CONF-8410152--1

LIGHT YOUR RUNWAYS AND TAXIWAYS WITHOUT ELECTRICITY

K. W. Haff
Program Manager
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Radioluminescent Light Program

OAK RIDGE NATIONAL LABORATORY

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Presented to

WORKSHOP ON
THE MANAGEMENT OF AIRFIELD LIGHTING

October 25-26, 1984

Sponsored by:

FLORIDA ENGINEERING SOCIETY
ENGINEERS IN GOVERNMENT
FLORIDA DEPARTMENT OF TRANSPORTATION

Clearwater Beach, Florida

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History of Radioluminescent Light Program at Oak Ridge National Laboratory

Radioluminescent lights are not new! The earliest important commercial work in RL lights was done in the early 1900 period. The radionuclide used was radium. The current nuclear age, with its ability to produce numerous radionuclides, has made it possible to advance RL light technology to its current state. Also important to the present state-of-the-art are the advances in phosphor development that have occurred during the past 40 years as a result of the growth of need in the electronics and communications market and the fluorescent lighting market.

The availability of nuclear reactors for the production of radionuclides made many materials other than radium available for evaluation for light production. The new radionuclides of interest were beta emitters, strontium-90, promethium-147, carbon-14, krypton-85, and tritium. The use of radium, which is expensive and has a severe biological hazard, was discontinued with the advent of these new radiation sources. Promethium, a pure beta emitter, was used to produce lighting devices with good intensity. The promethium-147 technology was similar to that used for radium; i.e., the phosphor was mixed with promethium oxide and viewed through a transparent window. The half-life is short and a potential contamination problem reduces its utility. Carbon-14, on the other hand, is a very long half life isotope (>5000 years) and has been used for fabricating light standards of low intensity. The long half-life makes the light yield quite constant when compared with some of the shorter half-life isotopes. Strontium-90 was used for a short time in light-producing paints; however, like radium its biological toxicity precludes its use for all except special situations. Its long half-life (30 years) and high-energy beta emission make it an excellent candidate for light production, however.

The energetic beta emission of krypton-85 makes it an ideal candidate for light production too. Brighter lights than can be produced with tritium are possible. Krypton-85 is a byproduct of nuclear fuel processing and, therefore, potentially large quantities of this material may become available. This potential provided an incentive to direct attention to uses of the radionuclide rather than dispose of it as a radioactive waste. The need for reliable, economical, lights for airfield applications by both the military and in remote civilian locations appeared to be a large enough application to utilize the large quantities potentially available.

Work was initiated under the U.S. Department of Energy Byproduct Utilization Program at ORNL to develop and test krypton lights to determine their utility for airfield lighting. This program was organized in 1979, and U.S. Air Force liaison was established to insure that the program was relevant to national needs and to define the various military needs.

Lights using krypton-85 were fabricated under this program and tested as airfield threshold markers, runway edge markers, and taxiway markers. Figure 1 is a typical early krypton light. The lights were configured in various geometries (Figure 2) and required a light pipe and shield for the gamma ray that is produced along with the beta rays during the decay of krypton-85. High purity quartz tubes were used to avoid browning of the light tubes by the gamma rays.

The demonstrations of the lights stimulated interest in them and the advantages of no power supply and general reliability that they represented encouraged the sponsors to continue efforts in the development. It became apparent, however, that the heavy shielding required severely limited the portability of the system. Additionally, the moratorium on nuclear fuel processing caused concern that the availability of krypton was questionable

