station commenced in 1967. Stage 2 (Unit 3) construction started in 1977. NLH has been fortunate in that it has not experienced a fire which resulted in a significant loss of equipment or buildings. The fire protection equipment provided at the facility was designed to the standards in effect at the time of construction and has been augmented at intervals. However, the present extent of protection does not comply with modern standards.

Plant's Role in Power System

The annual production at the Holyrood Generating Station varies from year to year, as it is used to supplement energy from Hydro's hydraulic assets. It is a significant part of the Hydro generation and in a typical year will produce 20 % of the island system's energy production. The loss of the plant, or one of the units, would seriously limit Hydro's ability to serve the needs of Hydro's customers.

Background

When originally constructed, the Holyrood Generating Station was equipped with fire protection considered to be state of the art at that time. Over the years, standards for fire protection have evolved to require greater coverage and Hydro has from time to time upgraded protection in various areas of the facility. Such upgrades have been driven by legislation, revision of design standards and research performed by such organizations as National Fire Protection Association and Factory Mutual (FM).

For a number of years concern has been expressed about the vulnerability of power plants to spray and pool fires which could develop following the rupture of lubrication oil tanks or piping. Standards have existed for some time for the protection of assets from such fires and the Holyrood Generating Station is equipped with fire protection equipment to address such fires, designed in accordance with standards which existed at the time of installation. In recent years some major losses have occurred as a result of oil system fires in power plants, which caused FM to reconsider the adequacy of fire protection stipulated in existing standards. To test the efficacy of the designs required by these standards, FM constructed a mock up of a turbine-generator set and lubricating oil system and performed a number of fire tests using a test sprinkler system which provided various sprinkler water densities. The tests revealed that the sprinkler water densities stated in existing standards were woefully inadequate to control or suppress an oil system fire. FM continued testing with increasing sprinkler water densities until a density was reached which was adequate to control the fire. Appendix I contains photographs taken during these tests. FM issued recommendations for the modification of existing fire protection systems in the form of a memorandum, which is contained in Appendix II.

Fire Protection Review

A review of Holyrood's fire protection was undertaken with the assistance of our insurer and FM, to identify shortcomings as identified in the tests performed by FM and in general plant fire protection. A number of deficiencies were found and solutions identified:

1. Administration office block – no sprinkler protection provided at present

2. Maintenance shops (mechanical, electrical, instrumentation) and associated offices washrooms and sub-compartments. – no sprinkler protection provided at present

3. Unit 3 mezzanine area below turbine generator – no sprinkler protection provided at present

4. Unit 3 ground level floor below turbine generator – inadequate sprinkler protection provided at present – inadequate sprinkler protection provided at present

5. Unit 3 hydraulic oil connections to east and west main steam valves, east and west intercept valves, and blow down valve.

6. Main lube oil filter bank No. 1 – no sprinkler protection provided at present

7. Main lube oil filter bank No.2 – no sprinkler protection provided at present

8. Unit 1 seal oil skid – no sprinkler protection provided at present

9. Unit 2 seal oil skid – no sprinkler protection provided at present

10. Unit 3 seal oil skid – no sprinkler protection provided at present

11. Unit 1 light and heavy oil pump sets – inadequate sprinkler protection provided at present

12. Unit 2 light and heavy oil pump sets – inadequate sprinkler protection provided at present

13. Unit 3 light and heavy oil pump sets – inadequate sprinkler protection provided at present

14. Gas turbine generator building – no sprinkler protection provided at present

    For Items 1 through 14, sprinkler protection will be provided as the acceptable solution.

15. Risk of oil sprays in the event of failure in a threaded pipe joint, flanged connection, or seal associated with the pressurized oil pipes inside enclosures. To address this risk, non-combustible enclosures will be constructed around areas identified by items 5,6,7,8,9, and 10,

16. Risk of spray leaks which will not be contained by new metal enclosures as noted in item 15. To address this risk, fire resistant boots will be installed at all flanged and threaded pipe joints in piping systems that contain mineral oil at pressures above 50 psig.

