

# Rules for Classification and Construction

## VI Additional Rules and Guidelines

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### 8 Electrical Engineering



### 5 Guidelines for the Restoration of Electrical Systems following Damage caused by Fire, Water and Extinguishing Agents

**The following Guidelines come into force on December 1<sup>st</sup>, 1998**

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Published by: Germanischer Lloyd Aktiengesellschaft, Hamburg  
Printed by: Gebrüder Braasch GmbH, Hamburg

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## Section 1

### General

#### A. Procedure

1. These Guidelines describe the measures to be taken for the restoration of electrical equipment following damage caused by fire, water and extinguishing agents and contain preventive measures to avoid damage. The measures include both initial measures and the restoration measures suitable for the removal of contamination. Where the term restoration is used in these Guidelines, it implies the repair of damaged equipment in accordance with a proven and by GL accepted procedure.

2. The properties and service ability of the equipment after restoration must be the same as they were immediately before the damage occurred. On the basis of the conditions given in these Guidelines, it may also be possible to restore operating systems which, if they break down, can directly endanger ship safety, such as for instance the remote control system for the main machinery or the electric drive systems of a ship's steering gear.

3. Whether the damage is put right by replacing the affected components or by carrying out a recognised repair procedure, depends essentially upon the damage pattern and therefore on the reparability and availability of new equipment or new machinery. Given the variety of damage patterns and the complexity of the different repair measures, it is assumed that this work will be performed by competent specialised firms.

4. Since the propulsion, manoeuvrability and ship safety of modern ocean-going vessels depend upon the availability of the ship's power supply, the issue of damage to electrical equipment caused by fire,

water and extinguishing agents is relevant in these circumstances.

5. This is particularly true with regard to consequential damage which will be discovered at a later date as a result of inadequate measures being taken or failure to carry out restoration. In these cases the equipment can fail or its availability can be impaired even after months.

#### B. Risks

1. Over the past years, the power output of ship mains, the quantity of components installed and the extent of the cable networks on ship newbuildings has been constantly increasing. The increased output of power generators and motor-driven consumers is linked to an increase in short-circuiting power, representing a high, and frequently underestimated potential risk for crew and equipment. Short circuits in ship supplies are generally linked to arcing which causes considerable damage if protective devices do not break the short-circuit current in time.

2. An additional risk comes from materials which in a fire form corrosive and toxic products which can spread over large areas and also be deposited at some distance from the damage site due to the thermal currents generated by the fire and through air-conditioning systems and supply trunks. Materials of this kind are often used for structural components and for insulation in electrical equipment; but they can also be found in many non-electrical equipment.



## Section 2

### Fire Damage

#### Note

*Electrical equipment which has been exposed to fire, flames or intensive radiant heat must generally be replaced by new components. However, a problem greater than direct fire damage of this nature is, in the majority of cases the so-called consequential fire damage. This arises due to soot deposits and other toxic and corrosive products. Consequential fire damage can in many cases be removed successfully by out prompt restoration measures.*

