IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper | Volume-5, Issue-10 | E-ISSN: 2347-2693

On Electrodeless Induction Lamps

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Available online at: www.ijcseonline.org

Received: 14/Sep/2017, Revised: 27/Sep/2017, Accepted: 10/Oct/2017, Published: 30/Oct/2017

Abstract — This paper reviews the current technology & trends of electrodeless lamps, videlicet, fluorescent induction lamps & sulphur lamps. Induction lamps utilize the principle of electromagnetic induction & visible light is generated by phosphor coating in case of fluorescent lamps and by sulphur molecules in case of sulphur lamps. The methodologies of light generation, lighting characteristics, application areas, advantages & disadvantages in their utilization & the future scope of improvement are hereby duly expounded & analysed.

***Keywords* —** Induction Lamp, Sulphur Lamp, Energy Efficient Lighting, Plasma Lamp

I. INTRODUCTION

Induction lamps (or commonly known as electrodeless lamps) are principally high frequency (HF) light sources, which follow the elementary principles of converting electrical power into visible radiation by electrostatic or electrodynamic induction. Sulphur lamps employ the former while induction fluorescent lamps employ the latter. The fundamental difference between induction fluorescent lamps and conventional fluorescent lamps is that the former operate without electrodes. The absence of the electrodes in the induction lamps enhances the lamp life. The invention of induction lighting is based on the application of the principles of induction and light generation via a gas discharge.

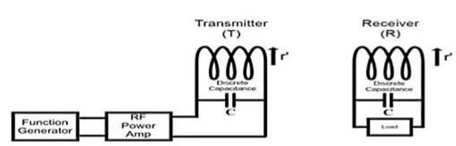
This section (Section I) introduces the types of induction lamps and the underlying principles of light generation, Section II reviews some of the scholarly literature regarding electrodeless forms of lighting with their underlying principles and characteristics, Section III reviews the technology regarding the fluorescent induction lamps, Section IV reviews the technology & developments regarding light generation of sulphur lamps, Section V draws a comparison in a tabular form between fluorescent induction lamps and sulphur lamps regarding various lighting parameters and also mentions of the spectral power distribution characteristics, Section VI sheds light upon the application areas of induction lamps and Section VII concludes the review with general inferences.

II. LITERATURE REVIEW

Turner, B. P., Ury, M. G., Leng, Y., & Love, W. G. [1] showed the efficient conversion of energy contained in microwaves to visible spectrum light utilizing sulphur. They demonstrated that the optical depth of the plasma made only the visible radiation exit the glass envelope. The used sulphur plasma with a 3.4 Kw microwave source & appropriate RF shielding to have 120 lm/W efficacy with a CRI of 86. Wharmby, D. O. [3] reviewed & evaluated the technological developments in electrodeless discharge lighting & opined that it can become highly energy efficient & emulate the broad spectra akin to that of the incandescent lamps. Shaffer, J. W., & Godyak, V. A. [4] researched upon the development of low frequency electrodelss fluorescent lamps having high luminous efficacy, high system efficiency, long lamp life & excellent photometric characteristics suited to general purpose illumination. Shinomiya, M., Kobayashi, K., Higashikawa, M., Ukegawa, S., Matsuura, J., & Tanigawa, K. [5] developed an early prototype of an electrodelss fluorescent lamp of 25 W power rating, 1000 lm light output, 13.56 MHz operating voltage frequency & proposed that it was an instant starting fluorescent lamp over a wide range & variation of ambient temperature.

III. FLUORESCENT LAMPS

Fluorescent lamps relying on the principle of electromagnetic induction have no electrodes in the glass discharge tube [9]. These employ the principle of electrodynamic induction.

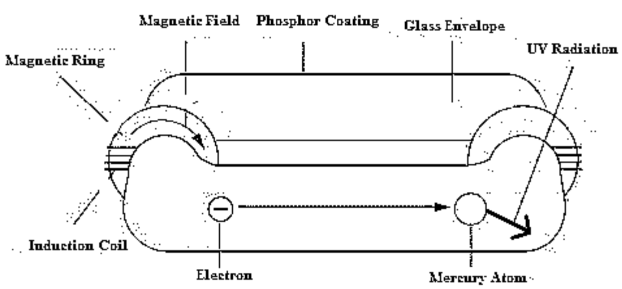


(Fig. 1 – Electrodynamic Induction)

Resonant inductive coupling or electrodynamic induction is the near field wireless transmission of electrical energy between two magnetically coupled coils that are part of resonant circuits tuned to resonate at the same frequency. This process occurs in a resonant transformer, an electrical component which consists of two high Q coils wound on the same core with capacitors connected across the windings to make two coupled LC circuits. Resonant transformers are widely used in radio circuits as bandpass filters, and in switching power supplies. Resonant inductive coupling is also being used in wireless power systems. The two LC circuits are different devices; a transmitter coil in one device transmits electric power across an intervening space to a resonant receiver coil in another device.