FIGURE 1

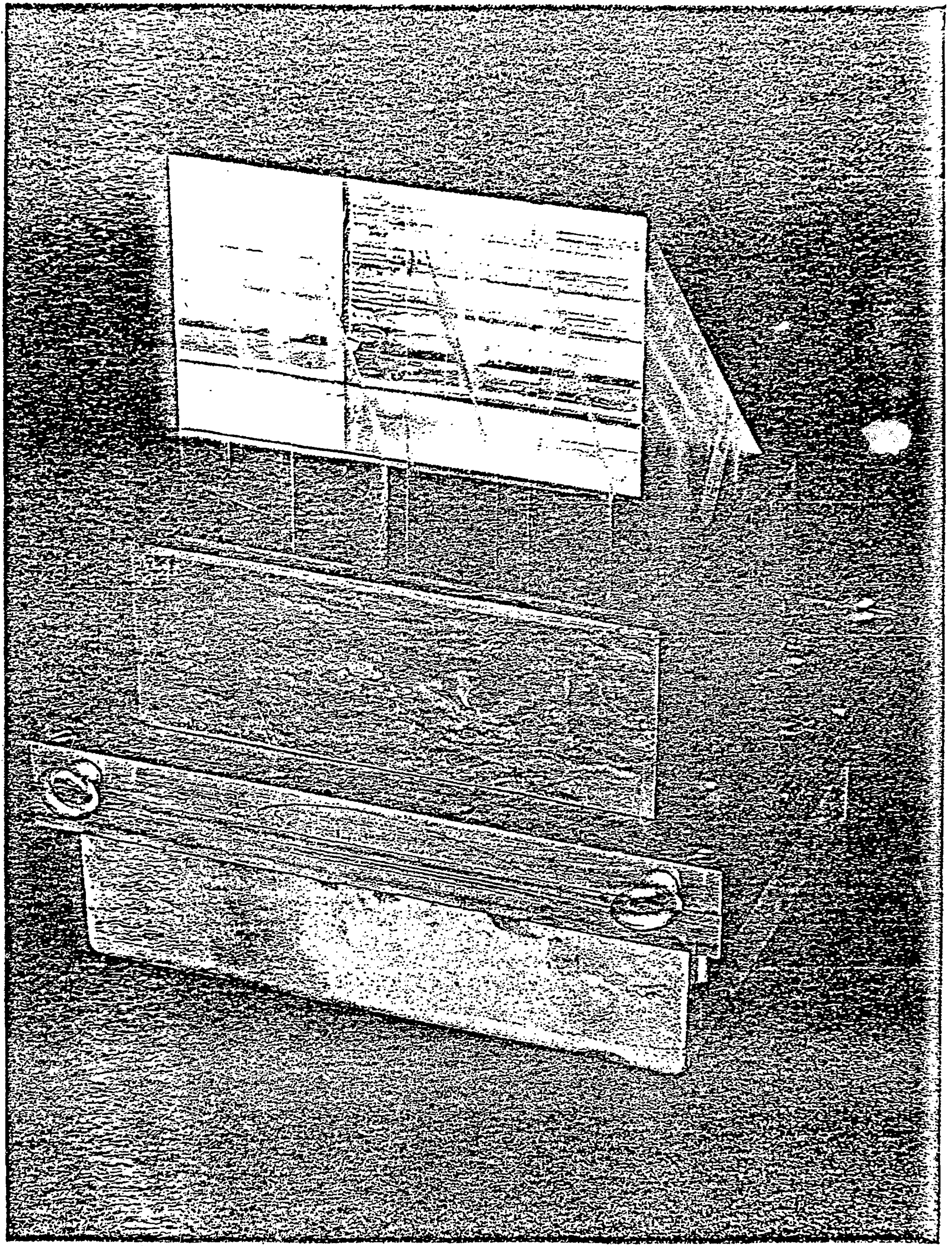


FIGURE 2

and our attention was turned to the use of tritium as the most likely radionulide candidate. The program effort concentrated on new designs that would extend the existing tritium technology to provide lights with sufficient output and intensity for airfield use.

Tritium is an isotope of hydrogen and is available in commercial quantities. It is a pure beta emitter and there is no external radiation through the light tube. Its biological hazard is very low, it has a half-life of approximately 12 years and being a gas it is quickly dispersed in the unlikely event of release from a light tube.

There are two types of lights which can be made with radionuclides. One, which has been mentioned earlier, is a paint that can be applied to surfaces in which resins are prepared with mixtures of the radionuclide (usually as the oxide with material other than tritium - with tritium the hydrogen isotope is incorporated directly into an organic resin) and phosphor and acts as a binder for them. This technique is inefficient in the use of tritium because of the degradation of the low-energy beta particle in the resin and the opaque nature of the paints do not permit light to escape.

Tritium used as a gas contained in a glass tube coated with a phosphor on the interior is a more efficient light source and has become the most widely accepted method for its use in light products. The tubes are filled with tritium and are then flame sealed. The seals have proven to be reliable and easily fabricated and glass has been demonstrated to be a leak-free container for tritium gas. Many commercial applications already existed for this type of lighting device including exit signs, military ordnance fire control devices, and illuminators for gages.

The ORNL program was, therefore, directed toward improvement in light output and light source design to maximize intensity of the lights. The light intensity of tritium lighting devices is much less than that obtainable with electric systems. It has been necessary, therefore, to provide field demonstrations with sufficient numbers of lights to show their potential as landing aids. The early fixtures clearly did not achieve their aim, especially for fixed-wing aircraft. Figure 3 is a typical fixture used in Alaska in the winter of 1982-83. The natural tendency is to compare the system to an incandescent system and this is a difficult problem to overcome. The solution has been threefold: 1) increase the light output, 2) increase the size of the light fixture, and 3) give pilots some experience flying on the RL systems. Acquisition distances of 4 to 6 miles have been routinely reported in the Alaskan environment and in the remote area we use for testing in North Carolina (Camp MacKall). As more demonstrations under actual field conditions were conducted the need for fixtures with relatively large physical dimensions of the light-emitting areas has become obvious if acquisition distances in excess of four miles was to be achieved. This goal is required if large aircraft in the C-130 size range or fast moving military aircraft are to use the lights as landing aids.

The goal was achieved by a combination of tube design, phosphor and phosphor coating techniques, quality assurance, and new tritium loading techniques. This combination resulted in a tube which has approximately 100% more light output than tubes previously produced. The new tube was placed in an array to provide a panel approximately one foot square. The panels are then placed in fixtures which vary from one panel to six panels in width. The fixtures can be stacked for special cases if need be.

