

RISK ENGINEERING GUIDELINE

FIRE PROTECTION MEASURES RELATING TO INDUSTRIAL
POWER PLANTS' TURBINE OIL SYSTEMS

HDI Risk Consulting

Property

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General.

Fires in industrial power plants often lead to considerable property damage. Serious impacts on connected infrastructures in production operations are often the result. The systems feeding oil to the turbo-generators are critical. This is because any leakage at this point can lead to the uncontrolled escape of oil, which can quickly ignite on contact with hot surfaces. Companies can significantly mitigate these fire risks at a reasonable cost.

Industrial power stations with up to 50 MW capacity are the primary target group for this Risk Engineering Guideline. The fire protection measures described below should contribute significantly to making steam turbine operation even safer. The protection concept described here can also be applied in principle to larger power plants.

1 Risk situation and loss examples.

Steam turbine fires and fires in their oil-bearing systems have occurred repeatedly in the past. Without fixed protection systems the extent of the damage exceeds many tens of millions. Considerable business interruption losses occur in addition to simple property damage. This is the case for instance when industrial power plants are a permanent part of a critical production operations infrastructure. The reason being that turbine failure interrupts the power generation. At the same time, the heat output, needed for drying or cooking processes for instance, must then be reduced. Both result in more than just lost revenues from power infeed. Production processes can also be significantly disrupted and

can be interrupted even longer depending on replacement or restoration times after fire damage. The impacts for the entire company can be just as extensive, and even pose a threat to the company's entire existence.

A case study: The fire brigade responded to a thermal-power-station fire on a night in the summer of 2012. Lubricating oil escaped from a steam turbine bearing. Part of this oil ignited on the system's hot surfaces. A smoke/heat detector actuated a fixed stationary fire fighting system, largely containing the fire. A squad of firefighters also deployed a multipurpose nozzle with 100-200 l/min with foam. This enabled the escaping oil to run into the collection basin without any risk. No one was injured, an environmental hazard was avoided, and prolonged turbo-generator downtime was prevented. The successful fire fighting could be traced back to the installation of a water spray fire fighting system: A low-pressure, water mist fixed protection system in this case.

2 Cause of loss/hazard source.

The causes of such serious industrial power plant fires are often identical: Leakage of the turbine oil systems. Specifically, oil often escapes under high pressure as a spray/mist and ignites on hot surfaces. Sensitive monitoring systems can in fact quickly detect these kinds of leaks. However, not all oil circuits can be immediately or completely shut off with the result that oil can continue to escape and ignite. Without adequate fire protection measures, there is the potential for a property damage and business interruption loss as well as for personal injury.

