Radiation Safety Aspects of Fluorescent Lamp Starters incorporating radiation source

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Abstract

A fluorescent lamp starter is a switch which applies the voltage to the fluorescent tube after sufficient preheating to allow the tube to conduct an electric current. Radioactive substances used in the starters are ^{85}Kr, ^{147}Pm, ^{3}H and ^{232}Th. In India, fluorescent lamp starters are classified as consumer products and users are outside regulatory control. However, regulatory control is exercised over the manufacturers at the production stage.Tritium activity measured in the lamp starters ranged from 400 - 4500 Bq with a mean activity of 1.78 kBq. Thorium activity measured varied from 0.44-3.3 mg. The results of radiation safety assessment of the workplace and radioactivity estimation in the starters are discussed in this paper.

Introduction:

A fluorescent lamp starter typically contains radioactive material to produce ionisation within the starter. The starter is basically a switch which applies the voltage to the fluorescent tube after sufficient preheating to allow the tube to conduct an electric current. The starters significantly extend the functional life of the tube.

Lamp starters consist of two electrodes one of which is a bimetallic strip sealed in a small glass bulb containing an inert gas mixture. The bulb is mounted in a small cylindrical container of aluminium or polycarbonate; fitted with two contacts and also with a small capacitor to suppress any radio interference caused by the starters. The glass bulb is generally of diameter 7.5 - 8.0 mm with wall thickness of 0.6 - 0.8 mm and the canister is of 21mm diameter. Radioactive substance is used in the starter for pre-ionisation of gases within the starter for low starting voltage in the lamps. Radioactive substances used in the starters are ^{85}Kr, ^{147}Pm, ^{3}H and ^{232}Th.

There is not much information available on the radiological safety aspects of the fluorescent lamp starters. A monitoring programme conducted in these industries is reported here.

Regulatory Aspects:

In the regulation of manufacture and use of consumer products, there are the major areas of concern, 1. Radiation safety of workers and workplace 2. Radiation safety of the general public or users of the products 3. Environmental impact due to manufacture and use.

Radiation safety of the workers and workplace is ensured by compliance to recommendations of the International Commission for Radiological Protection (ICRP).

The prescribed limit for members of the public is 1 mSv. Radiation exposure to individuals in the general public as a result of marketing, installation repair and use of consumer products must be kept even lower than the prescribed limits for members of the public. In setting up the limits for individual doses, the potential cumulative dose from the use of multiple products and from other sources must also be considered. Hence one tenth of the prescribed limit (100 μSv) has been apportioned for doses due to use or handling of consumer products. Considering at least 10 products being used in a year the individual dose limit is set at 10 μSv for each product. These products are released for unrestricted use by members of the public and the collective dose to the entire population should not exceed 1 person Sv in any year under normal conditions.

In India, the manufacture and supply of consumer products containing radioactive substances for use in public domain is subject to authorisation by the competent authority; Chairman, Atomic Energy Regulatory Board (AERB). To exercise regulatory control over the manufacturers at the production stage, the manufacturer's facilities are assessed and ensured that they are capable of meeting the prescribed safety standards; thereafter, periodic inspections are carried out to ensure that safety standards are continually met.

Approval has also to be obtained by the manufacturer for the product before releasing it in the market because once these consumer products are sold, it is not possible to exercise control over the radiation doses to the public consequent to their use. For this, standards are specified for the products requiring approval. The standards are defined in terms of radioactivity limit or mass of radionuclide in each product and test requirements for the product. Products not satisfying these regulatory conditions are not allowed to reach the public domain.

An authorisation for manufacturing a consumer product is considered upon adequate demonstration that the product performs a function which can be fulfilled only by using a radioactive substance or that the function has definite advantages such as

- safety of life and property,
- Protection against personal injury,
- Improving reliability or dependability of a product in respect of its safety functions,
- The fulfilling of an advantage not covered by (i) to (iii) above but judged to be of equal importance and
- the use, and disposal of the product does not give rise to unacceptable radiation doses to individual members of the public and the population at large. The products are required to be designed and constructed in accordance with the AERB standard specifications (1) so that they can be accepted with reasonable confidence that the members of public are adequately protected from unacceptable radiation exposure.

The radioactive material introduced into fluorescent lamp starter bulbs is either one of ^{85}Kr, Tritium, ^{147}Pm and Thorium and the glass bulb enclosed in an outer container is made of metal or polycarbonate material. Tests specified include; temperature, external pressure, immersion, drop and bump tests specified by the AERB safety standards.