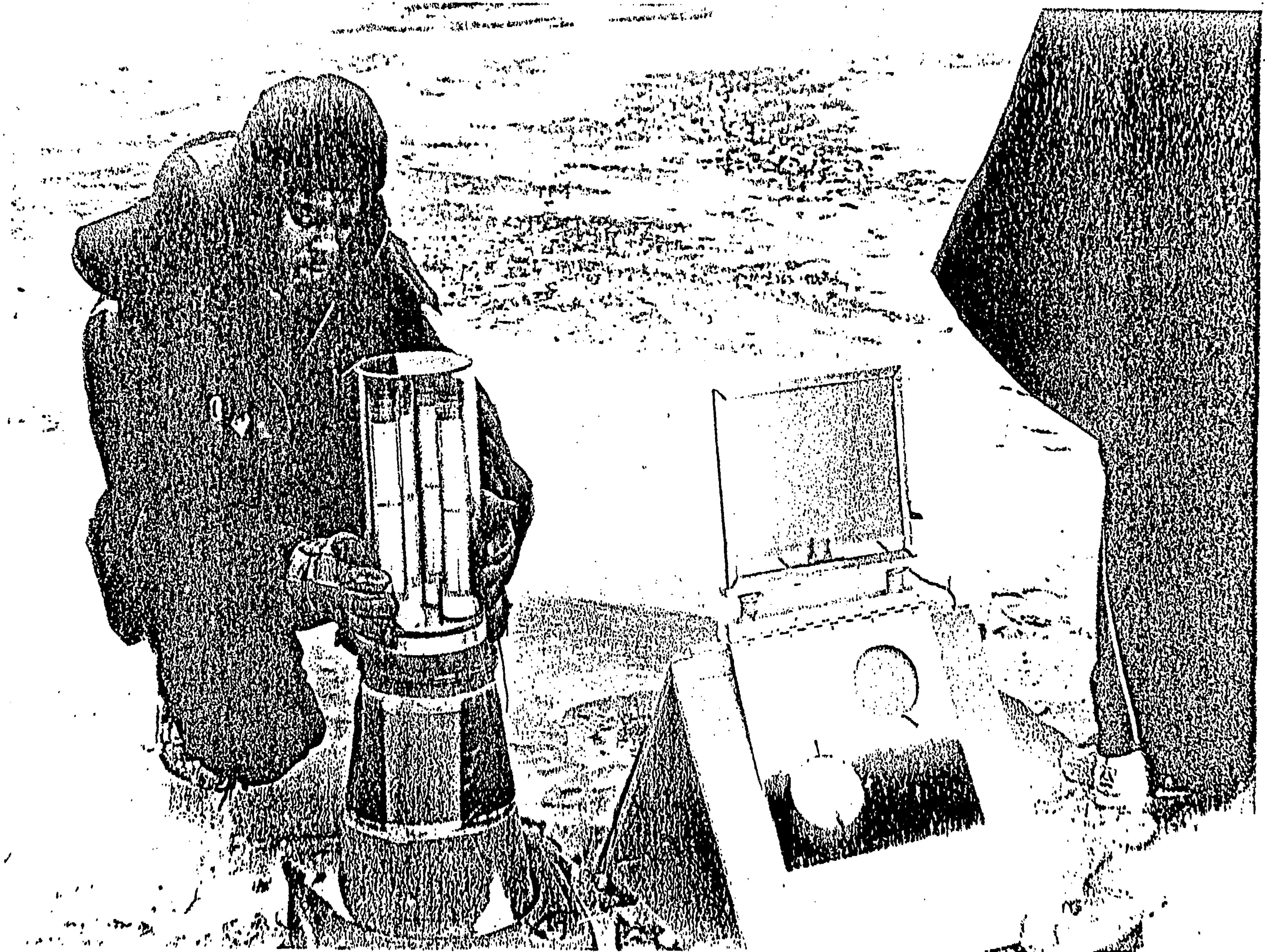


FIGURE 3

There has been a progression of fixtures and light tube designs, some of which are shown in the following photographs. Figure 4 is a sketch of the circular and crescent cross-section tubes. The crescent-shaped tube is the current tube of choice. Figure 5 shows some of the numerous tube cross sections which have been examined and compares their efficiencies.

The currently used fixtures are the seven-tube panel (Figure 6), the superwand (Figure 7), and the hand-held wand (Figure 8). All of these fixtures utilize the crescent-shaped tube and can be provided with an infrared phosphor or visible phosphors in a variety of colors.

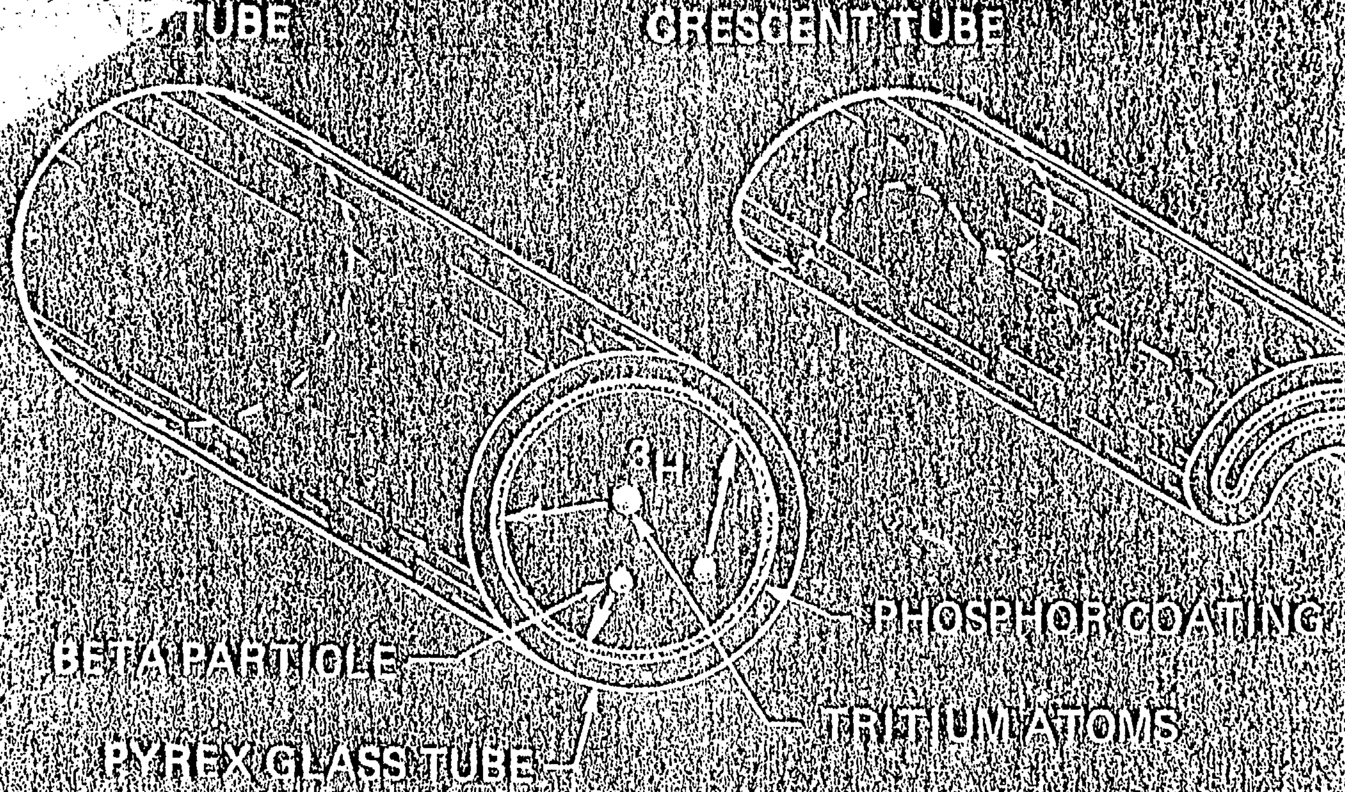
Field Testing of Radioluminescent Lights

