RopeLight FIRES

Rope lights have become a popular alternative for landscapers, decorators, and individuals looking for a lighting source that can provide a chic appearance without the economic impact. The flexible construction of rope lights (Figure 1), allows them to be effectively installed in hard to reach places without large labor costs. While they bolster the luminance of an area, the lights are not without hidden dangers. During the last several years, our lab has been consulted on multiple occasions in regards to fires believed to be caused by ROPE LIGHTING.

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INTRODUCTION

The standard circuitry for rope lights is rather straightforward. The lights are made by stringing multiple bulbs in series, placing multiple series in parallel combinations, and then packaging them in clear or colored transparent PVC tubing. Figure 2 shows a schematic of a typical rope light circuit. The result is a string of lights that has a fixed length that can be strung out over an area.

The rope light assembly is in many ways similar to Christmas tree lights, which are governed by *UL 588*, Seasonal and Holiday Decorative Products. The utilization of rope lights, however, is slightly different. Rope lights are often used in new residential construction to provide accent lighting in coves and around edges of rooms. As such, the rope light becomes part of the permanent lighting in a building or house.

FIGURE 1

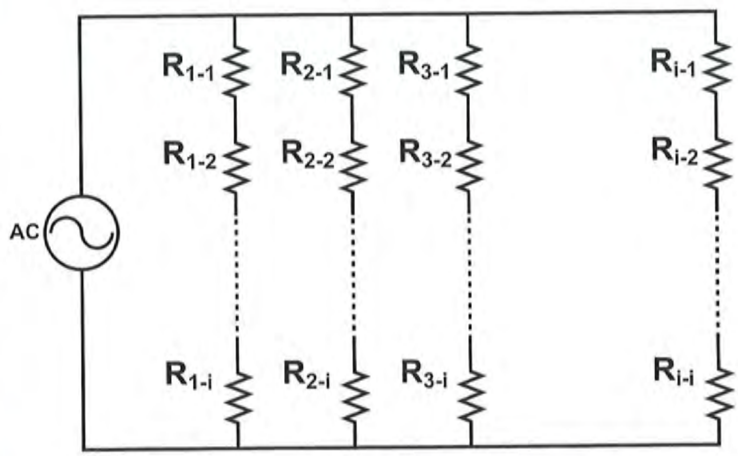


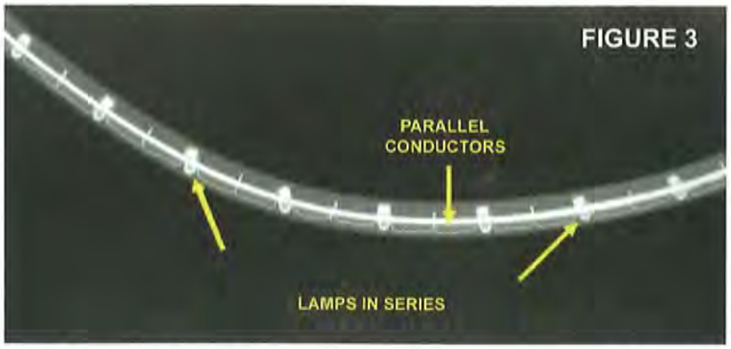
FIGURE 2

One rope light (new) examined in our lab was 18 ft (5.5 m) in length, and was rated at 54 watts power dissipation or 3 watts per foot (9.8 W/m). The results of electrical testing carried out using an Agilent 6813 A power analyzer can be seen in Table 1.

TABLE 1

VOLTAGE	120V
CURRENT	0.456A
WATTAGE	54.7W
WATTS DENSITY	3W/ft
BULBS	216
BULB WATTAGE	0.253W

For the particular rope light examined above there were 9 strings internally, each having 24 lights in series. Inspection showed that the hot and neutral conductors extended the entire length of the string. Each bulb was rated at 5 volts, 0.05 amperes, and 0.25 watts. Fusing at the beginning of the string made use of two 5 ampere fuses, one for each leg. An x-ray view of a portion of the rope light is shown in Figure 3.



While the rope lights are similar to Christmas tree lights, there is one very salient difference. They are being installed for permanent use. With a normal string of tree lights, the installer wraps varied lengths of lights on the tree until he/she runs out. Installation of rope lights requires a specific length. The installer (often an electrician) installs lights; if there is excess length, the rope light is either coiled up or thrown in an attic. The astute reader already sees the problem - trapping and accumulation of heat flux.