17. In the event of a plant emergency requiring quick release of the explosive hydrogen gas from the generators, operators must walk beside potentially dangerous equipment to reach the control valves. To address this risk, the hydrogen and carbon dioxide manual valve stations, presently located below the generators, will be relocated to an area immediately outside the control room. In the event of a plant emergency requiring quick release of the explosive hydrogen gas from the generators, this modification will allow a more rapid response by operating personal. This action can then take place without operators having to walk beside potentially dangerous equipment.

18. The existing fire emergency response plan needs to be reviewed and plant personnel require training in emergency procedures. Hydro proposes to engage a fire prevention consultant to prepare operating procedures and devise a detailed and comprehensive training program for operators who must respond to a large fire emergency.

Cost

The total cost to implement these recommended fire protection enhancements is $ 1,846,300.

Implementation

The deficiencies identified occur in many areas of the plant, making it impractical to fully implement the above solutions in a single year without causing major disruptions to other plant maintenance activities. It is therefore recommended that the modifications be performed over a two year period.

Recommendations

1. Improve fire protection provisions to bring the level of protection to an acceptable level, as outlined above.

2. Implement the improvements over a period of two years.

APPENDIX I

FACTORY MUTUAL FIRE TEST PHOTOGRAPHS

Test facility. The object at left represents a lubricating oil tank, the pedestals at centre represent the turbine/generator support structure and the cylindrical object on top of the pedestal represents the turbine/generator.

Fire test, mimicking the failure of an oil line, with burning oil flowing down from the turbine/generator to the plant floor

Spray fire test, mimicking a stream of burning oil from a pressurized lubricating oil pipe.

Pool fire test, mimicking burning oil which would collect on the ground floor of a plant during an oil system fire.

APPENDIX II

FACTORY MUTUAL MEMORANDUM DATED 2004-08-20

Memorandum

RECOMMENDATIONS IN ENGINEERING BULLETIN 06-04
Reference with Data Sheets 7-79 and 7-101

TO: Distribution **AT:** FM Global

FROM: Paul Dobson, Glenn Mahnken **AT:** Engineering Hazards

SUBJECT: Turbine Building Fire Protection **DATE: August 20, 2004**

1.0 SCOPE

This memorandum contains the recommendations from Engineering Bulletin 06-04 (Revision 1 dated August 5, 2004) which will be incorporated into future revisions of FM Global Data Sheet 7-79 (Fire Protection for Gas Turbine Installations) and Data Sheet 7-101 (Fire Protection for Steam Turbines and Electric Generators). In the interim period until those Data Sheets are revised, this memorandum is intended to assist FM Global engineers to convey the recommendations to FM Global insureds that are involved in design and construction of new plants or are making upgrades to fire protection in existing power plants.

Engineering Bulletin 06-04 addresses protection criteria for lubricating and control oil fire hazards in steam and gas turbine buildings without a "full area operating floor", ie without a solid operating floor that extends the length and width of the building footprint. In this type of building design (referred to as "**turbine building**" in this bulletin), the turbines and auxiliary oil equipment are mounted on mezzanines or pedestals and much of the building is open from the ground floor to the roof. In many countries, this type of turbine building commonly houses modern indoor combined cycle power generating units, as well as steam or gas turbine units associated with cogeneration plants. In Canada and other areas of the world, a standard indoor plant design for conventional utility steam turbines also lacks a "full area operating floor" and therefore comes within the scope of this bulletin. In plants with mixed construction (i.e. having partially solid operating floors and partially open from the ground to the roof), protect open areas in accordance with this bulletin if there is a potential for oil fire in the open area.

1.1 Hazard

The hazard includes direct heat damage to the roof and crane, the turbine, and other building contents from a fire involving flammable (mineral type) lube oil, hydrogen seal oil or control oil. Also, in the case of combustible roof construction, collapse of roof steel has caused additional damage to turbine components. If the overhead crane is damaged and requires replacement, the outage will likely be extended. If emergency drainage and containment for oil releases is inadequate, a fire could occur outside the locally protected area, the fire protection system will not be activated and fire discovery will likely be delayed. Over 50% of the fires reported in turbine buildings are oil spray fires. A large oil spray fire could quickly result in severe local damage to structural steel and equipment that the fire impinges on. It is expected that a bearing lube oil release on the turbine pedestal will be at low pressure, which should not result in a significant oil spray fire, if any. Depending on the spill rate and path, oil flowing off the turbine or generator pedestal could result in a severe 3-dimensional spill fire accompanied by a pool fire on the ground floor.