#### A. Fundamental Effects

1. Much electrical equipment is made from PVC among other things and some rubber mixtures which, in a fire, develop corrosive gases which are not only extremely dangerous to humans but also can cause major damage to technical equipment. PVC can, for example, be found in the housings of computers and switchgear and, in numerous other equipment, which is not part of the electrical outfit of a ship. Insulation of cable and wiring on merchant vessels is primarily made of PVC or special rubber mixtures. In a fire, a potential risk comes from cables which are laid in bundles throughout the ship and contain large quantities of insulating materials in a small space.
2. PVC is made of acetylene and hydrochloric acid (HCl) and in its original composition it is a brittle material containing approximately 56 % by weight of chlorine. In the manufacture of cables, fillers and plasticisers are added which reduce the chlorine content of the PVC to roughly 30 %. Like fluorine, bromine and iodine, chlorine belongs to the halogen group of elements.
3. At temperatures above approx. 80 to 90 °C the plasticisers leave and the material becomes embrittled. At higher temperatures, from approx. 140 to 160 °C, PVC segregate gaseous hydrochloric acid which condenses on cool surfaces and, when it comes into contact with moisture, forms liquid hydrochloric acid. Due to the thermal currents caused by the fire or by fans in operation, this gas can reach locations which are far away from the site of the fire. By this way hydrochloric acid comes to the surfaces of equipment and the associated corrosion can lead to failure of this equipment once it has had sufficient time to react. The hydrochloric acid has a catalytic effect only on the corrosion process. This implies that the hydrochloric acid scarcely decomposes or at a very slow rate only, and that especially on iron surfaces heavy corrosion occurs, even if small quantities of hydrochloric acid only are involved in the process. Therefore it cannot be assumed that the corrosion process will be halted without restoration measures being taken.
4. Fig. 2.1 shows the corrosion on a metal surface affected by hydrochloric acid as a function of relative humidity. With a relative humidity of less than 40 % corrosion is extremely low, which means that in this case it is possible to delay corrosion effectively on equipment, if care is taken after a fire, to ensure the appropriate ambient conditions.
5. The combustion products from PVC can be fatal to humans. If breathed in, they immediately attack the respiratory tracts and, if the concentration is high enough, it only takes a short time before death is caused by asphyxiation.
6. In addition to the generation of hydrochloric acid during a fire, a further drawback with PVC is the huge amount of soot it produces. Fig. 2.2 shows the light absorption caused by soot as function of the duration of the fire. The values given in the diagram were measured during a test fire and show that even when the fire has been burning for just a short time, visibility is virtually reduced to nil.
7. Soot is electrically conductive and capable of binding hydrochloric acid and later releases it again onto the surface. This may possibly increase the punctual concentration of hydrochloric acid and, in the long term, lead to corrosion. If it enters electrical equipment, soot must be removed.
8. At particular risk from the ingress of the products from fire (soot, hydrochloric acid and other harmful substances) are open switchgear, such as for instance contactors, generator switches and controls, as well as equipment which has internal ventilation, such as computers or electrical machinery designed e.g. for protection class IP22, IP23 (with open ventilation).