Numerous field tests of radioluminescent lights have been conducted. These tests have been instrumental in establishing the usability of the lights and for use as developers to point out those areas needing attention in the development. Figure 9 is a list of the major field tests that have been conducted in the program. I will show a video tape taken during three of these tests. The first segment was taken from a helicopter at Camp MacKall, North Carolina, the second segment was taken at Central, Alaska in December 1983, and the third segment was taken near Richland, Washington in a recent test to compare the lights against FAA requirements for a waiver to regulations for use in Alaska.

We are currently planning two major field tests - one is a pretest for the second - at McEntire Army Air Field, South Carolina and Spandahlen, FRG for a NATO exercise. These tests will be the first extensive testing by jet aircraft and will use more lights than ever used previously. Figure 10 is the layout proposed for this test.

ORNL-DWG 83-15566

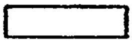
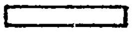
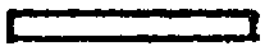
RADIOLUMINESCENT LIGHT SOURCE



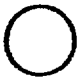
	L	W	VOL
ROUND TUBE	9½″	½″ OD	18.6 cc
CRESCENT TUBE	9½″	7/8″	21.0 cc

LIGHT OUTPUT FROM VARIOUS TUBE GEOMETRIES

BLACK BACKGROUND

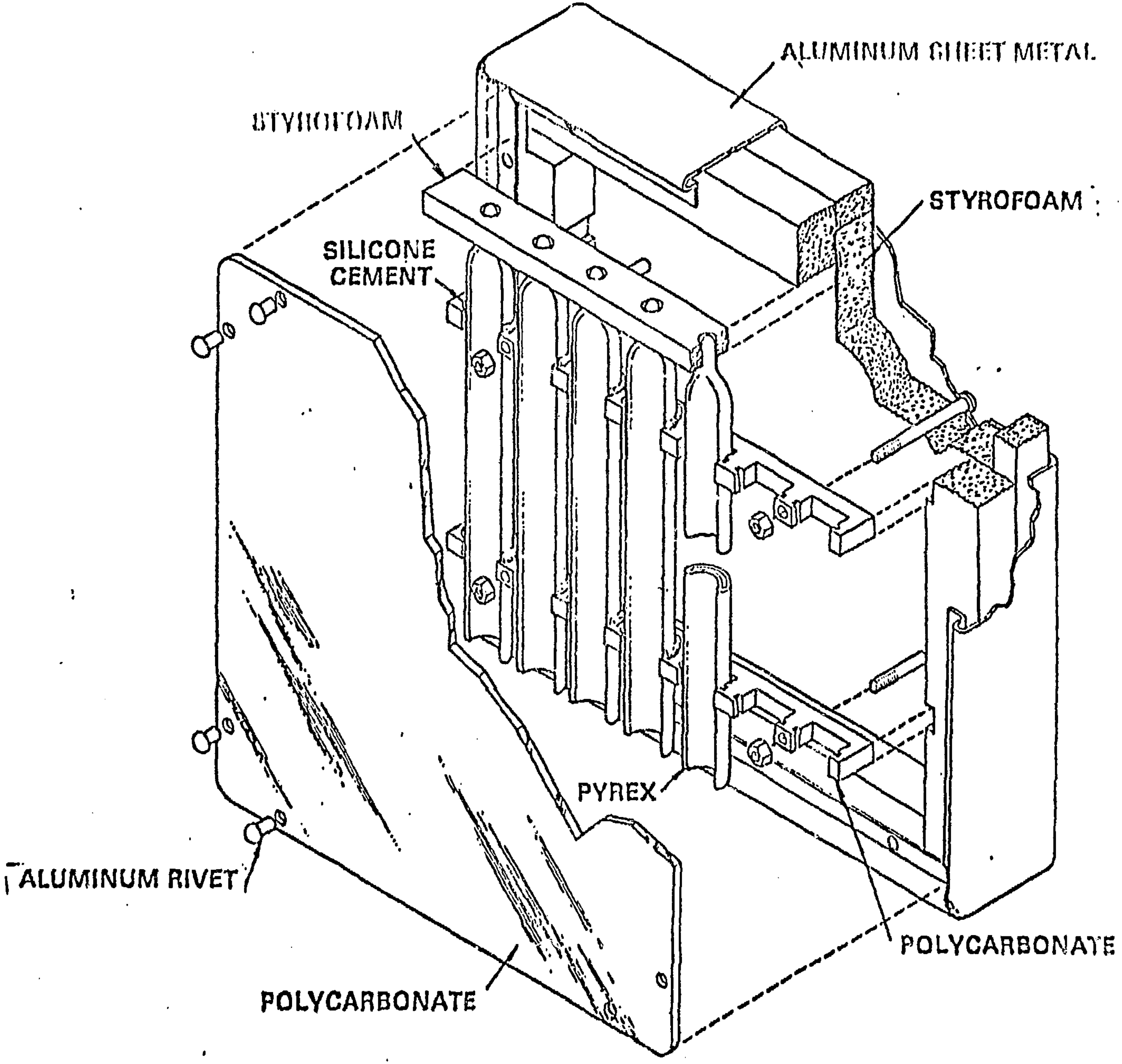
	ALL 0.72 in.	Cd/L. inch X 10^{-3}	VOLUME cc/L. in.	Ci*/L. inch	Cd/Ci X 10^{-3}	FT. LAMBERT
3/16 in.		1.220	2.64	5.52	0.22	1.1
1/8 in.		0.872	1.47	3.07	0.28	0.80
1/16 in.		0.532	0.71	1.48	0.36	0.50