2.0 RECOMMENDATIONS

2.1 Eliminate/Mitigate Unenclosed Oil Fire Hazards

1. When purchasing new equipment, encourage the equipment manufacturers to avoid or reduce the use of flammable (mineral type) oil for control oil systems; instead use FM Approved industrial fluids. Also, encourage the use of Approved fluids for lubricating systems.

2. Where feasible, enclose equipment inside fire-rated or noncombustible enclosures with adequate automatic fire protection, as well as oil spill containment and drainage provisions. See OS 7-79 for protection guidelines for enclosed equipment.

3. Install spray guards, shields, barriers, or spray hoods for pressurized oil equipment such as lubricating and control oil pumps, control devices and flanged or screwed fittings in order to deflect potential high pressure sprays of combustible lubricating and control oil. If removable metal flange shields are used they should be installed so that the perimeter of the flange is covered and an overlap is provided which extends down on both sides of the flange. The shield may be held in place with a band or with screws (Ramco Manufacturing Co., Inc; Kenilworth, NJ 07033, manufactures flange shields for maritime applications. There are no FM Approved flange shields). Inspect and maintain spray guards, shields, barriers and hoods as follows:

a. Itemize, tag and inspect all spray guards, barriers, and hoods on a monthly recorded basis.

b. Establish a spray guard supervision program and documentation system to ensure proper replacement of all shields, guards, barriers, etc. that are removed for maintenance activities. Supervision of such programs should be equivalent to or included in the plant's lock-out tag-out program.

c. Provide periodic training of maintenance and operations personnel on the purpose of the barriers and their proper maintenance.

4. Conduct a thorough, documented, oil fire risk assessment for all flammable lubricating and control oil systems to identify potential release scenarios, sources of large leaks, and determine the specific conditions necessary that would permit the safe shutdown of lube oil, seal oil and control oil systems. Include the following in the assessment:

a. Determine the various conditions that would permit the safe shutdown of the lube oil, seal oil, or control oil systems.

b. Determine potential flow paths for the released oil, from leak source to pooling areas and drains.

c. Ensure that all floor areas that oil can flow to, especially via pedestal openings, are locally sprinklered and provided with adequate containment and emergency drainage.

d. Identify pressurized flammable oil systems and potential oil spray sources, including the operating pressure, quantity of the connected oil supply, and potential spray "targets."

5. Ensure that oil fire prevention is addressed through on-going appropriate plant programs and procedures, such as:

a. Appropriate maintenance procedures-to minimize the potential for accidental releases of oil during and following maintenance activities

b. Oil fire awareness training programs for operators and maintenance personnel

c. Emergency response plans for oil release situations

d. The facility's "managing change" program

e. Self-audits

2.2 Ceiling Sprinkler Protection

1**.** Install automatic sprinkler area protection at the roof level of turbine buildings if the roof is combustible (including Class 2 steel deck).

2. Design ceiling protection in accordance with the criteria provided in Table 2.1:

Table 2.1 Ceiling sprinkler design criteria for turbine buildings with combustible roof construction

Type of Sprinkler System	Sprinkler Temperature Rating	Density gpm/ ft^2 (mm/min)	Area of Demand ft^2 (m^2)
Wet	High	0.20 (8)	5000 (465)
Dry			8000 (740)
Hose stream demand: 750 gpm (2840 l/min) Duration: 60 min (Water supply duration may need to be increased when local conditions exist that could delay fire fighting efforts - such as lack of drainage, inaccessible areas, etc.)			

The criteria in Table 2.1 are for protection of the roof only. Due to excessive clearances, ceiling sprinklers will have minimal if any impact on control of oil fires in typical turbine buildings. If local protection is inadequate, large spray or pool fires could develop and will likely result in operating areas that significantly exceed the ceiling sprinkler demand areas indicated in Table 2.1.

2.3 Local Deluge/Sprinkler Protection for Unenclosed Oil Fire Hazards

Apply the recommendations below retroactively. These recommendations have been developed based on engineering judgment taking into account the findings of a series of large-scale pool and spray fire demonstration tests conducted by FM Global in 2004. It is expected that most turbine building fires will be adequately controlled by the local protection criteria recommended below, if installed in combination with appropriate drainage/containment and effective emergency shutdown procedures.