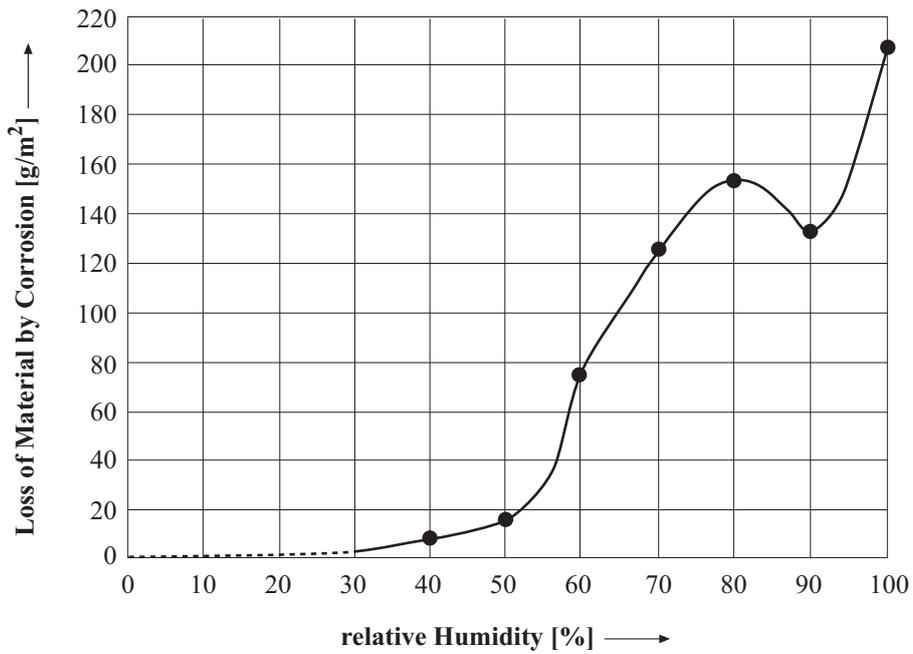


Fig. 2.1 Loss of material caused by hydrochloric acid on unalloyed steel

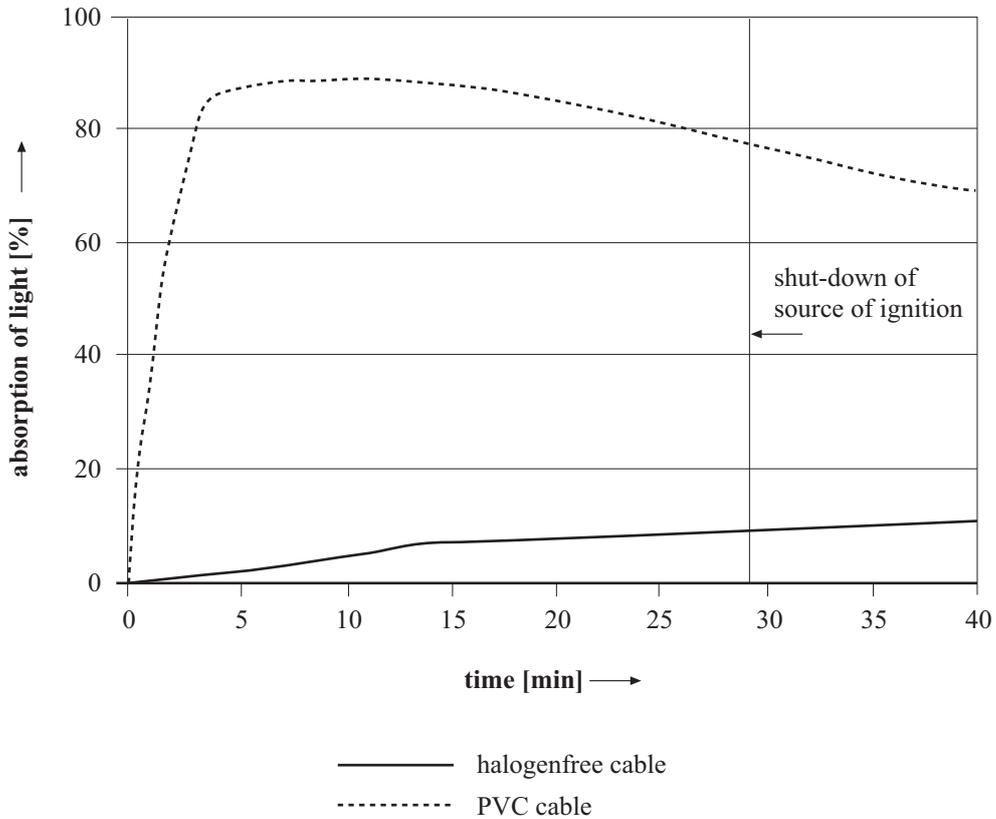


Fig. 2.2 Light absorption caused by the soot from burning cables

9. Beside PVC cables are often manufactured from mixtures containing rubber. In its original form rubber is a combustible material. Only when mixed with additives rubber becomes flame retardant properties. Cable production for merchant shipbuilding uses chloride in order to reduce flammability. Exposed to a fire, rubber cables containing chloride react similar to PVC cables with regards to the generation of hydrochloric acid and soot.

10. The drawbacks mentioned before can be widely avoided if halogen-free additives are used instead of chloride. For some years now, the industry has been offering halogen-free cables which in the past have mainly been used in special onshore installations, in naval shipbuilding and in the offshore sector. In a fire, halogen-free cables generate hardly any corrosive combustion products and, as can be seen from Fig. 2.2, produce significantly less soot than comparable PVC cables.

11. The GL Rules therefore specify the exclusive installation of halogen-free cables in service spaces and public areas on passenger vessels.

## B. Procedures to Reduce Damage in Fire

### 1. Procedures to be followed during a fire

In a fire the primary concern must be the cautious fighting of the fire by the use of the appropriate type and quantities of extinguishing agent. In order to reduce consequential damage, the following measures must be adopted during the fire itself.

- Fans and air-conditioning systems must be switched off to prevent the spread of combustion products into locations which are not directly affected by the fire. The independent ventilation of electronic equipment such as computers has also to be switched off where possible.
- All electrical equipment endangered by the fire and not required for fire-fighting purposes must be switched off.

