# APPLICATIONS DEVELOPED FOR BYPRODUCT $^{85}Kr$ AND TRITIUM

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## ABSTRACT

The radionuclides, krypton-85 and tritium, both of which are gasses under ordinary conditions, are used in many applications in industries and by the military forces. Krypton-85 is produced during the fissioning of uranium and is released during the dissolution of spent fuel elements. It is a chemically inert gas that emits 0.695 Mev beta rays and a small yield of 0.54 Mev gammas over a half life of 10.3 years. Much of the $^{85}Kr$ currently produced is released to the atmosphere; however, large scale reprocessing of fuel will require collection of the gas and storage as a waste product. An alternative to storage is utilization, and since the chemical and radiation characteristics of $^{85}Kr$ make this radionuclide a relatively low hazard from the standpoint of contamination and biological signifigance, a number of uses have been developed. Tritium is produced as a byproduct of the nuclear weapons program and it has a half life of 12.33 years. It has a 0.01861 Mev beta emission and no gamma emission. The absence of a gamma ray energy eliminates the need for external shielding of the devices utilizing tritium, thus making them easily transportable. Many of the applications require only small quantities of $^{85}Kr$ or tritium; however, these uses are important to the technology base of the nation. A significant development that has the potential for beneficial utilization of large quantities of $^{85}Kr$ and of tritium involves their use in the production of low-level lighting devices. Since these lights are free from external fuel supplies, have a long half life ($\geq$ 10 years), are maintenance free, reliable, and easily deployed, both military and civilian airfield lighting applications are being studied.

## BACKGROUND AND HISTORICAL OVERVIEW

A brief Historical perspective on the development of radioluminescent lights follows. In 1977, the U.S. Department of Energy (DOE), through Battelle Columbus, conducted a modest program in developing $^{85}Kr$ self-luminescent lights. Krypton, at 5 percent $^{85}Kr$ enrichment, along with Xenon, is collected during fuel element reprocessing at the Idaho National Engineering Laboratory. The gases are then cleaned and separated, and the krypton is enriched in $^{85}Kr$ by thermal diffusion at the Oak Ridge National Laboratory.

Battelle fabricated two lights, each containing approximately 17 curies of $^{85}Kr$ enriched to approximately 11 percent. The design of these original lights was for coal mine emergency exit illumination. Battelle was unable to enlist the support of this light development from either the U.S. Bureau of Mines or the independent coal mine owners. However, at the request of the U.S. Air Force, Andrews Air Force Base, the two lights were deployed and evaluated by helicopter air crews. As a result of this evaluation, the Commander of Air Force Logistics Engineering determined that the potential application of beta self-luminescent lights was worthy of Department of Defense (DOD) support.

In 1980, a new program effort with DOE funding support was undertaken at the Oak Ridge National Laboratory. This effort was initially aimed at developing krypton taxiway lights and tritium runway distance markers. In 1982, the program, called the DOE Project Firefly, has been expanded by the U.S. Army to include tritium airfield runway edge and threshold lights, aircraft formation lights, and aircraft cockpit instrumentation lights.

## RADIOLUMINESCENT LIGHTS DEVELOPMENT

Engineering models of lights that contain 30 curies of $^{85}Kr$ have been fabricated and field tested for use as runway edge markers, taxiway markers and threshold markers. The light output is adequate for taxiway markers, and they offer a favorable cost benefit ratio over conventional lights. Increased intensity will be required for runway edge lighting. Special applications for military and remote airfield lighting are the major thrusts of the present lighting development efforts. Tritium developments sponsored by the U.S. DOE an the U.S. DOD have concentrated mainly on lighting application and has spanned a wide range of activities including phosphor development and improved fixture development, ruggedizing to increase the shock resistance and residue damage potential, physical testing to ANSI and other standards, light output improvement, and fluid testing under a variety of conditions and climatic extremes to include desert and artic conditions.

Phosphor Development. Candidate samples of phosphors for testing with tritium to maximize light output were obtained and tested for light output when exposed to tritium. From this group, one yellow-green and one infrared phosphor were selected for use in fabrication of light tubes. The yellow-green phosphor increased light output approximately 20% over the best phosphor used in earlier work. Phosphor particle size has been identified as an important parameter in light output; however, work has not progressed to the point of selection of an optimum size for a given phosphor.

Phosphor coating thickness control and proper composition of binders for the application of phosphors to glass tubes are required to obtain uniform coatings of phosphors on tubes. In earlier work with binders, a silicone binder that provided a highly stable adhesive for phosphor coatings was used. However, this preparation was a proprietary product and has been discontinued. Work was then conducted using the conventional phosphoric acid binders, and satisfactory methods for coating tubes were developed.

Ten phosphor manufacturers and suppliers in the U.S., Europe, and Japan were contacted in a search for more efficient phosphors for use with tritium and krypton-85. The search resulted in a phosphor with a 20% greater light output.

