DEPARTMENT OF THE ARMY

US ARMY COMMUNICATIONS - ELECTRONICS COMMAND

ENVIRONMENTAL ASSESSMENT

AND

FINDING OF NO SIGNIFICANT IMPACT

RENEWAL OF NUCLEAR REGULATORY COMMISSION LICENSE NUMBER SMB-1300 GOVERNING NIGHT VISION SYSTEMS

FORT MONMOUTH, NEW JERSEY

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LIST OF ABBREVIATIONS

AAH	Advanced Attack Helicopter
ALI	Annual Limit on Intake
AR	Army Regulation
Bq	Becquerel
CECOM	US Army Communications-Electronics Command
CFR	Code of Federal Regulations
CFV	Cavalry Fighting Vehicle
CONUS	Continental United States
DA	Department of the Army
DAC	Derived Air Concentration
DARCOM	US Army Materiel Development and Readiness Command
DESCOM	Depot Systems Command
DOD	Department of Defense
DOT	Department of Transportation
DS/GS	Direct Support/General Support
EAA	End Article Application
EPA	Environmental Protection Agency
FLIR	Forward Looking Infrared
Gy	Gray
Hq	Headquarters
IAW	In accordance with
ICRP	International Commission on Radiological Protection
IFV	Infantry Fighting Vehicle
IR	Infrared
ISU	Integrated Sight Unit
M-1	Full Tracked Combat Tank (Abrams Main Battle Tank)
M-2(IFV)	Bradley Fighting Vehicle System
M-3(CFV)	Bradley Fighting Vehicle System
M60A3	Full Tracked Combat Tank (Battle Tank)

MLAR	Multilayer antireflective
MOU	Memorandum of Understanding
MSC	Major Subordinate Command
NCAD	New Cumberland Army Depot
NICP	National Inventory Control Point
NODLR	Night Observation Device Long Range
NRC	Nuclear Regulatory Commission
NVS	Night Vision Sight
PICA	Primary Inventory Control Activity
PM	Project Manager
RPO	Radiation Protection Officer
RRAD	Red River Army Depot
SAAD	Sacramento Army Depot
SHAD	Sharpe Army Depot
SICA	Secondary Inventory Control Activity
SLAR	Single layer antireflective
Sv	Sievert
TADS/PNVS	Target Acquisition Designation System/Pilot Night Vision System
ThF_4	^{232}Thorium fluoride
TIS	Thermal Imagery Sight
TOW	Tube-launched, optically tracked, wire-guided
TTS	Tank Thermal Sight
TWS	TOW Weapon System

I. Finding of No Significant Impact

1. The US Army Communications-Electronics Command (CECOM), as the US Nuclear Regulatory Commission (NRC) license manager for all US Army Materiel Development and Readiness Command (DARCOM) activities procuring Night Vision Systems, has prepared an environmental assessment prior to NRC License No. SMB-1300 renewal. The NRC license is a broad scope source material license encompassing all forward looking infrared (FLIR) systems within night vision equipment. The FLIR systems incorporate ^{232}Thorium Fluoride (ThF_4) coated optical elements for optimal night viewing capabilities in defense/weapon system functions.

2. Army contractual specifications require optical systems operable in the eight to fourteen micrometer infrared spectral region with high transmittance capabilities and the ability to withstand severe environmental conditions during tactical (field) use. The incorporation of ThF_4 within optical coatings enables conformance to these provisions. Alternative inorganic dielectric compounds proposed for substitution are unable to comply with necessary performance specifications.

3. The Environmental Assessment documents government contractual requirements for Thorium content within infrared or eyepiece elements to insure compliance to Title 10, Code of Federal Regulations (10 CFR) Part 40, and environmental durability requirements for coating integrity to insure safety and proper performance during implementation of night vision equipment. In addition, Army regulatory policy compliant with 10 CFR Part 20 is outlined establishing maximum safety and management protocol governing the control of night vision devices, inclusive of proper possession, use, storage, transfer and disposal.

