DESIGN CONSIDERATIONS OF LUMINAIRES FOR NUCLEAR POWER PLANTS

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1. Introduction

Due to global increasing demand for electrical energy several nuclear power plants are under design, construction and reconstruction world wide. This is the situation in Central Europe as well (e.g., Mohovce [1], Paks [2]). The reconstruction concerns lighting systems of the power plants as well, becasue they are out of date: mercury and sodium vapor lamps used nowadays exhibit relatively low efficiency and high power consumption. So, a part of the produced electricity is expended on lighting inside the power plant itself. E.g., if mercury or sodium vapour lamps are replaced by linear luminescent tubes, they can provide the same illuminance with much lower power consumption.

The high number of nuclear accidents and incidents in nuclear power plants [3,4] have called a social protest against them. In Central Europe the disaster in Chernobil [5] and the accident in Paks [6] called the attention to the safety problems with nuclear power plants. Recently the disaster in Fukushima [7,8] shocked the society world wide (see Fig. 1), and safety requirements to nuclear power plants and to nuclear energy in general, have been reconsidered.

Fig. 1: Fukushima Daiichi, March 2011 [8]

Despite accidents, nuclear power plants seem to be the most efficient, economic, safety and environment friendly solution for production of electrical energy [9,10]. But safety requirements should be reconsidered taking into account all the possible risks of operation, environment, and natural and human attacks. In this paper the requirements, possible materials and light sources for luminaires usable in nuclear power plants are briefly reviewed taking safety issues into account.

2. Requirements to luminaries

Of course, the standards for basic and general requirements concerning lamps and luminaires, as efficiency, lifetime, content of poisonous and dangerous materials, etc., are valid for nuclear power plants as well (see, e.g., Ref. 11 for Russian Federation).

These requirements are in particular important in nuclear power plants. High efficiency is important because the maintenance and operation of the power plant itself consumes a considerable part of the produced electricity.

Long lifetime is in particular important for underwater luminaries used in pools of fuel handling. Direct and complementary operations in fuel handling pools, as e.g., changing lamps, are very time consuming and costly.

Long lifetime needs that all materials used should be radiation resistant up to such a dose, which befalls the materials during the lifetime of the luminaire. The estimated dose is in the range of 1-10 kGy per year. Materials of mechanical parts can loose their strength due to radiation, while materials of diffuser or lenses change their color and loose their optical transparency.

Limited content of poisonous, dangerous, and chemically reactive materials in lamps (e.g., Hg, Pb, Na) can yield severe problems, if the lamp is broken mechanically and the material leaks to the operating area, or – in particular – if it leaks to the handling pool of fuels. It is very important either for underwater luminaires the possibility to change the lamp simply by hand without any tool to avoid drop of tools or parts of the lamp into the pool [12].

Further requirements for luminaires is avoiding sharp edges and corners, which can damage the safety gloves or clothing of staff. Smooth surface is also required to decrease dust absorption and to make clean easier. The surface of luminaries should be acid- and base-resistant, because cleaning is performed with a weak acidic or alkaline solution.

Luminaries should be hermetically closed from environment for both underwater and in-air lighting. It is important to avoid entering humadity into luminaries and leakage of dangerous materials from them. Hermetic isolation requires small windows for relamping.

However, hermetic isolation is conflicting with the requirements of cooling. The temperature of lamps during operation should not exceed the maximum operation temperature.

Luminaires should be explosion proof as well, which also requires hermetic isolation and avoiding sparking and high working temperatures above 120 ^oC.

They should sustain extrem environment: high temperature up to 90 ^oC and high humadity. They should withstand a major earthquake up to acceleration of about 10 g. This requires robust body made of a strong material. But it is forbidden to use catalytic materials, as Al or Zn. E.g., at high temperatures Al promotes water dissociation yielding hydrogen. That was the origin of explosion in Fukushima power plant.

It is very important the short and long term stability of lingting. So, the number of electronic components should be decreased as possible, or they should be ignored at all. E.g., in the case of luminescent lamps inductive ballast is prefered against electronic ballast.

It is a requirement to install emergency lighting that should provide enough illuminance in the operating areas for a long period up to 24 hours in the case of catastrophic situation.

3. Materials and lamps

As mentioned above, materials for body and mechanical parts should be strong enough to sustain earthquakes, and cannot contain catalytic metals. The most suitable materials satisfying these requirements seem the different types of stainless steel. Their mechanical strength and chemical resistivity are excellent. Further on, their optical reflectance can be modified in a wide range, which is useful, e.g., for substitution of aluminum reflectors.

Choosing materials for diffusers or lenses isn't so easy. Glass is the classical material: it exhibits good transparency for visible light and rather good mechanical properties. But its radiation hardness isn't very good. Radiation hardness can be improved by increasing crystallinity: quartz and fused silica exhibit better performance. But these materials are rather expensive, so their application decreases the economical effect. Borosilicate glass seems to be a better choice [13]. From plastics polycarbonate can be considered [12].

As sealing materials, silicon and viton seem suitable.

The most common light sources used nowadays in nuclear power plants are the tungsten-halogen and high-pressure sodium vapor lamps. However, it is considered more optimal to use linear luminescent tubs in operation areas since their better efficiency. Recently LEDs are introduced as light sources in a few nuclear power plants also for economic reasons [14]. But their radiation hardness and performance at elevated temperature is rather questionable, which can influence the lifetime and decrease the economic effectivness.

3. Summary

Requirements for luminaires usable in nuclear power plants are briefly discussed. The main parameters required are high efficiency, long lifetime, radiation hardness, and lack of poisonous, dangerous, chemically reactive, and catalytic materials. It is a requirement either to install emergency lighting in nuclear power plants.

The most suitable material for mechanical parts seems the stainless steel. For diffusers or lenses borosilicate glass or polycarbonate can be used. As sealing materials, silicon and viton seem suitable.

Replecement of mercury or sodium vapour lamps by linear luminescent tubs increases of lighting efficiency. In some nuclear power plants LEDs are introduced recently as light sources.

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