Fabrication and Light Fixture Development. Runway distance markers were fabricated and supplied to Tyndall Air Force Base for testing and evaluation. These 4 x 4 ft square markers were assembled and shipped to Tyndall for installation. Each marker contained flat glass light tubes 1/4 in. thick x 3/4 in. wide that varied in length from 4 to 22 in. Thirty individual units were fabricated that comprised both runway distance markers and taxiway information signs.

Approximately 150 runway edge lights comprised of 120 visible and 30 infrared lights were fabricated and tested. These units consisted of three individual pyrex light tubes containing 32 Ci of tritium each and packaged inside a 1-1/2 in. diameter polycarbonate tube sealed unit. Each unit had 10 in. of light projection over its 15 in. of total length. In use, up to four units are deployed on a base placed on the ground at the edge of an airfield runway. This arrangement makes it easy to deploy the units and provides for spacing between individual lights on the holder. Thus, the apparent light size is increased, making the acquisition distance greater than is possible with individual lights.

Ruggedizing. Military use of radioluminescent lights requires ruggedized systems to permit air dropping, rough handling, and exposure to environmental extremes. Clear polycarbonate provides more resistance to breakage than any of the transparent construction plastics available and is used to enclose the pyrex glass tubes containing the phosphor and radionuclide. The tubes are shock mounted on silicone rubber foam spacers and resist breakage under normal handling and shipping conditions. High-speed photography was used to observe deflections in the pyrex tubes that occur during mechanical shock conditions. The photographic observations are presently being evaluated. The objective of this effort is to develop methods for testing and diagnostic examination that will permit the fabrication of fixtures that will meet military combat requirements.

Physical Testing. Testing of light fixtures and shipping cartons to meet ANSI and DOT standards were carried out. Two lighting systems were tested. Runway distance markers were tested to meet the ANSI standard for self-luminous signs, and an NRC license for use of the markers at Tyndall Air Force Base was obtained. The hand-held lights, consisting of three tubes in a polycarbonate fixture, were tested according to ANSI standard tests and passed. In addition, a percussion test was carried out to determine the impulse required to distort the polycarbonate cover tube to the point of breakage of the internal pyrex light tubes. Shipping containers were procured and Type A package certification testing was conducted.

Light Measurement. Light output measurement is required for evaluation of phosphors and to optimize geometry for fabrication of light fixtures. Equipment was installed in a totally dark, non-reflective walled area. This equipment consists of an EG&G, Model 550 Photometer. One hundred fifty candella measurements were made for krypton-85 lights fabricated and tested for runway edge lights and for taxiway lights. Infrared light output was obtained using this photometer also.

Field Testing. A major effort in this program involved fabrication of fixtures and field testing for military applications. This effort introduced the military to the potential of radioluminescent lights as a reliable and long-lived light source for low-level lighting. Suggestions from user personnel provided the direction needed to make the program functional and to expand participation of various military services.

Ft. Rucker Alabama Test. A demonstration of visible lights, with both krypton-85 and tritium lights, was given during a General staff conference at Ft. Rucker, Alabama, in March 1982. This demonstration provided several General officers with a first hand observation of the lights and their potential applications. It also permitted reviewing with night vision equipment by the conference attendees. A full test in May 1982, also at Ft. Rucker, was conducted to demonstrate helicopter landing field marking. This test used single three-tube tritium light wands set out in a line extending from each end of two parallel runways to provide alignment for aircraft maneuvers. Lights were deployed for five nights and used in training exercises. Both visible and infrared lights were used in this test. Pilot evaluation was favorable and the lights were judged to be adequate for lane marking in remote field applications.

Pope Air Force Base, North Carolina. A field test was conducted at Pope Air Force Base, North Carolina to compare visible and infrared radioluminescent lights with battery operated units. The battery operated infrared units were judged to be about two times brighter than the radioluminescent lights. The radioluminescent lights, however, appeared to be adequate for most requirements and have the added advantage of reliability not possible with battery operated units. The radioluminescent lights have many potential military applications. At the field test it was usggested that paratrooper wrist altimeters be fitted with tritium lights. Two units were obtained and illuminated with tritium light sources for evaluation.

Naval Ship Yard - Connecticut. A test was conducted to determine the visibility of a standard three-tube light under conditions of murky waters as might be encountered during a ditching of a helicopter from the deck of a ship. The objective was to provide an exit light that is unaffected by electrical power failure to orient the pilot of the aircraft, in or under water. Further testing was judged to be necessary with increased intensity of light or one of different spectral quality.

Fort Huachuca, Arizona. A field test was conducted at Fort Huachuca, Arizona to test use of lights under desert conditions and in a low-ambient light environment. The test was set up at a simulated base airfield of the type used by advance combat rapid deployment forces. One hundred twenty lights were fabricated and deployed as runway edge lighting and threshold lighting. Helicopter and Mohawk aircraft were used in this test. The lighting system was reviewed by Army rapid deployment officers and enlisted personnel and was judged to be acceptable as a landing aid when used with radar guidance for field location. Recommendation of a second bare base test to be made in Hawaii was put in form of an Army request by the Hawaiian base commander who was visiting Ft. Huachuca. A glide slope indicator was set up using both visible and infrared lights and was used successfully by helicopters.