Manufacturing facility:

The safety requirements for the manufacturer are:

a) Radioactive source procured for use should be kept separately and safely with proper identification.
b) At the time of source preparation for use, only the minimum required quantity should be drawn from the stock solution.
c) Radioactive sources should be under the custody of a responsible person having adequate knowledge of radiation safety and is entrusted with responsibility of maintaining source inventory and handing over sources to persons involved in introducing the source into the product.
d) Coating of radioactive source in the glass bulb should be done in a separate area, away from the other manufacturing facilities.
e) The worktable where radioactivity is handled should have smooth surface.
f) The floor should be lined with smooth impervious flooring material.

Manufacturing Process

A lamp starter is manufactured in the following steps:
Radioactive material is added or applied to the glass bulb. These bulbs are subjected to several mechanical processes such as, for fixing the electrodes, creating a vacuum, filling with an inert gas and sealing. The inert gas mixture is generally 40% argon, 45% helium and 15% hydrogen. After sealing, they are sent for quality control and further sealed in an aluminium or polycarbonate canisters. One set of machinery would mean a rotary machine and auto vacuum machine gas filling and sealing machine. With one set, an industry can manufacture 15,000 - 18,000 bulbs in a day.

a)Thorium users:

There are about 45 industries handling thorium oxide in the manufacture of fluorescent lamp starters. Thorium oxide is supplied to these industries by indigeneous suppliers. The quantity of thorium used during 1992-1996 is given in Table-1.

Each industry handles about 25 to 90 kg. annually. The quantity used will depend upon the area, machinery and work force available with the industry. As per the regulatory requirements, all these industries are situated in industrial areas and are registered with the local government body. In a typical industry on a table top a few gram (200-300g) of thorium is drawn from the bulk storage and is mixed with nitro-cellulose, acetone, butylacetate and this mixture is coated on the inner surface of glass bulb. In each industry thorium oxide coating in the bulb is isolated from other machining or manufacturing work. In a few industries the coating process is mechanised whereas in some places, it is done manually. The number of bulbs coated in a day is generally in the range of several hundreds to thousands.

The entire machinery is housed in a big hall with general ventilation fans fitted on the walls at the ceiling height. The ceilings are generally at height more than 10 m. Large doors and windows in the hall are kept open generating natural air currents within the building. A sketch of a typical manufacturing facility is given in fig.1.

b)Tritium Users:

In India, there are 5 industries handling gaseous tritium in glow lamps amounting to 12.77 TBq annually and 3 industries use tritium titanium suspension of total activity 342.25 GBq annually.

^{3}H when used in gaseous form, is mixed with inert gas mixture with a specific activity of 370 MBq per litre. There is no separate handling of radioactivity. It is filled along with the inert gas mixture.

In liquid form it is tritium titanium suspension to which binder and colour are added and are coated in the inner surface of the glass bulb.

c)Promethium Users:

At present Pm-147 is used in sealed form, it is directly plated on the surface of the inner wire of lead in wires made of nickel, iron etc.. then the overcoated nickel layer covers the radioactive layer and is completely sealed. Specific activity of the wire is about 3.7 kBq per cm and the Pm-147 activity in a piece would vary from 1.85 -18.5 kBq.

Work Place Monitoring:

a)Thorium handling Workshop

Air sampling: Samples were collected using high volume Staplex air sampler and using TFA GF 41 10cm diameter filter paper as medium with flow rates of 0.566 - 0.7075 m^3 / minute in breathing zone for known period of time. The sampling time varied from 10-30 minutes. The samples were collected from areas where there is likelihood of airborne activity due to thorium handling.

The filter paper samples were stored for a period of three weeks for the short lived activity of radon/thoron daughters to decay. Filter papers were counted in an alpha scintillation counting set up with a ZnS(Ag) scintillator (ECIL make CM 4553A). Counting periods were of the order of 1000 seconds. The counting efficiencies ranged from 8-17%. The background count rates were in the range of 60 - 100 counts for 60 minutes. The characteristics of the filter paper as quoted by the manufacturer are 95% collection efficiency for 1 micron particles and obtaining 70% count with a penetration absorption of 30%. Applying these corrections on the gross alpha activity measured, ^{232}Th activity was estimated assuming equilibrium among all the daughter nuclides.

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Contamination on surfaces: Fixed and removable contamination on the work surface were directly measured using alpha contamination monitor (ECIL make). Measurements were made on floor area, work tables etc. The counting efficiency was established using a standard reference source of strength (2.5x10^5 dpm). The counts per minute observed were converted to dpm/100 cm^2 after correcting for detector efficiency.

The air samples were collected using Staplex high volume sampler for a sampling time of 60min and the results are presented in table-2. External exposure levels measured near the bulk storage and near the thorium coating table. The gamma exposure levels ranged from 0.5 μSv/h-5 μSv/h after correcting for the background.