BLACK BACKGROUND

	3/4 in.	Cd/L. inch X 10^{-3}	Cd/Ci X 10^{-3}	Ci*/L. inch	VOLUME cc/L. in.	FT. LAMBERT
STANDARD CRESCENT		0.920	0.306	3.1	1.44	0.82
UNGROOVED CRESCENT		1.564	0.21	7.44	3.56	1.23
UNGROOVED CRESCENT OPEN WINDOW		1.188	0.16	7.44	3.56	1.06
WHEATON CRESCENT OPEN WINDOW	1-1/8 in. 	1.280	0.18	6.94	3.32	1.14
10 mm		0.660	0.15	4.28	2.05	
8 mm		0.516	0.18	2.84	1.36	
6 mm		0.312	0.20	1.60	0.77	

*2.09 Ci/[illegible] AT 660 mm Hg (ABS.).

FIGURE 5



SEVEN TUBE LIGHT PANEL

ORNL-DWG 84-9035

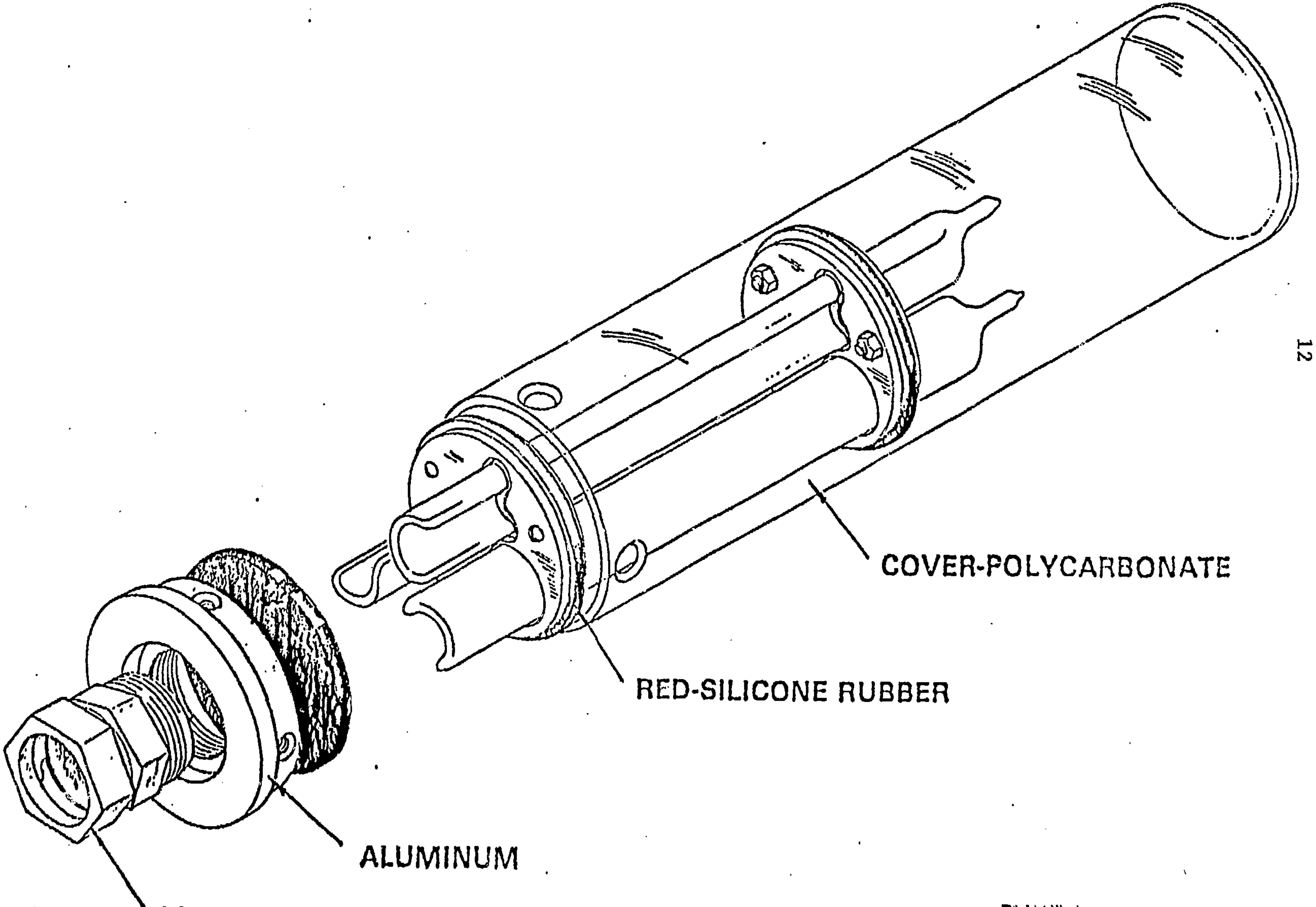
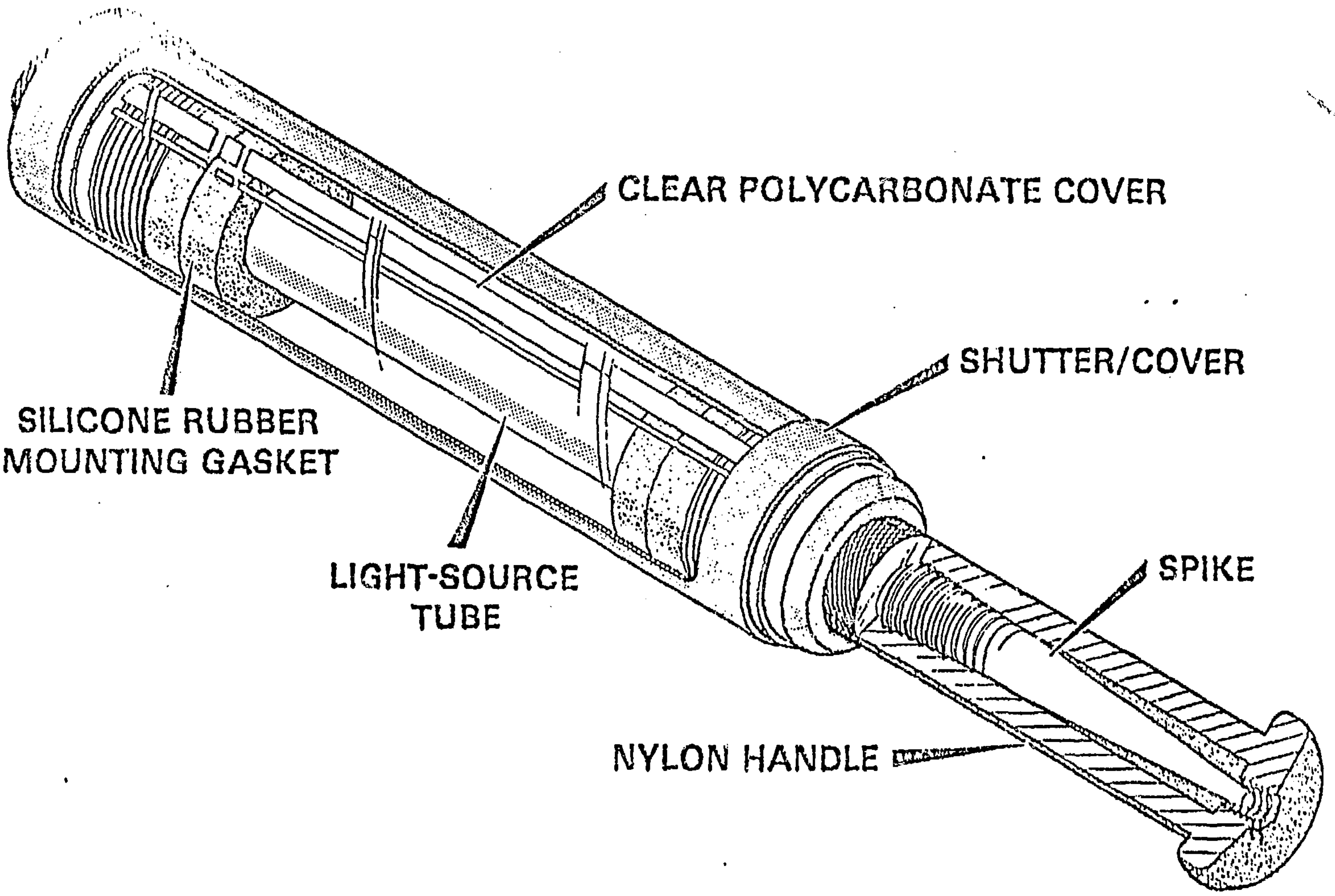


FIGURE 7

ORNL–DWG 84-8703



TRITIUM RADIOLUMINESCENT LIGHT
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MARCH 21–22, 1984

FIGURE 8

FIELD TESTS OF RADIOLUMINESCENT LIGHTS

1982-1984

Test Site	Sponsor	Test Objective
Ft. Rucker, AL	U.S. Army	Airfield Lighting
Pope AFB, NC	U.S. Air Force	Infrared Light Testing
Naval Shipyard, CT	U.S. Navy	Underwater Visibility
Ft. Huachuca, AZ	U.S. Army	Bare Base Airfield Lighting and Rapid Deployment
Marine Air Station, Bogue, NC	Marine Corps	Jump Zone Marking Airfield Lighting
ORNL (3 tests)	U.S. Army National Guard	Night Vision Testing
MacKall Army Air Field, NC	U.S. Air Force	Test of Lights Prior to Arctic Tests
Hilo, HI	U.S. Army	Bare Base Lighting
Ft. Benning, GA	U.S. Army	Helicopter Landing Zone - Pathfinder Uses - Night Vision Testing
Tyndall AFB, FL	U.S. Air Force	Runway Distance Markers
Alaska (3 tests)	U.S. Air Force	Airfield Lighting - Joint DOD Arctic Maneuvers
Alaska (2 tests)	State of Alaska - DOT	Remote Airfield Lighting - Taxiway Marking
St. Petersburg, FL	State of Florida DOT and City of St. Petersburg	Airfield Lighting in Urban Area - Taxiway Marking
Richland, WA	State of Alaska - FAA	Test of Lights to FAA Criteria for Use in Alaska