A. External Coil Lamps

In external core fluorescent induction lamps, the magnetic cores are wrapped around a part of the discharge tube. The magnetic cores are usually made of Ferrite. A high frequency input electric current from a ballast produces high frequency magnetic field inside the glass tube. The construction of such a lamp is duly shown herein:

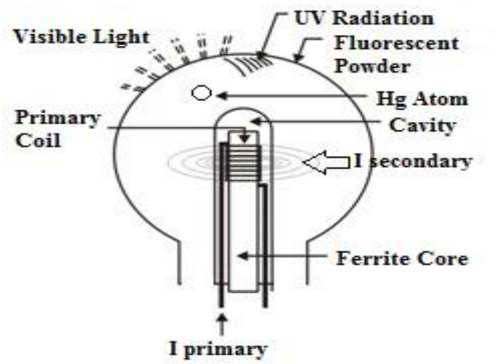


(Fig. 2 – External Coil Fluorescent Induction Lamp)

The alternating magnetic field induces an alternating electric voltage in any enclosing closed path as per Faraday's laws of electromagnetic induction. This in turn excites the mercury vapour which produces ultraviolet radiation. The inner phosphor coating absorbs most of the ultraviolet content & emits visible light.

B. Internal Coil Lamps

In the internal core fluorescent induction lamps, a glass tube duly protrudes bulb-wards from the bottom of the discharge vessel, effectively forming a cavity. This tube a power coupler, which is nothing but a simple coil wound over a cylindrical ferrite core. The coil and ferrite assembly forms the inductor, which couples the energy into the interior of the lamp.

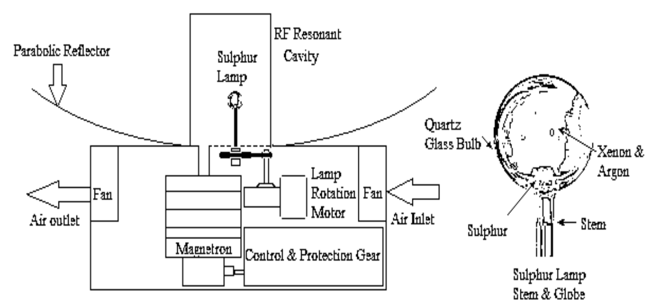


(Fig. 3 – Internal Coil Fluorescent Induction Lamp)

The antenna coils then receive high frequency electric power from an electronic ballast. The frequency of supply is variable, but usually 13.6 MHz & 2.65 MHz frequencies are common. A special resonant circuit in the ballast generates an initial high voltage kick to start a gas discharge; thereafter the voltage is finitely reduced to its rated operating levels.

IV. SULPHUR LAMPS

Sulphur lamps are highly energy efficient sources of visible electromagnetic waves. A glass envelope containing a suitable fill material such as a noble gas or a mixture of noble gases is placed in a high intensity field region of a microwave cavity [7]. During the starting phase, the microwave energy is inadvertently coupled to a starting gas.



(Fig. 4 – Sulphur Lamp Assembly)

As the lamp envelope heats with progression of time, the fill material vaporizes and is gradually excited by the microwave energy. The excited fill thus emits its characteristic electromagnetic spectra. In the sulfur lamp, the mechanism responsible for radiation, as proposed by Turner, B. P., are transitions from the excited B3S state to the X3X state [1] of the sulfur dimmer. Each transition possibly has substructures due to vibrational and rotational substructures being superimposed on each electronic state. The sulphur lamp consists of a fused quartz glass bulb containing about 26 mg of sulphur powder [8] and xenon - argon gas at the end of a thin glass spindle. The bulb is duly enclosed in a microwave-resonant mesh. A magnetron is utilized to bombard the bulb with 2.45 GHz microwaves via a waveguide. The energy transmitted to the gas by microwave elevates the pressure of the gas to 5 atm, which in turn heats the internal sulfur powder to a brightly glowing plasma of visible light. The energy transmitted to the gas by microwave elevates the pressure of the gas to 5 atm, which in turn heats the internal sulfur powder to a brightly glowing plasma of visible light.

V. LIGHTING PARAMETERS

The lighting parameters such as CCT, CRI, luminous efficacy, lamp life & perceptible colours are tabulated herein:

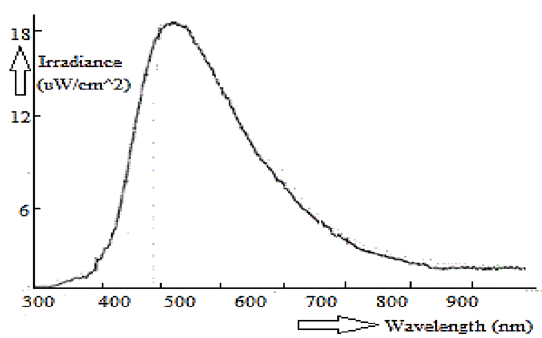
(**Table 1** – Lighting Parameters)