### 2. Procedures to be followed after a fire

- Fumes shall be vented into the open air and the affected area shall be secured against access by unauthorised personnel.
- Water used for fire-fighting shall be removed and equipment shall be protected against dripping water.
- All equipment which is suspected to have suffered fire damage should, if possible, be switched off and carefully checked for soot deposits and other fire damage before it is returned into service. If soot deposits or damage

are found, the equipment must be restored to condition before being started up again. A quantity of damage is caused by the only fact that contaminated or damaged equipment is returned back into operation after a fire.

- The fire zone and the areas adjoining it have to be checked for corrosion caused by combustion products. Safe signs of corrosion include colour changes on the metal surfaces of door fittings, heat sinks for the power electronics, electrical conductors and other objects. Non-corroded equipment in locations where corrosion caused by the fire has been discovered on equipment shall be treated in the same way as contaminated equipment unless it can be ascertained without doubt that no damage has been occurred.
- Electronic equipment which shows signs of consequential fire damage, or which is suspected, that such a damage might occur, should be stored in dry compartments not affected by the fire. The progress of corrosion can be significantly reduced if the relative humidity in the compartment used for storage is reduced to below 40 % by the use of dehumidifiers. The buffer batteries in electronic equipment must be disconnected. Non-portable equipment may be covered by tarpaulins to form a temporary shelter with dehumidifiers used to provide a dry atmosphere.

## C. Restoration of Electrical Equipment Following Fire Damage

1. General, contaminated equipment should be restored by a specialist company, the repair measures performed being agreed with GL.
2. For assessment and limitation of the restoration measures required, the degree of contamination shall be determined by a chemical analysis. The values given in Table 2.1 can be used as guidance, if restoration is necessary.

Table 2.1 Limit values

		Electronic/ Electrical systems	Mechanics
Hydrochloric acid (HCl)	µg/cm <sup>2</sup>	< 5	< 10
Chlorides (NaCl)	µg/cm <sup>2</sup>	< 10	< 10

3. Slight damage to equipment which, in the event of any consequential damage arising, does not affect the ship's safety can be restored using onboard facilities. Restoration work requires compressed air, brushes, or distilled water for rinsing contaminated electronic assemblies or the windings of electrical machinery. Finally, the restored equipment must be thoroughly dried.

4. If compressed air is used to remove water or fire residue, care should be taken to ensure that these substances do not move to places from where they cannot be removed.

### 5. Damage to switchboards and switchgear

Switchboards which have been contaminated by combustion products, for example during a fire in the engine room, should be checked as described below and should only be returned back to operation when considered essential for ship operation:

- A visual inspection of the entire switchboard shall be performed
- The contaminated parts shall be cleaned using brush, cloth, industrial vacuum cleaner or compressed air. The use of compressed air demands particular caution.
- An insulation measurement of the switch system must be conducted. The control switches on the distribution systems must be opened so that the undamaged part of the switch system does not adversely affect the measurement results. The insulation resistance should be greater than 1 k $\Omega$  per volt of rated operating voltage, but must be at least 1 M $\Omega$ . However, a much higher insulation resistance in the range of several M $\Omega$  is to be aimed at.
- Terminals must be replaced as necessary if they can only be partially cleaned following fire damage and so adversely affect the insulation value of the switchboard as a whole.
- All switchgear in the affected areas must be carefully inspected. Particularly at risk is switchgear whose housings are not completely enclosed, such as contactors and open power switches - so called air circuit breakers (ACB). Fully enclosed power switches, so-called moulded case circuit breakers (MCB), are less susceptible to contamination.
- Open power switches and fully enclosed power switches with rated currents in excess of 100 A (standard value) can in most cases be restored by the manufacturer or by an accredited company. Fully enclosed power switches with rated currents less than the standard value quoted should be replaced by new equipment if restoration is not economically.

- Contactors which are operational but which have obviously been affected by the combustion products, or contactors which have an increased noise level, should be replaced by new equipment at the earliest opportunity. This also applies accordingly to controls and other components with a low IP protection class.
- If, after a fire, corrosion is discovered on a switch system, the protective earths and terminal connections shall be subject to a special test. If hydrochloric acid has penetrated into connection components, the function of these connections will be adversely affected due to increased resistance (caused by corrosion).