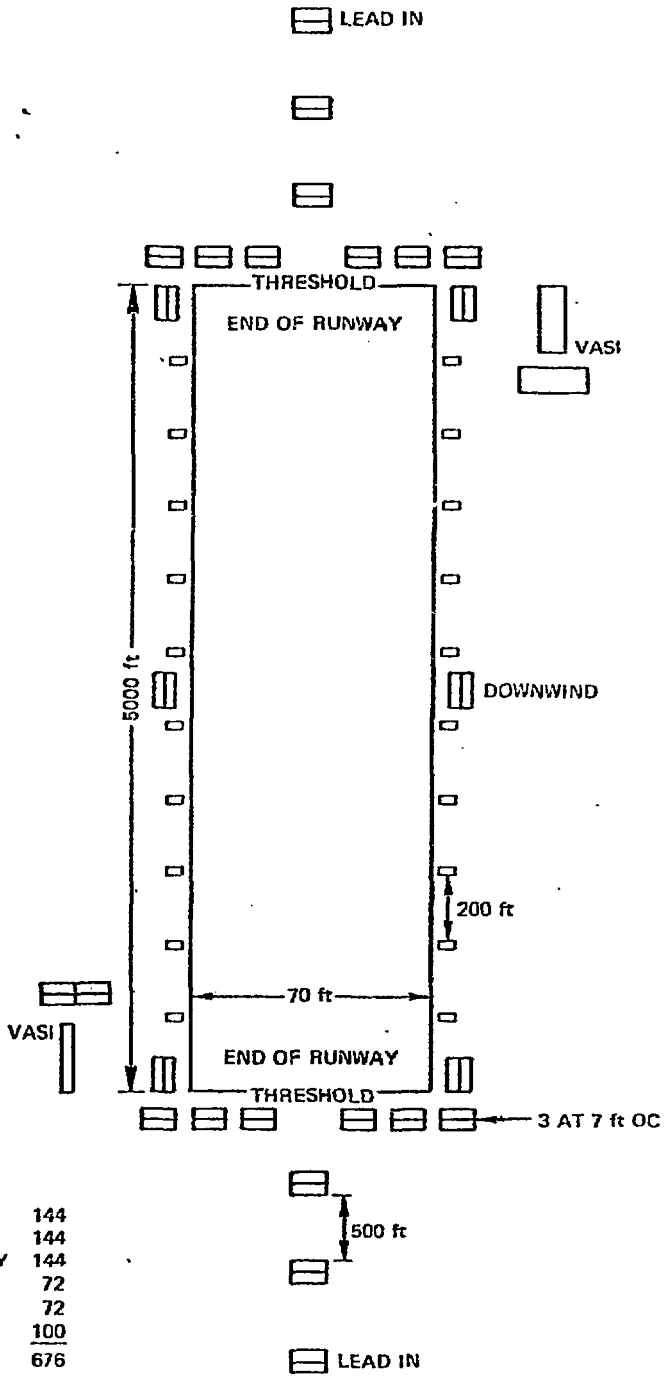
Planned Tests

McEntire Army Air Field, SC	U.S. Air Force	Pretest for NATO Exercise
Germany	U.S. Air Force	NATO Exercise

FIGURE 9

ORNL-DWG 84-11027

AIRFIELD LIGHTING LAYOUT - NATO DEMONSTRATION JANUARY 1985



LEAD IN	144
THRESHOLD	144
END OF RUNWAY	144
DOWNWIND	72
VASI	72
EDGE LIGHTS	100
TOTAL PANELS	676

FIGURE 10

Safety and Quality Control

The ORNL RL light program has as its second primary goal the safety of the general public and the users of the lights. To this end, a rigorous safety testing program and quality control program have been instituted. All RL light devices are tested to demonstrate that they meet or exceed the requirements of Level 4 of ANSI Standard N540[1] (Figure 11). The Level 4 requirements are shown in Figure 12. In addition to the ANSI Standard tests, each tube is subjected to an internal pressure test (Figure 13). Other quality control checks are shown in Figures 14 and 15. They include liquid nitrogen thermal shock tests on the tubes, coating checks of the phosphor, vacuum drying of the tubes to eliminate water in the system, and other measures to assure that water does not get into the system, leak tests, and photometric tests of the finished tubes and units.

The safety of the tritium lights is assured by the above quality control measures and the inherent characteristics of the tritium itself. Tritium is a low-energy beta emitter (0.0186 MeV). There is no detectable ionizing radiation on the exterior surface of the light tube. The tubes are, of course, further encased within protective packages.

We have assessed the result of a breakage of the tubes and subsequent release of the tritium gas. Tritium as $^3H_2$ is relatively innocuous in that very little of the material is absorbed either by the skin or lung tissue. Tritiated water or tritium oxide on the other hand is quite readily absorbed. Therefore, it is very important to keep water out of the system and hence the measures to do this in the quality control measures taken. A typical analysis of tritium gas in our system is shown in Figure 16.

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[1] American National Standard N540; Classification of Radioactive Self Luminous Light Sources.