We have analyzed several fires involving rope lights at residences, to include two of the following:

1. The fire occurred in a ~ 4 ft x 4 ft (1.2 m x 1.2 m) square cove at ceiling level, with a 20 ft (6.1 m) rope light. The extra 4 ft (1.2 m) of rope had been thrown in the attic and insulated over with cellulose insulation. An indoor residential fire sprinkler pipe was nearby, and ruptured from heat of the fire, extinguishing the fire. Examination of the rope lights in other coves showed that there was browning of the cellulose insulation. The male plug (blades) had been cut off and removed, as had the in line fuse holder; the rope light was hard wired in place. Watt density was 3 watts per foot (9.8 W/m) for the rope light *(Figure 4)*.

2. The fire occurred in the attic space above a bathroom. The attic space was adjacent to a bedroom with a tray ceiling. The rope light was installed in the shelf around the base of the ceiling. An extra 16 ft (4.9 m) of the rope light had been discarded in the attic and subsequently insulated over. The watt density of the light was 5.5 watts per foot. Inspection of the rope light revealed that it had been directly wired into a switch in the bedroom. There were no in-line fuses installed along its length *(Figure 5)*.

DISCUSSION

In analyzing a rope light fire, one has to get past the initial "no way, no how" attitude that can be quickly developed. If someone posed the question as to whether or not a string of 0.5 watt light bulbs can cause a fire from overheating, many would intuitively respond "No". While this seems to be a reasonable answer, one needs to analyze the "rope light" as a "heat tape" that dissipates heat at particular watt density. An additional "feature" of the "heat tape" (rope light) is that it emits photons.

In terms of analysis, the rope light can be evaluated in many ways as if it were heat tape. For those who are not familiar with heat tape, it is generally a light weight, flexible material with a resistance heating mechanism internally; it is flexible enough to configure to various geometries and locations so that it can be wrapped around pipes. Three important heat tape caveats are as follows:

1. Do not make multiple wraps of the tape in one location

2. Do not insulate the heat tape with substances that trap heat, such as thermal insulation (fiberglass, cellulose, foam, etc.)

3. Use heat tapes only on circuits protected by GFIs

A warning label from a sample rope light we purchased has the same warning concepts as the three mention above.

The third caveat that listed, GFI protection, flows straight from the National Electrical Code, *NEC Article 427*[1]. Modern heat tapes have metal braids/shields along their length; unusual electrical activity that may cause a fire can be interrupted by the GFI's action. On a rope light, there is no ground shield; therefore, the only condition that the GFI can normally detect is someone getting shocked. A GFI will not prevent a fire on a rope light, given the absence of the ground shield/braid, unless the rope light is arcing/faulting to a grounded surface.

There have been substantive changes in rope lamp design in the last several years. In 2002, UL introduced *UL 2388 Standard for Flexible Lighting Products* covering all portable flexible lighting products with a maximum voltage rating of 120 VAC[2]. The major differences as compared to the industry standards of before are outlined below:

1. Field connections shall be limited to detachable power supply cords and interconnection of extension segments[3].

2. Field connections shall not permit accessibility to uninsulated current carrying parts during installation. There shall be a supply end with a female configuration and a mating side with a male configuration[4].

3. Interconnecting shall not require any assembly by the user other than the connection of the mating male and female connectors[5].

4. A heavy duty power cord (SJT) with a fused plug be used on all outdoor rope light but does not require a fused plug for indoor use[6].

5. Mounting system designed not to pinch or damage the insulation on the flexible jacket[7] (i.e. no staples).

6. Lower maximum temperature gradients allowed during standard installation as compared to previous standards[8].

In effect, the changes do not allow any more field cuts, splices, or repairs on the lighting. All rope light must be pre-cut at the factory and have molded ends that can be easily connected. Any assembly by the installer must be on molded pre-cut lengths, and when these lengths are assembled together to extend the length of the lights the ends must be fused. The primary reasons for UL making the changes were, as one distributor put it, *"... to eliminate improper installation of rope lights by the do-it-yourself end consumer"*[9]. However, we are seeing a mixture of problems created in part by not only the installers, but the distributors of the rope light as well.

On the part of the installers, we are seeing a general unfamiliarity with the UL requirements. We have on several occasions seen the male blades cut off the rope lights, and then the rope light spliced directly to house wiring. When this occurs, the rope light (in our opinion) is permanently wired, using #18 AWG wiring. Number eighteen wiring, one could reasonably argue, should be protected by 10 amp or smaller overcurrent protection. The typical 15 or 20 ampere thermal-magnetic circuit breaker just cannot respond in a reliable fashion to overloads or faulting loads served by 18 AWG wiring. This is apparently the UL thought process that requires the fusing of the rope light.