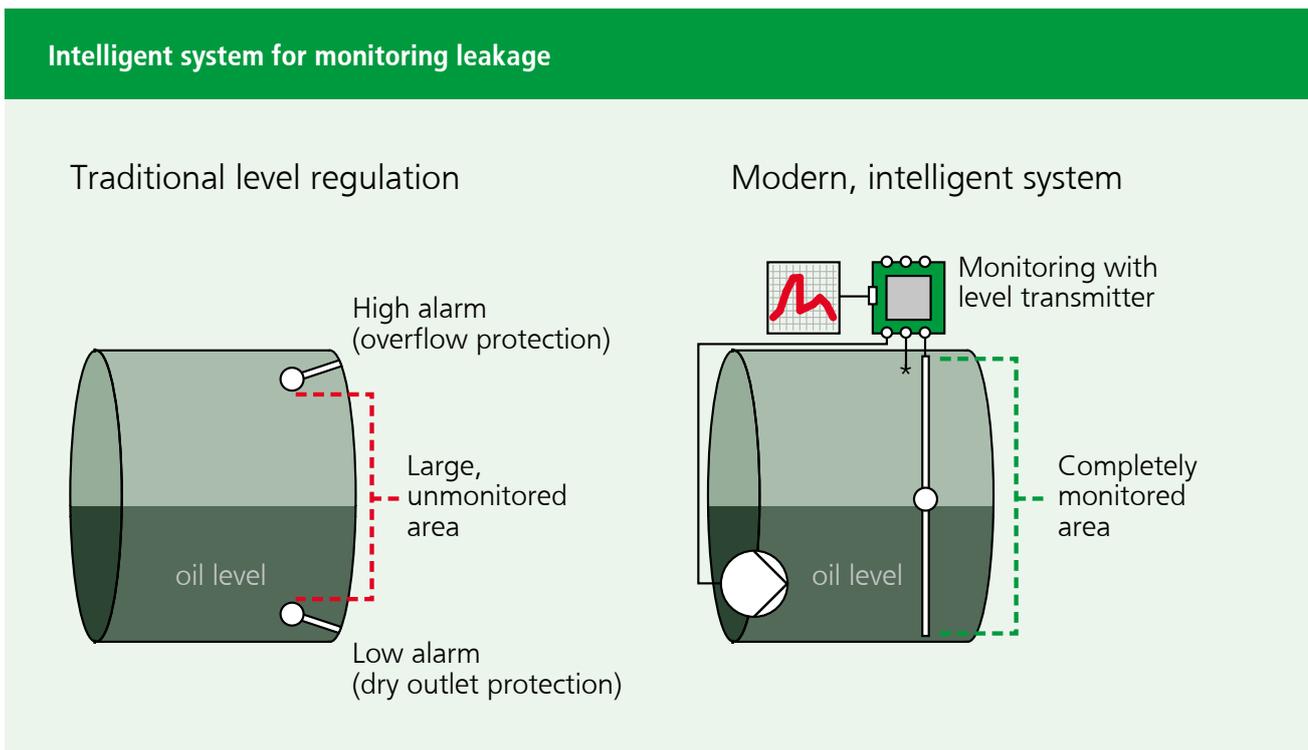


Fig. 1: Comparison between traditional level regulation (left) and modern intelligent systems (right)



Fig. 2: Spray protection sleeves on oil flanges

Oil leaks are detectable primarily on bearings- and oil control systems as well as on shaft seals. This has the following causes:

- errors during installation, repair or inspection as well as operating errors;
- violent oil pipeline rupture resulting from mechanical damage of the turbo-generator set due to impermissible overspeed, vibrations and sudden failure of the turbine shaft or generator rotor.

Escaping oil ignites on contact with hot surfaces, e.g. the turbine housing, steam lines, valves, hot bearings, or electrical units. Among other things, this can cause:

- spray fire at the leakage point;
- surface fires on insulation, for instance through the use of soft-jacket insulations;
- pool fires.

3 Protective measures.

Supplementary fire protection measures (the implementation of which is often cost effective) are thus necessary to reduce the risk of fire. These include:

1. leak detection by intelligent leak monitoring systems;
2. controlled shutdown of the turbo generator by activating the "fire protection switch";
3. reducing the probability of escaping oil ignition through constructive preventive measures;
4. fixed protection systems e.g. water spray fire fighting systems;
5. organizational measures such as conducting emergency exercises adherence to safety measures during maintenance and repair work.

3.1 Detection of leaks by intelligent monitoring systems

Oil systems should be equipped with intelligent, electrical leak monitoring. The alarm threshold or sensitivity should be set based on normal operation so that the leakage of even minor amounts of oil is detected. See fig. 1 on page 2:

Comparison between traditional level regulation (left) and modern intelligent systems (right).

Furthermore it may also make sense to selectively install local collection pans, which are equipped with liquid detection, on bearings or valves.

3.2 Controlled shutdown of turbo generators by actuating the fire protection switch

An audible and visual alarm must occur in the turbine house as soon as the above mentioned monitoring systems detect a leak or a critical decline in the oil level. Likewise a constantly manned location – here for instance the power plant control station – must receive an alarm signal.

The next step is for operating personnel to actuate the "fire protection switch". This enables the turbo generator to shut down in a controlled and safe way. The fire protection switch must be situated close to the turbo generator set, in the constantly occupied control room, and along a suitable escape route. As a rule this will automatically initiate the following measures, among others:

- actuate the turbine trip;
- switch off the control oil pumps and close the fire protection slider;
- reduce bearing lubrication to emergency operation.

Important: Shutting down and cooling down the turbine takes a certain amount of time. During this time, a few oil circuits, such as the emergency oil supply of the bearings, must remain in operation so that the bearings are not damaged.