### 6. Damage to electrical machinery

6.1 In a fire, machines with open ventilation are the ones most at risk because the flow of cooling air is passed over the windings and other internal components. These machines are typically designed to protection class IP22/IP23 and are used as generators or driving motors. Surface-cooled machines in which the cooling air passes over the outside of the housing (e.g. protection class IP44/IP55) are at low risk from the combustion products of a fire.

6.2 Soot or powder extinguishing agents can be removed from the machinery by mechanical means with the aid of compressed air or using an industrial vacuum cleaner. If corrosive products have got into a machine, it should be restored to condition by a specialist company. Where restoration by a specialist firm is not possible due to the area in which the ship is operating, the machine may be cleaned by the crew using distilled water for example. Finally, the machine must be dried thoroughly until an insulation resistance of at least 1 k $\Omega$  per volt of rated operating voltage is attained (minimum 500 k $\Omega$ ). However, a much higher insulation resistance in the order of several M $\Omega$  should be aimed at.

### 7. Damage to electronic equipment

- Electronic equipment which has been directly exposed to flames or intense radiant heat and exhibits deformation on housings, components on printed circuit boards are generally beyond restoration.
- Where a deposit of soot is discovered on printed circuit boards and other electronic components, these may be restored to condition with the use of vacuum cleaners, compressed air and brushes. In these cases it has to be avoided that soot may be moved into places from where it can't be removed. As an emergency measure, contaminated printed circuit boards may be cleaned with distilled water and then dried.

- Where the contamination of electronic equipment is so severe that hydrochloric acid has formed on the surfaces of printed circuit boards, plug-type connectors and other parts, an extensive restoration process must be carried out. As has already been mentioned, the corrosion process can be significantly delayed if equipment is stored in areas with low relative humidity (< 40 %). Where no such areas are available, the equipment may be covered by plastic toils. By the use of air conditioners or dehumidifiers, the relative humidity in these spaces can then easily be reduced to < 40 %. So damaged equipment may never be allowed to return back to operation prior to restore it to condition.

## 8. Damage to cables

**8.1** If large sections of the cable sheath have been damaged, or even the core insulation, the damaged section must be replaced by a new cable with the same construction. The new cable must be jointed by the use of splicing sleeves or by junction boxes.

**8.2** The industry offers repair sets for damaged cables. They have to be type tested by GL and may also be used for the repair of cables to supply essential equipment.

**8.3** If only the cable sheath is damaged by the effect of heat, a heat shrinking repair sleeve may be used. The conductor insulation beneath the sheath must be in proper condition. If in doubt, the damaged outer sheath must be removed so that tests can be performed. For this easy repair method the faulty section of cable to be repaired should not be longer than 1 metre.

**8.4** Repairs of cables must be authorised by GL.

## D. Preventive Measures

**1.** The risk posed to electrical equipment by the direct effect of flames, along with contamination caused by combustion products and extinguishing agents can be significantly reduced by the adoption of various measures. These include design measures such as the installation of halogen-free cables, as mentioned earlier, carefully made bulkhead providing of firestops on the cable bundles, as well as instructions to the crew as what to do in the event of fire.

**2.** It is also important that electrical equipment is carefully installed, that the systems are in generally good conditions and that the ship's mains have been thoroughly maintained, including checks carried out on the contactors and measurements of the insulation resistances at regular intervals.

**3.** In order to avoid short circuits, switchboards must be cleaned as and when required and carefully inspected after maintenance work to ensure that all tools and material residue have been removed from the system. All electrical connections must be regular checked to ensure that they are tight. It should be noted that busbar connections have to be tightened with a specified torque. Loose connections in heavy current systems may cause short circuits or may cause severe overheating which can lead to fire.

**4.** To protect the crew and equipment, work on electrical equipment should only be carried out by specialised personal. Work on the main distribution systems contains a particularly high risk potential. Replacing HRC fuse insert in a circuit which has inadvertently not been disconnected can cause a short circuit which leads almost unavoidably to injuries and property damage.