1. Provide local automatic deluge (preferred) or closed head sprinkler protection for equipment and areas that present pool or three-dimensional spill fire hazards, including under the turbine pedestal, under any walkways around the pedestal, under spray guards, shields, barriers, or hoods and all floor areas that released oil can flow to. Such areas should be identified by an oil fire risk assessment (see 2.1 [4] above). Where oil releases could accumulate in pools on top of the pedestal or solid mezzanines as a result of containment areas formed by curbs, kick-plates, etc., provide appropriate drainage or a local protection system for the pooling area on the pedestal.

See Figures 2.1 and 2.2 for a general conceptual layout of local protection, containment, and drainage.

Among the potential oil release sources that could result in pool fires are pipe flanges, oil pumps, filters, gauges, threaded joints and fittings, sight glasses, indoor oil coolers, bearings, and rubber hoses. Rupture of welded pipe should not be considered a potential release source. Welded pipe often will be located above floor areas that need local protection because oil could flow to them from any of the previously mentioned leak sources.

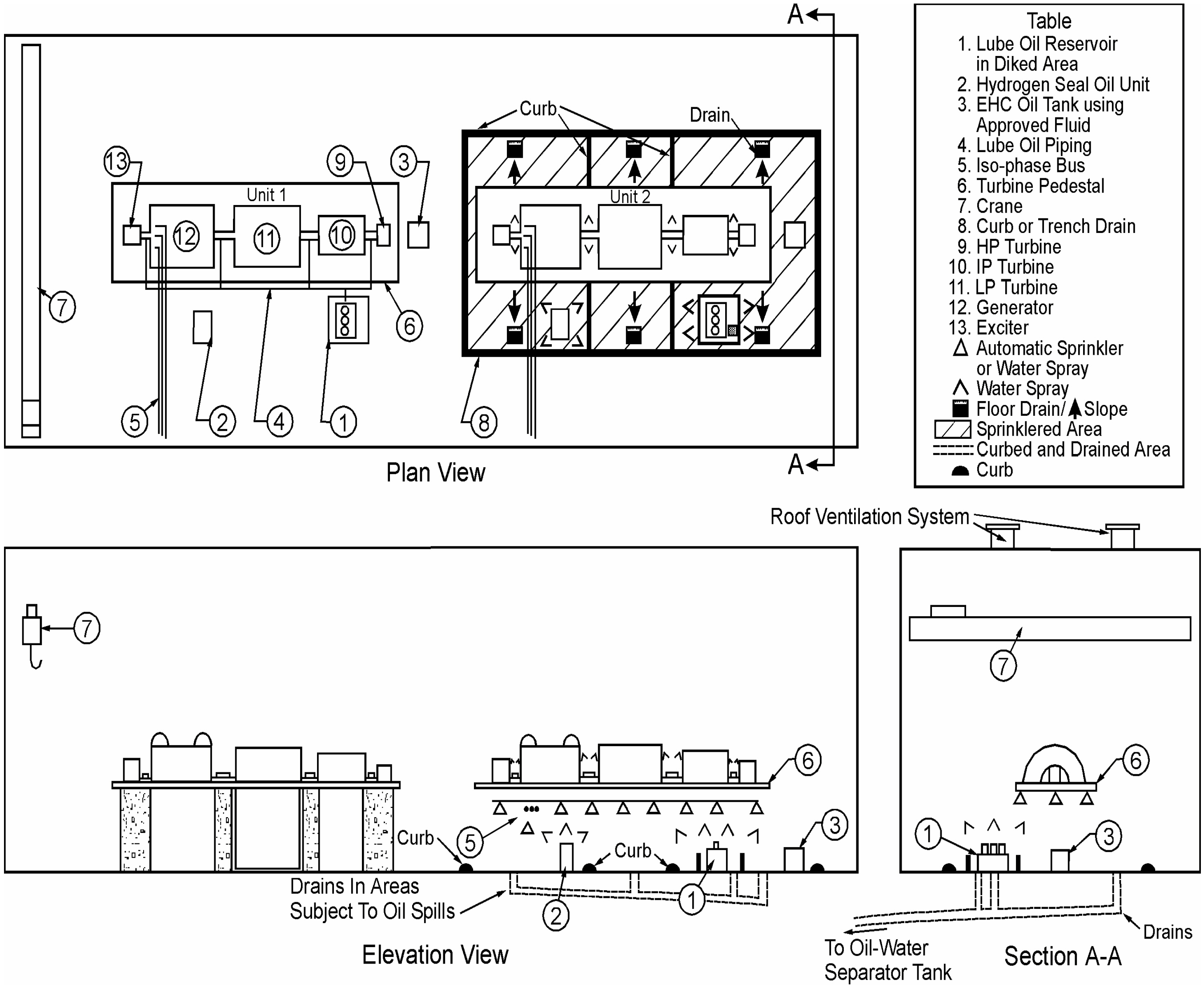

Figure 2.1 Local protection layout for unenclosed steam turbines and generators

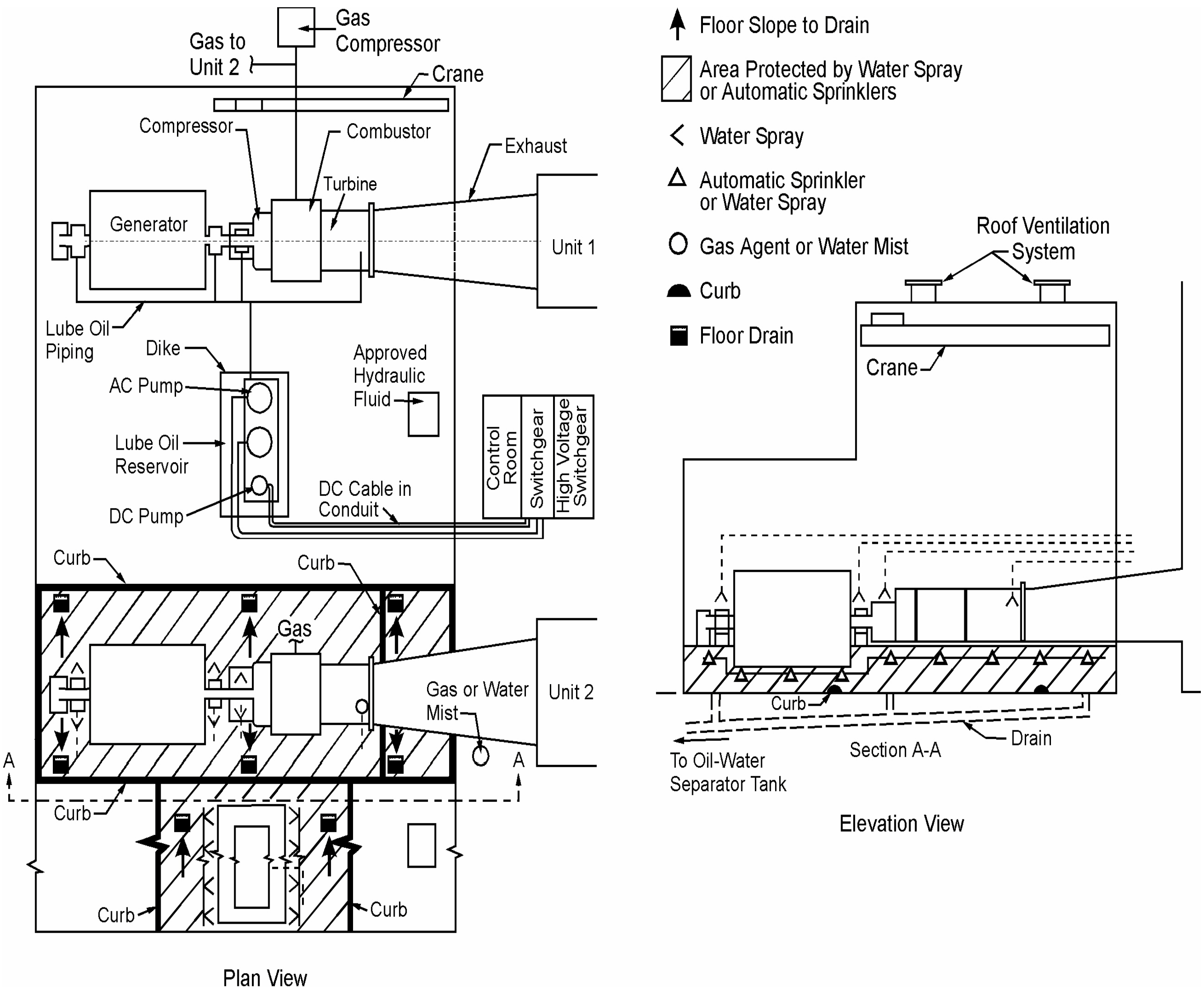

Figure 2.2 Local protection layout for unenclosed combustion turbines and generators