3.3 Constructive preventive measures for minimizing the risk of fire from escaping oil

Various and often simple safety measures can also be taken retroactively in existing industrial power plants to reduce the probability that escaping oil will ignite on hot surfaces:

- steam lines should be insulated as seamlessly as possible;
- spray protection should be installed out between the controller racks, pumps, and hot turbine parts;
- flanges and pipe connections on oil lines should be secured (See fig. 2);
- if possible, all openings leading from the turbine table downward into the turbine cellar should be sealed. This should prevent burning oil above the turbine table from dripping or flowing down into the turbine cellar;
- bunds/Catch pits/Containment must be installed in the turbine cellar to prevent a large fire from spreading to neighbouring turbines and other technical equipment.

Care should be taken when calculating the dimensions of the containment to ensure it is sufficient to hold the turbine oil system's entire oil volume. The containment can be smaller or lower if turbine oil and fire fighting water can be diverted into a separate oil collection vessel in a safe area.



Fig. 3: Low-pressure, fine-spray nozzle with protective cap

The following should be noted during the planning of new industrial power plants:

- oil lines should be welded through to the extent possible with as few flanges as possible;
- oil and steam lines should be laid separately from one another as far as is possible;
- oil lines should be positioned underneath steam lines;
- oil lines should be laid in inspectable oil-line channels made of steel sheet or steel reinforced concrete incl. drain to an oil collection vessel with leak monitoring. Pipe-in-pipe laying can be used as an alternative;
- the turbine oil vessel, including filter, cooler, and pumps, should be set up in a fire cut-off area (2 hrs fire resistant). Mechanical smoke extraction to the outside must be ensured.

3.4 Fixed fire fighting systems

If a fire occurred on a turbo generator, fixed fire fighting systems are in a position to protect people and machines in a risk-appropriate way. In this respect sprinkler (partially pre-action systems), water spray fire fighting systems and low pressure water mist fire fighting systems up to 16 bar have proven themselves on steam turbines, among others.

Furthermore, approved high pressure, water mist fire fighting systems exist with system pressures generally between 40 to 120 bar. Certifications and limits of application must be considered such as compartmentation and maximum volume. Gas extinguishing systems can also represent appropriate fixed fire fighting systems on gas turbines in special cases.

For simplicity, water-spray and low-pressure water mist fire fighting systems in use on steam turbines will be examined in more detail below.

In contrast to traditional water spray fire fighting systems, low-pressure water mist fire fighting systems work with slightly increased water pressures of between 4 and 16 bar at the spray nozzle. In return, the required water densities or water flow rates of fire fighting water are generally lower.



Fig. 4: Low-pressure, fine-spray nozzle/Spray pattern

These water spray nozzles are connected with one another via a pipeline network arranged surrounding the oil systems to be protected and connected to a water supply. Open fire fighting nozzles are involved here from which fire fighting water is sprayed over the entire surface of the area to be protected in case of fire. The protective cap shown in fig. 3 protects the nozzle from dirt and entry of particles into the pipeline during normal operation. However it is actuated when the pipe network is flooded thereby releasing the fire fighting water.

The following areas around the steam turbo generator set are under the protection of the water spray fire fighting system:

- oil room/oil vessel;
- oil pump area;
- oil pipe channels;
- bearing areas and the;
- steam turbo-generator set's valves.

If the oil vessel is integrated directly on the turbine table in the turbo-generator set (fig. 5) instead of in the turbine cellar, the former should also be incorporated into the fire protection system.

Automatic fire detection is done via flame detectors (UV detection) and/or multi-function detectors (heat and smoke detection). The danger of false alarms is minimized through the requirement for two-methods of detection to activate, before the fire fighting system is automatically triggered.

Smoke/Heat detectors should be provided with thermal baffles so that they detect smoke and/or heat as quickly as possible, see fig. 7.

In addition to automatic activation, it must also be possible to manually operate the water spray fire fighting system from a safe location. Manual triggers are generally installed in the control room, at emergency exits, and as close as possible to the machines to be protected. Alarm valve stations are activated when the fighting system is actuated. These release the water stream, see fig. 5 and pos. 7 in fig. 8.