## Section 3

### Damage Caused by Extinguishing Agents

#### A. Damage Caused by Powder Extinguishers

1. Ships are normally equipped with powder extinguishers which contain so-called NBC powder and are suitable for extinguishing solid, fluid and gaseous substances which are on fire. The powder used is electrically conducting, hygroscopic and has a corrosive effect when it comes into contact with moisture, with the result that it can inhibit the function of electromechanical parts and permanently damage electrical components. Furthermore it can reduce the heat dissipation of electronic equipment and must therefore be removed from all electrical equipment. Loose deposits of contaminants can be removed using brushes, vacuum cleaners or compressed air. It is a known fact that the injudicious use of powder-type extinguishing agents can cause considerable consequential damage and the cost of removing the powder can be higher than it would have been to repair the actual fire damage.

2. Due to the crystalline properties of powder extinguishers, mechanical parts may additionally be

affected by abrasion and following mechanical malfunction.

3. Due to the stated drawbacks of powder-type extinguishing agents, fires in or close to electrical equipment should be fought only by CO<sub>2</sub> or other suitable extinguishing agents.

#### B. Damage Caused by Foam Extinguishers

If foam enters into electrical components, the procedure to be followed is the same as that described in Section 4.

#### C. Damage Caused by Water Extinguishers

If water enters into electrical components, the procedure to be followed is the same as that described in Section 4.



## Section 4

### Water Damage

#### A. Assessment of Restorability

The restorability of electrical equipment following water damage is assessed by a visual inspection to determine the level of contamination, corrosion and bubbling on circuit boards and insulation materials. The following points must also be considered when ascertaining the potential extent of the damage:

- Was the electrical/electronic equipment in operation when it came into contact with the water?
- Did the electrical/electronic equipment come into contact with seawater or fresh water?
- How long was the electrical/electronic equipment in contact with the water?
- How old was the system?
- Are electrochemical reactions visible already at live parts?

#### B. Damage to Switchboards and Switchgear

The extent of the restoration measures depends upon the duration of contact, the volume and the nature of the water which has entered the switch system. If the damage was caused by fresh water only, rinsing with distilled water is probably sufficient, followed by the application of corrosion protection on metal surfaces, with any defective parts being replaced. In any case, careful drying is essential. Where a switchboard has been completely overflowed, only the busbar system and larger power switches are probably worth restoring. The remaining switch system components must be replaced.

#### C. Damage to Electrical Machinery

1. The restoration of large electrical machinery which has come into contact with sea or fresh water will, in most cases, depend upon technical and economic considerations, provided that the windings and insulation materials are in good condition, that the duration of contact with the water was not too long and that the corrosion process has not progressed too far. In these instances, restoration is typically carried out by washing, drying and applying a preservative to the winding and metal surfaces. When restoring a

motor, the bearings should also be replaced. A restored electrical machine may only be returned to operation again if the insulation resistance is  $\geq 1 \text{ k}\Omega$  per volt of rated operating voltage, but at least  $500 \text{ k}\Omega$ . It should be aimed at a much higher insulation resistance in the range of some  $\text{M}\Omega$ .

2. For economic reasons, the restorability of small electrical series machines is generally not feasible if a new winding is required. Only for special machinery is this expense worthwhile.

3. In the past few years, the insulation materials used in the electrical engineering industry have been improved as regards their hygroscopic performance and their mechanical properties. Consequently, new machines are often not as susceptible to potential water damage as older machines. If during the damage inspection process, corrosion is found on the winding or bubbling is discovered on the insulation materials, it will have to be assumed that the winding will have to be replaced. The final information about the status of a winding after restoration is proved by the high voltage test, the insulation resistance measurement and by a function test with the restored machine. The applied voltage for the high voltage test to be performed on a restored machine must be lower than those applied during test of a new engine (max. 80 % of the test voltage of a new motor) see GL Rules 1 – Ship Technology, Part 1 – Seagoing Ships, Chapter 3 – Electrical Installations. Rewinded electrical machines must be tested like new ones.

4. Where the restoration work involves work on the rotor which could cause them being out of balance, such as impregnation, the rotor will have to be re-balanced.