2. Design local protection against pool and three-dimensional spill fires as follows:

a. Provide a maximum 15 ft (4.5 m) clearance from the floor to the sprinklers. Install open (preferred) or closed sprinklers over the entire oil containment area, on maximum 10 x 10 ft (3 x 3 m) spacing. Provide sprinklers with a K-factor = 8.0 (115) and a design density = 0.30 gpm/ft^2 (12 mm/min). The demand area is 5000 ft^2 (465 m^2) if the closed sprinklers are directly under a solid deck or ceiling. If sprinklers are not directly under a solid deck or ceiling, design a demand area of 5000 ft^2 (465 m^2) or the containment area, whichever is less. Use 165°F (74 °C) in areas where local pool fire protection is present without a solid "ceiling". If sprinklers are located under a solid deck or ceiling, use 286°F (141 °C).

Note: k = 5.6 (81) sprinklers are acceptable in existing locations as long as the provided density is fully adequate.

b. For greater than 15 ft (4.5 m) up to 30 ft (9 m) clearance from floor to sprinklers, design as in part a) above, but provide a minimum density of 0.40 gpm/ft^2 (16 mm/min) and K-factor = 11.2 (161).

c. If adequate emergency drainage is not provided for containment areas subject to pool fires, then install either of the above protection options along with containment and/or curbing to hold sprinkler discharge inside the sprinklered area for 20 minutes or the rundown time of the turbine generator unit, whichever is greater. Provide local protection for all areas that sprinkler discharge may overflow to after the defined hold-up time.

d. As an option to either a. or b. above, for protection of areas subject to pool fires, provide an FM Approved foam-water sprinkler system designed for a density of at least 0.20 gpm/sqft (8 mm/min) or the minimum required density in the Approval listing, whichever is greater. Design for a demand area as in part 2a. above. Provide enough foam concentrate to last at least 20 minutes or the rundown time of the unit, whichever is greater. If adequate drainage is not available, design containment as in part 2c. above.

3. Use close-spaced (5 x 5 ft [1.5 x 1.5 m]) pendent deluge sprinklers, with orifice coefficient K = 8.0 (115) to protect against unenclosed oil spray fire sources. Provide a minimum end head pressure of 50 psig (3.9 barg). Locate these open sprinklers with approximately 6 ft (1.8 m) vertical clearance above the potential oil spray source and provide a minimum of nine heads on 5 x 5 ft (1.5 x 1.5 m) spacing. If multiple oil spray sources are present in the same general area, provide additional close-spaced heads as needed in order to provide a sprinkler grid that extends at least 5 ft (1.5 m) beyond each spray source. Preferably, provide a fire-rated spray barrier or hood above the deluge sprinklers. If a spray hood (see appendix A.7) is provided, sprinklers located under the hood may be closed head type (although open heads are preferred).

A spray fire source for the purposes of this recommendation is any unenclosed flange, threaded fitting, or hydraulic control device that provides containment for pressurized flammable oil at 50 psig (3.9 barg) or greater and could release at least 200 gallons of oil into the fire before the suction to the source oil pump runs dry. (If the largest possible oil release size is less than 200 gallons, provide close-spaced deluge sprinklers or, alternatively, provide a spray barrier above the source, with sprinklers designed as in part 2. above). Flanges on lube oil supply piping inside a gravity type return oil pipe are not considered spray sources for the purposes of this recommendation. Sprays can develop at pressures as low as 20-30 psig, but the heat release rate for such sprays is expected to be significantly reduced. Hydrogen seal oil systems on large generators may deliver oil to the seals at pressures in excess of 50 psig (3.9 barg).

Shields, barriers and hoods may be given credit for eliminating the spray fire hazard for the purposes of this recommendation if the conditions in par 2.1 [3] are met.