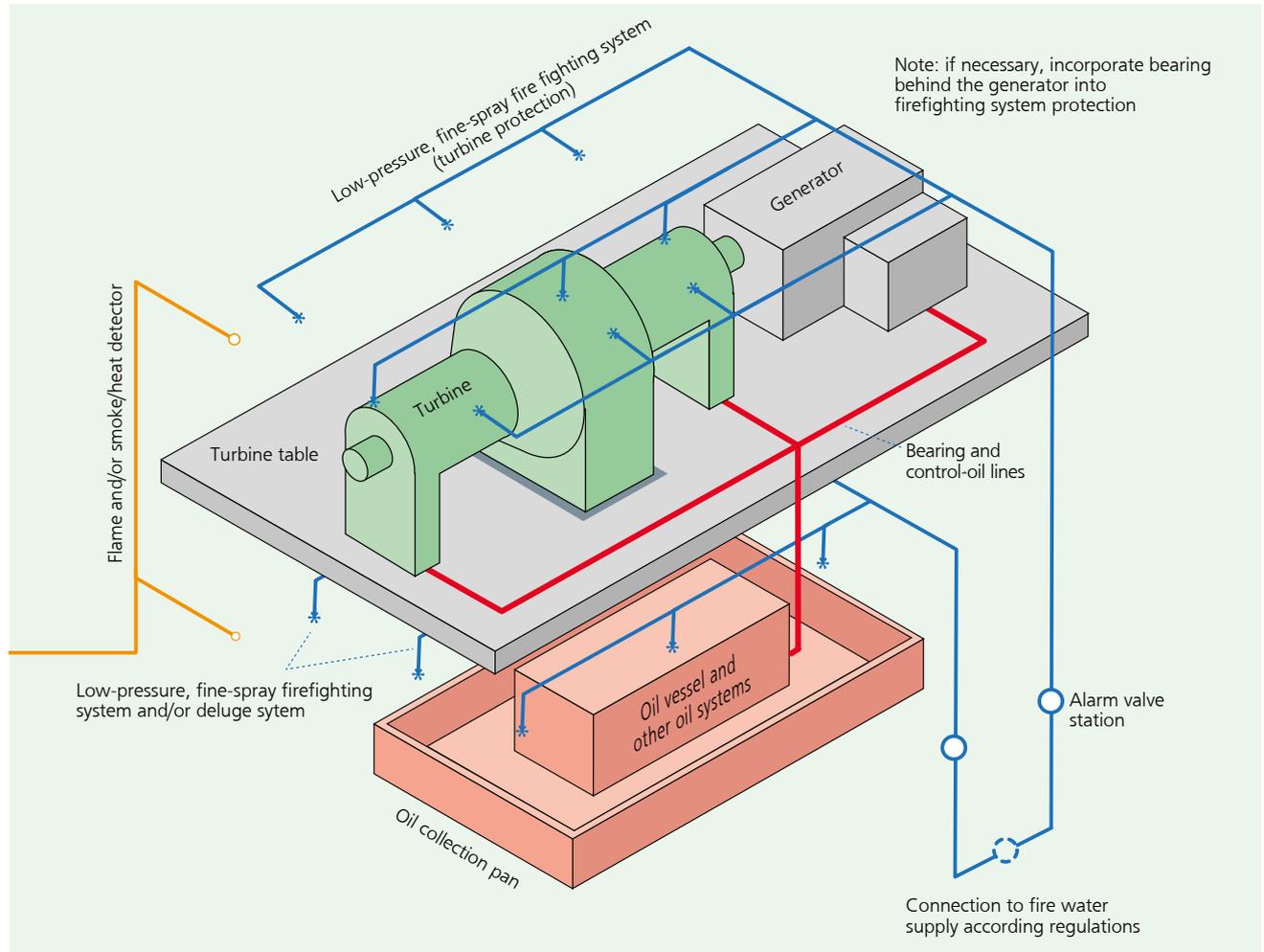


Fig. 5: Example of fixed protection surrounding the turbine oil systems (schematic overview)

The water is then generally supplied via a fire fighting system pump (Fig. 8, pos. 8), which draws water from a fire fighting water surge tank (Fig 8, pos. 2). The latter can be automatically refilled from the city's or the company's water network (pos. 4).

An electrical pump can be used for the fire fighting water supply if the energy supply is guaranteed during a fire around the turbine oil systems. This can be achieved via an emergency power generation unit. Otherwise a diesel pump should be installed instead of an electrical pump.

Fire water can also be taken directly from the water supply network in special cases. Then installation of a pump system and storage tank can be omitted. In return, the water utility company must be able to guarantee adequate water pressure and flow rates.

The direct connection is relatively simple to implement via an alarm valve station when sufficient public water is present. The water supply is delivered direct from the public drinking water supply, a direct connection should be installed that meets the respective utility companies regulations in addition to insurers requirements.