#### D. Damage to Electronic Equipment

In many cases electronic equipment suffered water damage can be successfully restored to conditions by a specialist firm if the system was not in operation while it was in contact with the water, and provided that the water did not penetrate into circuit boards or insulating materials and caused bubbling. Corroded plug boards and strip conductors can be reproduced by specialist firms.

**E. Damage to Cables**

1. The cables used on board ships are not suitable for permanent contact with water. This applies to both the cable sheath and the conductor insulation. Once water has penetrated, for example at the ends, a cable can continue to remain in operation for a limited period of time provided that an insulation measurement indicates that the insulation resistance is at least 1 k $\Omega$  per volt of rated operating voltage. For information the measurement should be repeated at intervals until the cable is finally replaced.

2. Cables for sea-going ships are not longitudinally watertight. Capillary effect in a cable can cause

water from flooded compartments to rise several metres above the level of the water surface. After this kind of damage, long lengths of vertical cable must also be removed in order to replace damaged cables.

3. General each lengths of cables which have come into contact with water must be replaced. It is impossible to ensure that they are completely dried and that, for example, salts which might possibly have penetrated into the cable together with the water, are removed. It must always be assumed therefore that a cable into which water has penetrated will fail at some later date.

## Annex A

### Checklist

#### Immediate Action to Be Taken on Electronic and Electrical Systems and Equipment Following Contamination by the Gases Produced in a Fire, Water and Extinguishing Agents

##### 1. General rules of procedure during the fire

- Limit fire damage by fighting the fire judiciously and swiftly using a suitable extinguishing agent.
- Switch off fans and air-conditioning systems to stop the spread of the products of the fire and prevent oxygen getting to the site of the fire.
- Switch off fuel and lube oil pumps. Isolate all tanks containing combustible fluids.
- Disconnect compressed air supplies where oxygen can be supplied to the site of the fire via this equipment.

##### 2. General rules of procedure after the fire

- Secure the site of the damage against unauthorised access.
- Switch off all electrical and electronic equipment which is damaged and that which is close to the fire site and not necessary to preserve life, disconnect the battery supply.
- Switch-off air conditioning systems.
- Do not switch equipment on again, do not perform a function test.
- Inform GL.
- Prepare a status report.
- Agree restoration measures with GL.

##### 3. Immediate Action to Be Taken Following Fire Damage

- Vent any residual fumes into the open (open windows, external doors etc.). (If fires have not been completed extinguished, there is a risk of the fire flaring up again).
- Inspect the fire zone and adjoining areas for contamination caused by combustion products. Safe signs of corrosion are indicated by colour changes on the metal surfaces of door mountings, the heat sinks of power electronics, electrical conductors and other terms.
- Move portable electronic equipment to dry compartments not affected by the fire.

Reduce the relative humidity to below 40 % as quickly as possible to delay the progress of corrosion (use dehumidifiers).

Remove the water used to fight the fire (sea water damage)

Protect non-affected areas from the spread of soot (partition off), and protect intercommunicating areas such as doors by putting down damp cloths or doormats.

Initiate final restoration measures.

**4. Immediate Action to Be Taken Following Water Damage  
(Including Water and Foam Type Extinguishing Agents)**

Immediately switch off all non-essential electrical supplies.

Ensure that such supplies cannot be switched on again (remove fuses, blank off switches).

Disconnect battery supplies (including back-up batteries in electronic equipment).

Pump out water.

Cover fixed equipment and system parts and protect against dripping water.

Remove wet items of equipment and materials (curtains, carpets etc.).

Wipe dry walls, ceilings and remaining items of equipment.

Dry by the use of suction equipment or wipe dry decks and floors.

Blow out electronic equipment and wet components with compressed air and dry with hot air (no hotter than 50-60 °C).

Move portable electronic equipment to dry spaces not affected by the fire.

Set up dehumidifier in damaged compartment.

Initiate final restoration measures.

**5. Immediate Action to Be Taken Following a Heavy Accumulation of Dust or the Effect  
of Powder Type Extinguishing Agents**

Switch off equipment which is susceptible to dust and corrosion straight away (risk of overheating, wear, creeping currents).

Remove dust and powder-type extinguishing agent.

Initiate final restoration measures.