Close-spaced pendent heads in the arrangement recommended above were used in testing conducted by FM Global. The spray fire was not extinguished, but the measured ceiling temperatures and heat release rate of a 40 MW spray fire were significantly reduced.

Only K=8.0 (115) sprinklers can be used for this protection scheme. Larger and smaller K-factors were tried and found to be ineffective with the same close spacing arrangement.

There were no obstructions present between the open heads and the spray source. Pendent heads may be more effective than uprights against pool fires accompanying the spray fire, if there are no obstructions to sprinkler discharge. Upright heads may be more effective if there are obstructions to the sprinkler discharge, but obstructions should be avoided where possible.

4. Activate spray fire deluge systems automatically by an FM Approved line type heat detection or flame detection system. Pool fire deluge systems may be operated by pilot sprinklers, line type heat detection, or flame detection. Also provide remote manual (“push-button”) activation of deluge systems from the control room or other accessible location outside the turbine building.

5. Provide water supplies to simultaneously feed all local systems which may be expected to operate simultaneously in the worst credible case scenario for the site, plus 750 gpm hose stream. Determine the duration based on the fire scenario or 60 minutes, whichever is greater.

2.4 Spill Containment and Emergency Drainage

1. Provide an engineered spill containment and emergency drainage system that will “contain and drain” any oil spills originating from turbine generator bearings, control equipment, piping flanges, pumps, or control equipment.

2. Consider subdividing large containment areas by use of additional curbing or drain trenches, where feasible, to limit the potential pool size (see Figs. 2.1 and 2.2).

3. Design emergency drainage capacities and floor pitch (to drains) per OS 7-83, or per equivalent engineering design criteria, to provide a discharge flow rate equal to the combined water spray and sprinkler demand plus 750 gpm (2850 l/min) hose stream.

2.5 Structural Steel Protection

1. Provide automatic water spray or apply fireproofing rated for hydrocarbon pool fire exposures to any exposed steel columns supporting the building, crane rails, or other major equipment, if these columns are located within areas where pool fires may occur.

2. Arrange water spray for column protection in accordance with OS 7-93, including the following:

a. Provide a minimum 0.25 gpm/ft^2 (10 mm/min) over the wetted area of the columns. ("Wetted area" is the surface area on the three sides of the reentrant space formed by the column web and flanges).

b. Locate water spray nozzles spaced on 10 ft (3 m) centers on alternate sides of "H" columns.

2.6 Emergency Shutdown Plan

1. Develop a documented emergency plan with appropriate posted procedures to secure the turbine generator unit and achieve lube and control oil pump shutdown as quickly and safely as possible, recognizing that under some circumstances, it may be better to shut off the pumps rather than continue to supply oil to a fire.

While a posted procedure is preferred, a documented procedure that is routinely reviewed and well known to all operators is also acceptable. Generally the DC pump cannot be shut off from the control room. The posted procedure should include where and how to shut off all pumps. If the only existing pump shut off is in an area that would not be not accessible during a fire, provide the capability to shut off the pump from the control room or another accessible area.

2. Clearly establish and document the authorization for designated personnel to make critical decisions regarding lube oil shutdowns during fire emergencies. Periodic training sessions should be held to give responsible on-site personnel the opportunity to deal with the decision-making issues involved in exercising this authority.

3. Locate the control room in a separate building. When the control room is located in the turbine building, do the following:

a. Isolate the room from the remainder of the turbine building with minimum one hour fire rated walls, roof and floor. Provide wired glass or rolling steel fire rated shutters or an automatic water spray protection system for any windows facing the interior of the turbine building.

b. Provide an independent air supply capable of pressurizing the room to maintain acceptable habitability during a fire event.

c. Seal penetrations between the control, cable spreading and relay rooms with a FM Approved fire stop system.

d. Ensure that equipment needed to safely shutdown the turbine such as actuation solenoid valves to break vacuum and shutdown controls for the a.c. and d.c. lube oil pumps are arranged for remote operation from the control room.

If operators cannot be expected to remain in the control room during a fire, make alternate provisions for emergency shutdown from an accessible location.

4. Keep a copy of the complete documentation available in the control room.

5. Conduct drills for all personnel who are designated to perform emergency shutdown functions.