Swipe samples were collected adjacent to the thorium coating area, and alpha contamination results are presented in fig.2. The levels observed were below the prescribed limit of 2.5 dpm.cm^{-2}.

b)Tritium handling factory:

There is no external hazard in handling tritium. Air sampling in the workplace was done by cold finger method. No significant activity(above the background) was detected. Swipe samples taken from the work surfaces also did not indicate any significant contamination.

Activity estimation in fluorescent lamp starters:

From the starter samples only the glass bulbs containing thorium were separated and sealed in a disc geometry and stored for a period of 3 weeks. In each disc 5 bulbs of the same brand were sealed and in all, 8 different brands were studied. In order to estimate thorium activity in a starter, initially a standard was prepared in the laboratory. For this, glass bulbs of length 2cm were cut. Very thin filter papers equal to the width of coating were cut and spiked with 50 μl of thorium oxide standard solution and dried. 10 μl of the standard solution was equivalent to 17.985 μg. The filter papers were introduced into the bulb by means of forceps. Preparation of such a standard avoided geometry correction. The glass bulb and the filter paper for the standard were chosen that their dimensions are similar to the samples. Similarly 5 standard bulbs were stored in one container. These were counted in HPGe gamma spectrometer identifying the four gamma peaks of 239 keV of ^{212}Pb, 583 and 2614 keV of ^{208}Tl and 911 keV of ^{228}Ac. Thorium estimation was done in the same steps as for gas mantles discussed elsewhere (2). The results are presented in Table-4. Thorium content is found higher than the limit of 0.05mg specified. The manufacturing units have been informed and action initiated in this regard.

For estimation of **tritium** in the starter samples glass bulbs coated with tritium were wrapped in cellophane paper and incinerated in combustion flask. Water of combustion collected was counted in Liquid Scintillation Counting System. The steps followed for estimation of tritium in watches was adopted here (3). Tritium activity in five bulbs ranged from 400 - 4500 Bq with a mean activity of 1.78 kBq.

Estimation **^{3}H in gaseous form** in lamp starters was done from the data collected from the industries. Out of 555 GBq of tritium gas 30 million pieces are made. Activity in one glass bulb works out to be 18.5 kBq. Permissible tritium activity in a fluorescent starter is 40 kBq [1].

Conclusion:

1. Fluorescent lamp starters are used in large numbers (in millions). This study has revealed that they are safe for unrestricted use by members of public because of low tritium activity (0.3-4.5 kBq) found in them, which is well below the maximum allowed activity of 40 kBq.

2. Thorium content in lamp starters is found higher than the specified limit of 0.05mg. The manufacturing units have been informed and action initiated.

Reference:

1. Atomic Energy Regulatory Board (AERB) - SS4, Radiological Safety in the design and manufacture of consumer products containing radioactive substances AERB, India,(1991).

2. G.Sadagopan, K.S.V.Nambi, G.Venkataraman, V.K.Shukla and S.Kayasth, Estimation of thorium in gas mantles to ascertain regulatory compliance, Radiation Prot.Dosimetry, 71(1),53-56,(1997).

3. G.Sadagopan, S.H.Sadarangani, K.S.V.Nambi, T.M.Krishnamoorthy and G.Venkataraman,Radiological safety aspects of Indian watches containing tritium, Radiation Prot.Dosimetry, 72 (1), 49-53,1997.

Table-1
Supply details of thorium oxide
to lamp starter industries in India

Year	kilograms
1992	257
1993	432
1994	370
1995	300
1996	418

Table-2

^{232}Th air sampling in fluorescent lamp starter industries

Industry Code	Thorium handled	Total air volume collected	Description of the facility	Thorium concentration
1	30 kg/y.	0.566 m^3	1 machinery set	0.05 Bq/m^3
2	30 kg/y.	0.849 m^3	3 machinery sets	0.07 Bq/m^3
3	30 kg/y	0.7075m^3	1 machinery set	0.05Bq/m^3
4	15 kg/y	0.566m^3	2 machinery sets	0.05Bq/m^3

Sampling time was 60 min.in all industries and sampling location was near the thorium coating table.