We note that some distributors[10,11,12] still sell the old standard rope light even though they are apparently familiar with the new standards. *UL 2388* requires all rope light manufactured after November 1, 2003 be subject to the new standard. But even 3 years after the specification distributors continue to sell the old product and compound the problem. The old product is not well protected. There are no fused ends on these products. The power cord (typically SPT-2) lacks the bulkiness of the SJT cord.

We recently purchased a spool of rope lighting where the distributor provided a kit of splices and adaptors, even though the manufacturer's instructions provided with the light specifically warns against any such action. While UL and the manufacturer specifically prohibit a string from being cut, the distributor provides the installer the hardware to splice the line. In effect, this confuses the installer on the reasons for new standards. This whole line of thinking also violates the intent of the NEC, *Article 110-3b*, which states that products shall be used per their listing[13].

We understand that an installation may not always be sized to the quantity of rope light available. For instance, rope lights manufactured under the new standard are in multiples of 2 ft (61 cm). Obviously an installation requiring an odd number of feet will not be an exact fit and so an installation must be adjusted. Based on the new standards, it is safer to undersize the installation than to over size and thus allow the excess to accumulate heat. Regrettably, this is not what we see happening.

TESTING

We acquired several configurations of rope lights and exposed them to "misuse" environments. We tested and observed the effects of coiling the strings on top of each other and applying thermal insulation to the coils—both of which are extremely problematic in terms of accumulating and trapping heat flux.

For the tests, we obtained 3/8 in (9.5 mm) diameter rope lights with rated watt densities of 5.5, 3, and 2 watts per foot. Ten feet (3 m) of each string was wrapped into several coils (~1 ft (30 cm) dia.) and placed on a paper covered table top. When the strings were plugged into a 120 VAC source, the changes in intensity (based on wattage density) were quite apparent. Figure 6 illustrates the difference in output for the different strings.


FIGURE 6

The strings were tested for 30 minutes and the temperatures were subsequently recorded via a FLUKE 51 K/J hand held thermocouple monitor and a FLIR/AGEMA 575 infrared camera. Figure 7 shows a thermal image taken after 30 minutes of testing the strings. Note the temperature of the 5.5 W/ft string is above 200°F (93°C), while the temperatures of the other two strings are in the low 100s°F (37°C). The strings were then covered with a 6 in (15 cm) layer of fiberglass insulation *(Figure 8)* and tested for 30 more minutes. The temperatures jumped to 330°F (165 °C) for the 5.5 W/ft and 215°F (101°C) and 165°F (74°C) respectively for the 3 W/ft and 2 W/ft strings *(Figure 9)*. The temperature on the 5.5 W/ft was enough to melt the transparent plastic tubing that encased the bulbs and discolor the paper cover on the table top. The other two strings appeared undamaged.