Parameters	**Fluorescent Induction Lamps**	**Sulphur Lamps**
Correlated Colour Temperature	2700K (Warm White),3000 – 3500 K (Neutral White), 4100 K (Cool White).	6000 K (Greenish White)
Colour Rendering Index	Usually 60 – 80	Around 79
Luminous Efficacy	50 – 70 lm/W	80 lm/W (prototypes) 100 lm/W (commercial)
Lamp Life	~ 8,000 – 10,000 hours	~ 60,000 hours
Perceptible Colours	Warm White, Neutral White, Cool White etc.	Greenish White

The spectral power distribution (SPD) characteristics are hereby given:

A. Spectral Power Distribution of Sulphur Lamps

The spectral power output curve of the sulphur lamp peaks at 510 nm. The CCT is of 6000 K with an approximate CRI of 79. Addition of calcium bromide (CaBr2) results in a peak at about 625 nm.

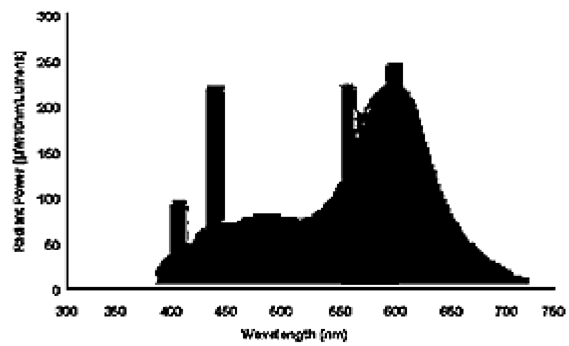


(Fig. 5 – SPD of Sulphur Lamp)

B. Spectral Power Distribution of Cool White Fluorescent Induction Lamps

The spectral power output of fluorescent induction lamp varies with the quality & quantity of phosphor material. Usually the cool white fluorescent lamps have more energy at lower wavelength & display arbitrary crests & troughs.

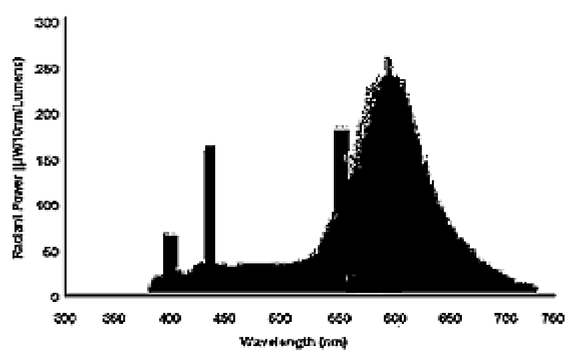
The spectral characteristic of a cool white fluorescent induction lamp is shown below:



(**Fig. 6** – SPD of Cool White Fluorescent Induction Lamp)

B. Spectral Power Distribution of Warm White Fluorescent Induction Lamps

For a warm white fluorescent induction lamp, the characteristic curve has more energy at higher wavelengths & the content of blue light is less than that of cool white fluorescent induction lamps. The spectral distrubution of a warm white fluorescent induction lamp is shown below:



(Fig. 7 – SPD of Warm White Fluorescent Induction Lamp)

VI. APPLICATION AREAS

Sulphur lamps may principally be used as light sources for plants [10] & might also be utilized as a light source in precision instruments. Light pipes & secondary reflectors are used to direct the light generated from sulphur lamps as a means of implementing a general illumination system. Fluorescent induction lamps are not widely marketed unlike the conventional fluorescent lamps but have been infrequently used in local lighting situations. These are also sometimes used for decorative purposes, monument lighting and analog clock face lighting.

VII. CONCLUSION

The fluorescent induction lamps are electrodelss fluorescent lamps that operate on the principle of light generation by fluorescence but the power is supplied by electromagnetic induction and the sulphur lamps are plasma lamps that generate light by B3S state to the X3X state transition of the sulfur dimmer The induction lamps have a longer lifespan than conventional counterparts due to the lack of electrodes in the discharge tubes. These have high luminous efficacy, low lumen depreciation & good colour rendering properties [4]. These lamps also can be characterized by their low flickering rate, and high optical brightness and may be duly utilized to phase out inefficient incandescent light bulbs [12] & can also be utilized in outdoor lighting purposes. However, their usages are still quite limited & these are mostly used for decorative & creative purposes. In addition to that, induction lamps have several drawbacks as well. Fluorescent Induction lamps contain mercury, which is highly toxic to health [11] & environment & may cause RF interference to communication systems. Sulphur lamps are bulky in build, not available in smaller power ratings, the utilized magnetrons are known to cause RF interference to local communication systems & the entire assembly requires active cooling systems.In addition, the advent & proliferation of LED lighting in both indoor & outdoor situations has dimmed the future prospects of induction lamps & the existence & usage of the induction lamps are mostly limited to laboratory prototypes & commercially these have not had much of an impact in terms of market share with several unsuccessful attempts.

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