Important: coordination with the responsible water supply company must occur before implementing a direct connection to the public drinking water supply network.

Pressure booster stations can also be installed at reasonable cost if pressure conditions are not sufficient to achieve for example 4 bar at a low-pressure water mist nozzle for instance with direct connection to the company's water network.

Alternative, water supplies are possible using pressurized-air/water tanks, elevated tanks, existing sprinkler systems, or in special cases using open bodies of water or groundwater wells.

The essential design criteria acc. CEA2109 or NFPA15 for water supply to water spray fire fighting systems on turbines' oil systems are:

- water density of 0,25 gpm/ft;
- operating time of at least 30 minutes.

Required water flow rates are in general significantly lower when using low-pressure, water mist nozzles. This can further simplify the provision of adequate fire fighting water.



Fig. 6: Flame detector

Water spray/deluge fire fighting systems and low-pressure, water mist fire fighting systems can also be implemented on turbines where no enclosures or sound-protection cabins are present.

An approved installation company – certified by an internationally recognised certification institute (such as LPS, UL etc.) - must produce a product manual approved by the recognised body or other AHJ (Authority Having Jurisdiction) when using water mist nozzles on turbine oil systems.

3.5 Organizational measures

Implementation of the following organizational measures is required so that the previously mentioned safety systems and facilities are always fully ready for use:

- development of emergency procedures and emergency instructions;
- regular, comprehensive employee training;
- regularly conduct fire protection exercises in conjunction with the fire brigade;
- regular inspection and maintenance of the turbine oil systems;
- monthly check of spray protectors' proper position i.e. pipe collars and spray-protection sheets. In addition, a review is required after each maintenance and repair task on the turbine;
- maintenance and inspection of the fire detector and fire fighting systems acc. NFPA, e. g. NFPA25, NFPA72 or equivalent;
- written documentation of maintenance and inspection tasks in an operations log;
- use of special safety measures during maintenance and repair tasks, i.e. hot work permit and release certification procedure incl. fire watch;
- appointing a fire safety engineer acc., NFPA1021 or equivalent;
- testing of interlocks;
- oil quality checks.



Fig. 7: Smoke detector with heat accumulation plate

3.6 Other requirements

Installation, function tests and expert approval as well as subsequent maintenance and inspections in accordance with applicable internationally recognised standards such as NFPA or certified by national or internationally recognised institution regulations must be conducted for the fire fighting systems.

Prior to installation, hydraulic calculations should be coordinated with an expert certified by national or internationally recognised institution, who also conduct initial approval and regular inspections.

Considerations should be given to determining the maximum demand of fire fighting water. This refers to scenarios in which multiple fire fighting systems and fire fighting-system areas may be actuated simultaneously. In special cases an additional supply of water for the fire brigade or other users has to be considered.

Finally, HDI Risk Consulting explicitly emphasizes that further fire protection in industrial power plants beyond fire fighting system protection of turbine oil systems may be necessary. Here are a few examples:

Expanded structural fire protection measures such as:

- design of fire areas/cut-off areas, smoke separated areas e. g. with smoke curtains and heat/smoke vents installed in the roof;
- fire-resistant protection of plant components/operating areas;
- installation of smoke extraction systems;
- fire resistive cabling (up to 90min).

Expanded system-specific fire protection measures such as:

- flashback protection in the boilers' fuel in-feed, e. g. in biomass thermal power stations;
- fire detection and fire suppression monitoring of electrical and technical rooms or utilities;
- fire protection systems at cable ducts, cable raiser or cable tunnel.