ORNL WS-32081

TRITIUM RADIOLUMINESCENT LIGHT TECHNOLOGY TRANSFER CONFERENCE
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ALL RADIOLUMINESCENT (RL) LIGHT DEVICES OF LATEST ORNL DESIGNS ARE TESTED TO DETERMINE PERFORMANCE LEVELS AS DESCRIBED IN ANSI N540-1975*

*AMERICAN NATIONAL STANDARD N540; CLASSIFICATION OF RADIOACTIVE SELF-LUMINOUS LIGHT SOURCES, NBS HANDBOOK 116, NATIONAL BUREAU OF STANDARDS, U.S. DEPARTMENT OF COMMERCE, WASHINGTON, D.C., JANUARY 1976

FIGURE 11

ORNL WS-32082

SUMMARY OF ANSI N540–1975 LEVEL 4 TEST REQUIREMENTS

DISCOLORATION	12 h LAMP
TEMPERATURE	– 55°C AND 80°C
THERMAL SHOCK	– 55°C TO 80°C
PRESSURE (REDUCED)	87-mm Hg abs
IMPACT	FREEFALL TO STEEL PLATE 1 m 20X and 2 m 2X
VIBRATION	60 min. SIMPLE HARMONIC MOTION HAVING AN AMPLITUDE OF 0.75 cm (0.30 in.) AND A MAXIMUM TOTAL EXCURSION OF 0.15 cm (0.06 in.), THE FREQUENCY BEING VARIED UNIFORMLY BETWEEN THE APPROXIMATE LIMITS 10 AND 55 Hz. THE ENTIRE FREQUENCY RANGE, BETWEEN 10 AND 55 Hz AND RETURN TO 10 Hz, SHALL BE TRAVERSED IN APPROXIMATELY 1 min.
IMMERSION	0°C TO 80°C 5 CYCLES – COLD BATH 15 min., HOT BATH 15 min.

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FIGURE 12

ORNL WS-32083

INTERNAL PRESSURE TEST OF PYREX TUBES

- TEST TO BURST
  - CRESCENT TUBE NO. 1 – 100 psig
  - CRESCENT TUBE NO. 2 – 150 psig
- ROUTINE QC INTERNAL PRESSURE TEST
  - 100% TEST – 50 psig

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FIGURE 13

QUALITY CONTROL SUMMARY

QC PRACTICES	REASONING
LN_2 SHOCK TEST TUBES FROM GLASS SHOP	DETECTS STRESS IN TUBING CAUSED BY FABRICATION
PRESSURE TEST (50 psig)	DETERMINES STRUCTURAL DEFECTS
COATING CHECK	DETERMINES DEFECTS AT A STAGE WHERE TUBES ARE SALVAGEABLE
VACUUM DRYING TUBES AFTER NECK-DOWN	ELIMINATES WATER CONTAMINATION THAT HAS OCCURRED DURING NECK-DOWN PROCESS
PHOSPHOR COATED TUBES STORED UNDER VACUUM	MINIMIZES WATER CONTAMINATION OF TUBES

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FIGURE 14

QUALITY CONTROL SUMMARY (cont'd.)

QC PRACTICES	REASONING
LEAK CHECK SEALED TUBES WITH TRITIUM MONITOR	DETERMINES GROSS TRITIUM LEAKS IN THE FLAME SEAL IN A CONTAINED ENVIRONMENT
LN_2 SHOCK TEST SEALED TUBES	DETECT STRESS IN TUBING CAUSED BY FLAME SEALING
LEAK CHECK WITH H_2O LEACH TEST	SENSITIVE LEAK CHECK
PHOTOMETRIC CHECK	ASSURES LIGHT OUTPUT PASSES MINIMUM STANDARD
LEAK CHECK ASSEMBLED LIGHT SOURCE	CHECK FOR LIGHT TUBE DAMAGED DURING FINAL ASSEMBLY

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FIGURE 15

ORNL WS-32043

ANALYSIS OF TRITIUM GAS

- SPECIFICATION OF > 95% ^3H
- SPECIFICATION OF > 98% ^3H AVAILABLE FOR RESEARCH APPLICATIONS
- TYPICAL ANALYSIS (mole %):

H_2 – 0.02
HD – 0.00
HT – 0.64
DT – 2.08
D_2 – 0.01
T_2 – 97.19

N_2 – 0.01
O_2 – 0.00
Ar – 0.00
H_2O – 0.00
HDO – 0.01
HTO – 0.03

T_2O – 0.01

TOTAL ^3H – 98.60

FIGURE 16

Analysis of the unlikely event that a light fixture is broken out of doors (as on a runway) has been made. The 50-year committed dose that an individual would receive is 6.53×10^{-3} Rem if a fixture containing 350 curies is broken and the individual is standing in the spot to receive the maximum dose. This is equivalent to approximately 1/10 the dose of a normal chest X-ray.

Calculations to assess the dose received by a person when the breakage of a light panel occurs in a small room (theft scenario) have also been made. In this case, the maximum dose that could be received is 3.09 Rem. (Again this assumes that one panel with 350 curies was broken and all material released at once.) This is equivalent to about 60 chest X-rays or 26 teeth X-rays. While this is a higher dose than we would desire it is not in any way life threatening or health threatening. It is about 60% of the annual dose allowed for a radiation worker.

Cost

The obvious question most of you have is "How much does it cost?" We have made a twenty-year life cycle cost breakdown for the Air Force. This cost breakdown is presented in Figure 17.

TRITIUM RADIOLUMINESCENT LIGHTS

Twenty Year Life Cycle Cost Breakdown

(Continuous Use)

Summary of Costs

1.	Initial Procurement	
	a. 200 units	$111,000
	b. Tritium at $1.10/curie	77,000
2.	Maintenance	8,800
3.	Inventory and Security (add to normal runway and airfield security)	4,800
4.	Installation	8,500
5.	Miscellaneous Costs	10,000
6.	Replacement Costs	
	a. Replace tubes in 300 units	136,500
	b. Tritium	57,800
	Total Costs	$414,400
	Annual Costs (Total/20)	$ 20,720

FIGURE 17