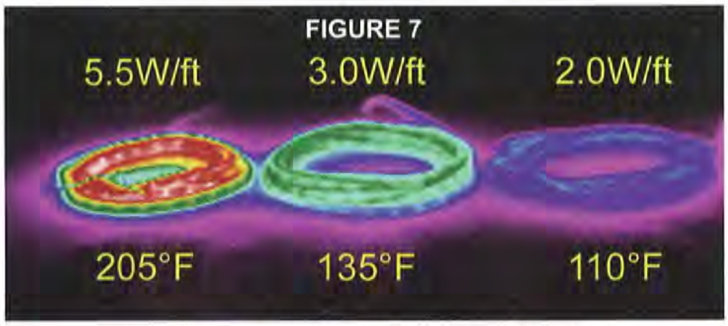
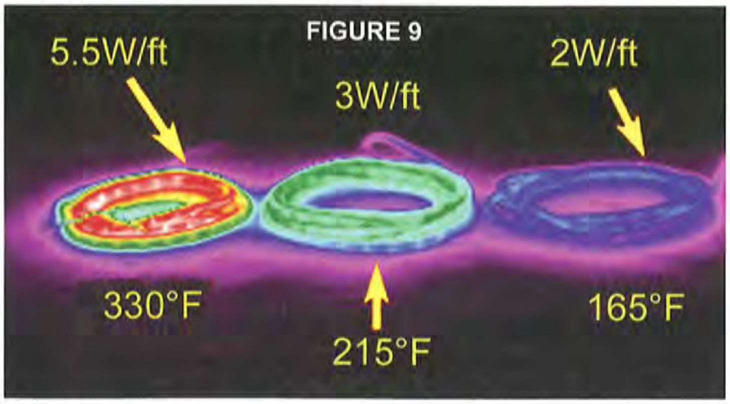
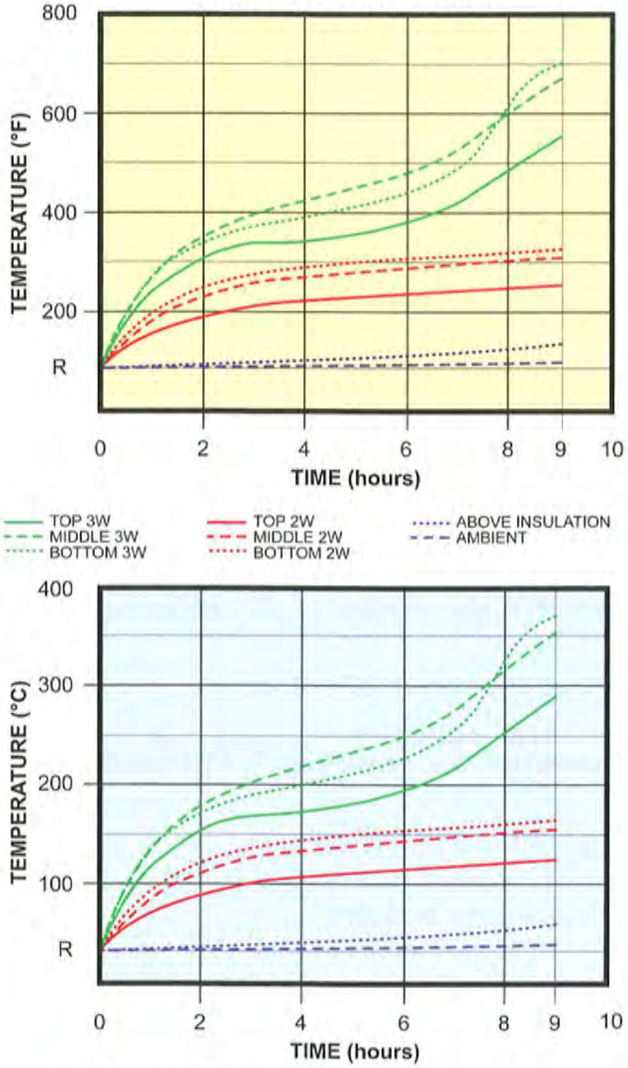
FIGURE 7


FIGURE 8

The 3 W/ft and the 2 W/ft strings were tested again. The second test setup consisted of a 4 ft (1.2 m) x 2 ft (0.6 m) wooden frame box, with gypsum board enclosing the bottom of it and an open top. The two strings were re-coiled, and then placed in the test box. The excess length was allowed to hang outside the box. The coils were mounted with thermocouples on the bottom, middle, and top, of the strings' coil (3 thermocouples per string). The thermocouples were monitored via a Stanford Research SR630 thermocouple monitor, controlled under Agilent-VEE software. A 12 in (30 cm) layer of fire retardant treated cellulose insulation was piled on top of the strings. A thermocouple was place just above the insulation and another thermocouple recorded the ambient. The strings were supplied 120 VAC for 8 hours and the temperatures were monitored. At the end of the test the voltages were removed from the strings and the temperatures were examined. The temperatures on the 3 W/ft string had reached just over 700°F (371°C) *(Figure 10)*. The temperatures for the 2 W/ft string reached over 325°F (162°C). At this time the box was emitting strong odors, most likely from charring on the insulation. Several hours thereafter, the box itself ignited and burned the testing table *(Figure 11)*.

FIGURE 10
TEMPERATURE vs TIME



CONCLUSIONS

Rope lights can indeed be a source of fire, despite what at first appears to be an innocuous level of heat dissipation. In our view, the rope light is akin to a light producing heat tape. Some of the caveats that apply to installing heat tapes also apply to rope lights. In general, we are finding both errors in both the manner in which the lights are installed, coupled with the accumulation of heat flux caused by thermal insulation and the coiling of excess length of the rope light. ●

REFERENCE:
1. NFPA 70, National Electric Code, Article 427.22-23, 2005 Handbook, pp 540-541
2. UL 2388, UL Standard for Safety for Flexible Lighting Products, Underwriters Laboratories, Inc, Dec. 2006, Sec 1.1
3. UL 2388, op. cit, Sec 15.2
4. UL 2388, op. cit, Sec 15.3
5. UL 2388, op cit, Sec 17.4
6. UL 2388, op cit, Sec 19.2
7. UL 2388, op cit, Sec 21.2
8. UL 2388, op cit, Sec 23.1
9. http://www.americanlighting.com/documents/ALRopeLightProgram.pdf
10. http://www.americanlighting.com op. cit.
11. http://www.centsibleholidaylighting.com/ropelightFAQs.htm
12. http://www.residential-landscape-lighting-design.com
13. NFPA 70, National Electric Code, Article 110-3b, 1999 Handbook, pp 31-32

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