Table-3

Thorium activity estimated
in fluorescent lamp starters

Sample code	^{232}Th mass (mg)
1	0.71
2	0.44
3	1.17
4	1.36
5	3.30
6	0.95
7	2.50
8	1.80

General layout of a lamp starter facility

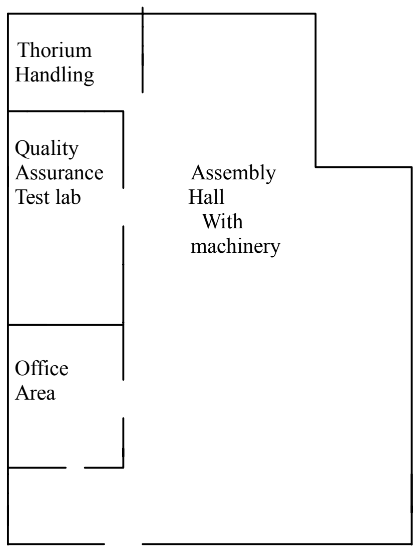

Fig.2

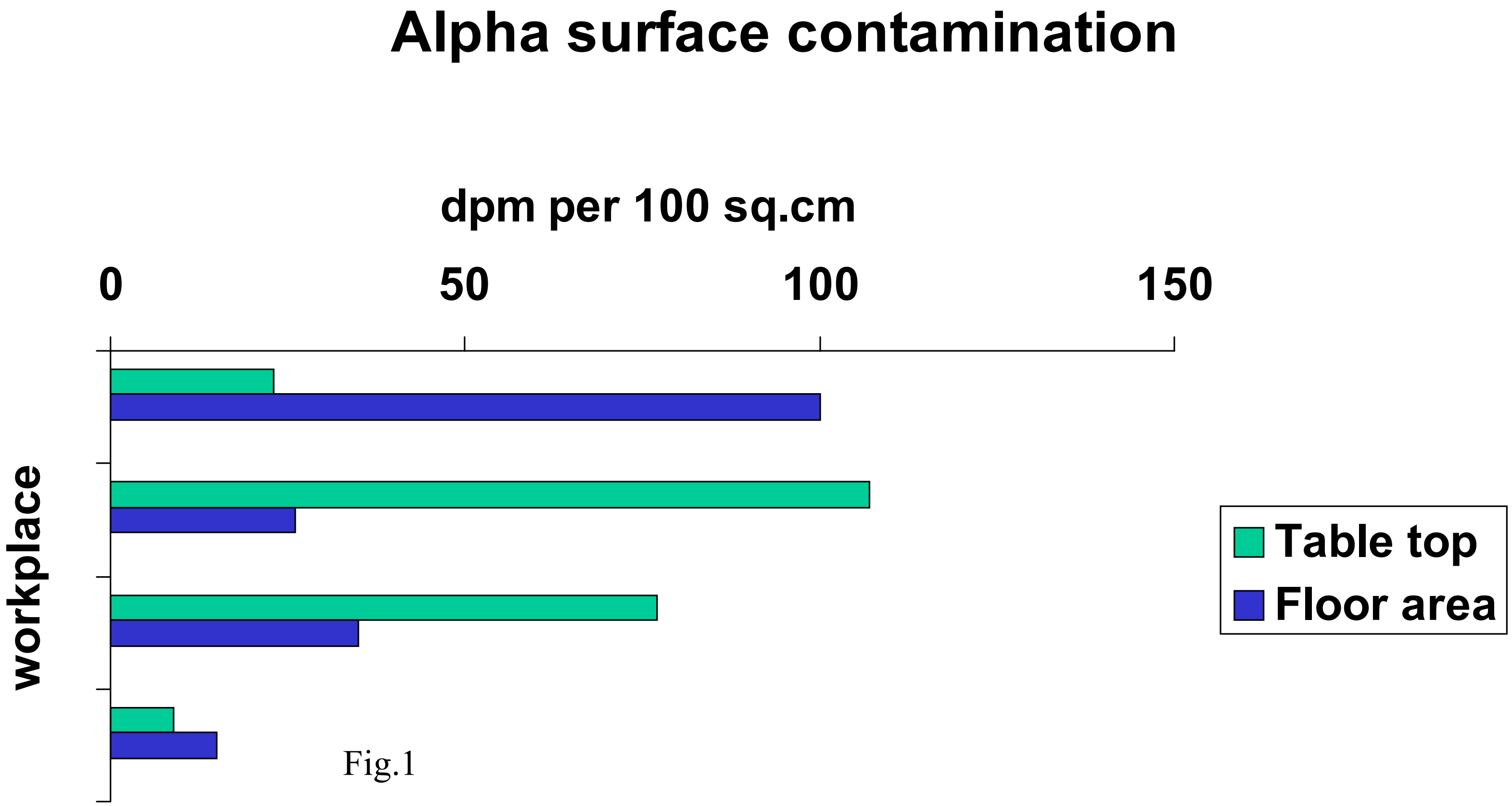
Alpha surface contamination
dpm per 100 sq.cm
0
50
100
150
workplace
Table top
Floor area

Fig.1