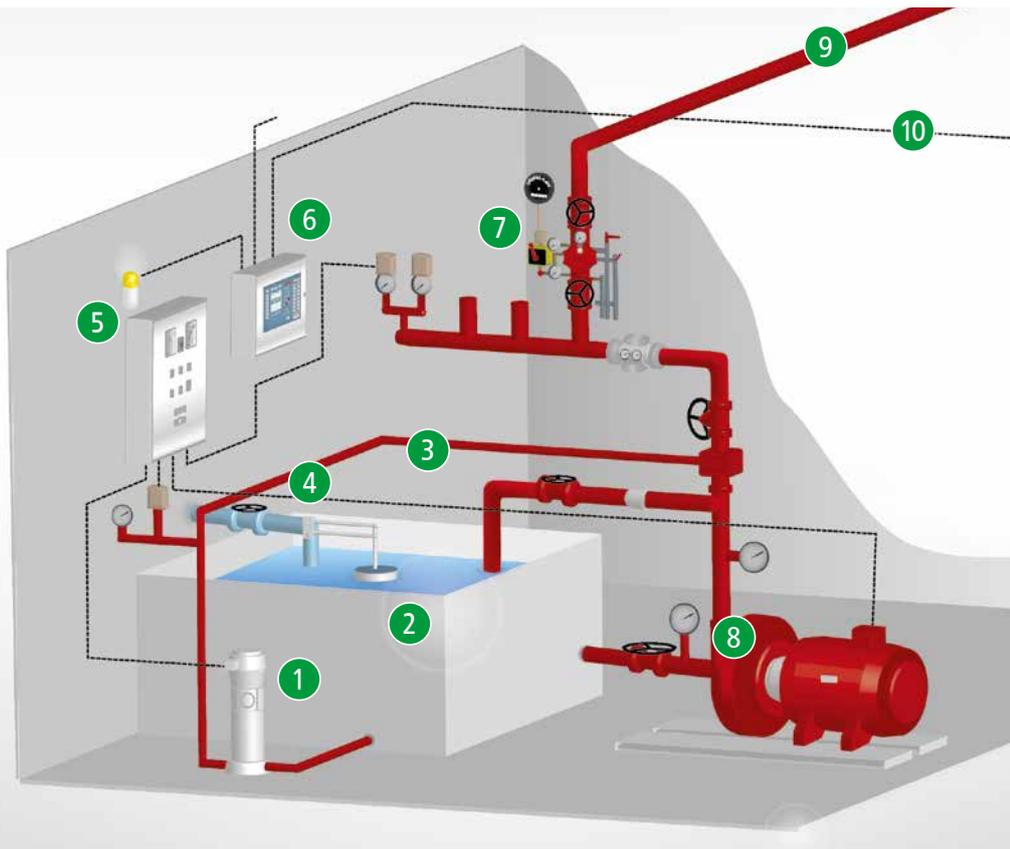


Fig. 8: Overview of fire fighting systems' water supply (Example)

1. Pressure holding pump
2. Storage vessel
3. Automatic feed device
4. City water connection
5. Pump switch panel
6. Central fire alarm system
7. Alarm valve station
8. Fire pump
9. Distribution pipes for protection at the turbine's oil systems (see also Fig. 5)
10. Signal transmission from flame and/or smoke/heat detector (see also Fig. 5)

4 References.

Local Standards should be complied with.

Internationally recognised standards:

HDI Risk Consulting checklists for organizational fire and explosion protection

NFPA 750 Standard on Water Mist Fire Protection Systems

UL 2167 Standard for Water Mist Nozzles for Fire Protection Service

CEN/TS 14972 Fixed Fire Fighting Systems – Water mist Systems

FM5560 Approval Standard for Water Mist Systems

EN 14972 Fixed fire fighting systems - Water mist systems – Design and installation, CEA2109 Spray water extinguishing systems

Specific standards (Best practise):

NFPA 13 Standard for the Installation of Sprinkler Systems, 2010

NFPA 15 Standard for water fixed systems for fire protection

NFPA 16 Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems, 2011

NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection, 2010

NFPA 22 Standard for Water Tanks for Private Fire Protection, 2008

NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, 2011

NFPA 70 National Electrical Code, 2011

NFPA 72 National Fire Alarm Code, 2010

NFPA 170 Standard for Fire Safety Symbols, 2012

NFPA 1021 Standard for fire officer professional qualifications

BS 5839-1:2013 Fire detection and fire alarm systems for buildings

Australian Standards (AS), New Zealand St. (NZS): AS/NZS 1670 and AS/NZS 1851

EN 54

EN 15182-3

EN 12845 Fixed Fire Protection Systems

About HDI Risk Consulting.

HDI Risk Consulting GmbH supports major corporations, industrial and mid-size companies with loss prevention and in establishing risk management systems.

HDI Risk Consulting offers its' customers access to some 180 engineers and experts from a wide range of technical disciplines. We aim to support companies with the management of risks and the development of individual risk-based concepts for insurance cover.

HDI Risk Consulting operates globally in the Property, Motor, Engineering and Marine markets, with particular focus on the identification and assessment of risks and the development of appropriate, individual protection concepts.

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