Marine Corps Auxiliary Landing Field, Bogue, North Carolina. A demonstration of runway edge lighting and classified infrared tests were conducted at the MCALF, Bogue, North Carolina, along with a meeting of the program technical guidance committee. The test involved runway edge lighting used by helicopters. A paratroop jump zone marking and paratroop jump test originally planned for this demonstration were scrubbed due to inclement weather. This has been rescheduled for the Spring of 1983 at Ft. Benning, Georgia.

Oak Ridge National Laboratory. A test was held at ORNL using a remote site set up as an air strip (grass) for helicopter landing and combat maneuvers with the radioluminescent tritium lights and night vision equipment. The aircraft, a Huey helicopter, was supplied by the North Carolina National Guard. Edge lighting and infrared glide slope markers were deployed for use in training with night vision equipment. The field will be used for prototype light testing.

Ft. Benning, Georgia. A test was held at Ft. Benning, Georgia to demonstrate utilization of infrared lights for helicoptor landing zones using night vision devices. The tests were presented by the Army Airborne Pathfinder Group and consisted of air dropping the pathfinders with the lights, setting up the helicopter landing areas, and landings of the helicoptors utilizing the lights.

Alaskan Air Command Tests. Arctic weather tests in which tritium lights were used for runway lighting and a VASI glide slope indicator. Aircraft, including C-130 cargo planes, were landed on the field utilizing these lights.

Instrument Lighting. Work was started in cockpit instrument lighting to fulfill a need for cockpit lighting that is compatible with advanced night vision equipment. Present incadescent lighting causes the electro-optical systems of this equipment, designed to operate at very low-light levels, to fail by aperture closing when excessive light is intercepted. The radioluminescent light is compatible with the advanced night vision equipment; therefore, it may be used for cockpit lighting. While limitations of no capability for changes in intensity or on/off warning light signals are a negative factor in instrument lighting, the reliability of light sources and ease of retrofit makes the effort attractive. An assortment of instruments that represent types used on Huey helicopters was obtained from the Aircraft Depot at Tucson, Arizona. Illumination is obtained by reflection onto the dial face from light sources placed in the frame around the dial. Good visibility was obtained. Two of the instruments have been fitted with visible light sources. Maximum instrument visibility can be obtained by back lighting the instruments. However, this would require major instrument redesign in some cases; therefore, its application would be limited and retrofit expensive.

A second area of radioluminescent light development related to instrument lighting involves external aircraft markers. Two helicopter rotor tip lights were prepared for placement on the ends of the rotor blade. These lights consisted of a doughnut shaped tube encased in polyester resin and attached to the rotor inspection plate. Extensive testing to determine structural integrity will be necessary before these lights can be deployed as an aircraft component. This work was started late in FY 1982 and will continue into the FY 1983 effort.

KRYPTON-85, TESTING APPLICATIONS

Some of the other uses of $^{85}Kr$ show its utility in process control, testing and production technology.

In a method for testing aircraft engine turbine blades, $^{85}Kr$ is introduced into a pressure chamber containing blades to be tested. Small fractures are filled with the gas where it is retained after removal of the blade from the chamber. When the blade is painted with a photographic emulsion, the gamma rays from the $^{85}Kr$ in its fractures provide an autoradiographic picture of its defects.

In another procedure, $^{85}Kr$ is impregnated into a metal component under pressure and temperature. When the component is removed from its pressure chamber, $^{85}Kr$ is retained until it is again heated to the temperature at which the impregnation occurred. This phenomenon can be used to determine the operating temperature of moving parts in an aircraft engine.

Krypton-85 is used in leak test procedures. The electronic industry requires precision leak testing components that are packaged into sealed units. A method has been developed in which the completed component is placed in a chamber containing $^{85}Kr$ gas under pressure. Any leakage of $^{85}Kr$ into the component can later be detected. The process is highly automated and is thus a very low cost procedure.

Krypton-85 is an ideal tracer for process control of gas systems. When introduced into a gas stream, residence times, reaction parameters and flow rates can be determined. As a tracer in oil field production, it can be used for flow studies, porosity measurements and for determination of the intercommunication of oil- and gas-bearing strata.

Gamma ray sources used for thickness gaging and density measurements are frequently fabricated using $^{85}Kr$. To obtain point sources of radiation, $^{85}Kr$ is enriched by thermal diffusion from $\sim 5\%$

concentration that occurs in fission to ~50%. The enrichment process is also used to produce $^{85}Kr$ for non-destructive testing and to increase light intensity in self-luminescent lights.


## SUMMARY

This paper presents fabrication technology for $^{85}Kr$ lights, deployment evaluations at different remote airfields, krypton purification methods, and general applications developmental work that can lead to large scale utilization of $^{85}Kr$ and tritium.