4. Initial overview of the incorporation of ThF_4 in optical coatings does not identify any radiological consequence leading to significant environmental impact or health hazard in consideration of pre- and post- procurement safety controls, the minimal quantity of ThF_4 required to produce specified optical performance, and the actual assembly into which optical elements are incorporated. Complete analyses are proposed for radiological considerations with regard to external exposure presented to occupational workers and highly improbable hypothetical incidents involving internal exposure to occupational or non-occupational individuals resultant from ingestion or inhalation subsequent to optical element damage, improper disposal, installation fire, and transport accident. Final computations for external and internal exposure levels presented through various pathways confirm that the incorporation of ThF_4 into optical coatings poses insignificant to non-existent radiological consideration for systems within Army management. Further, dose calculations identified levels which remain below regulatory requirements when hypothesized with severe assumptions for maximum possible exposure outcome. Additional analysis or review of the proposed action is not warranted based on the findings established within the general assessment.

5. The Environmental Assessment offers assurance in response to required Federal and Department of the Army (DA) regulations governing evaluation of Army actions leading to possible environmental quality degradation. Army policy requires environmental evaluations as an integral component of procurement or implementation of radioactive materials within any equipment as a responsible effort in insuring national environmental goals are attained. The Environmental Assessment is available for review upon request from Commander, US Army Communications-Electronics Command, ATTN: DRSEL-SF-H, Fort Monmouth, New Jersey 07703.

II. Environmental Assessment

A. Summary and Conclusion

1. The following Environmental Assessment supporting a Finding of No Significant Impact has been prepared prior to the proposed action of NRC license renewal governing ThF_4 coated optical elements within night vision equipment and in accordance with requirements of Army Regulation (AR) 200-2, Environmental Quality, Environmental Effects of Army Actions [1]. The basic objectives specified in AR 200-2 are to plan, initiate and perform all actions/programs with consideration given to minimize adverse effects on the quality of the human environment without impairment to the Army mission. The scope of this assessment evolves solely around the incorporation of ThF_4 coated optics within night vision assemblies inclusive of general system description, life cycle management, and proposed hypothetical scenarios for determination of possible radiological health hazard or environmental impact. Evaluations have led to the conclusion that no potential environmental degradation or radiological health hazard can be substantiated.

2. The electro-optical system incorporated into night vision assemblies contains ThF_4 on lens components to produce proper infrared spectral optics with high transmittance and low reflectance capabilities. The system allows conversion of infrared energy to visual display during night time tactical (field) activities. The general system description and life cycle management detailed in Section B outlines safety protocol which identifies compliance to all applicable Federal and Army regulations. To insure radiological, environmental, and performance requirements, contractual agreements for procurement of optical elements require testing of components for compliance to military specifications and 10 CFR Part 40. No optical element used in the proximity of the eye shall possess greater than 5.00E-02* percent by weight thorium in compliance with 10 CFR Part 40.13(a). Any optical element which is ThF_4 coated is never employed as the viewing eyepiece.

3. Testing for coating durability withstanding severe environmental conditions, optical performance and screening for detectable levels of contamination on optical elements are performed for compliance to military requirements. All testing and assessments have been exclusive of identifying any significant hazard or radiological exposure level to individuals involved in the use or handling of night vision equipment or subcomponents. Currently, technical manuals for items of issue which have been fielded contain within the proper warning statements for identification of the radioactive ThF_4 coating and specific handling/cleaning instructions for prevention of possible element damage or radiological hazard. Item control and inventory are more stringent than those for standard supply procedure due to the cost and sensitive nature of the item insuring authorized and limited possession.

* The use of exponential (scientific) notation, i.e., 5.00E-02 (5.00×10^{-2}) is employed in lieu of standard notation, i.e., 0.05.

4. The Environmental Assessment proposes various hypothetical incidents which completely dissolve any concern of environmental impact or risk to the health and safety of individuals involved with the night vision equipment. Determinations have been prepared incorporating radioactive material quantities in excess of actual optical element content to encompass current systems and those systems in research and development stages which would also be incorporated under the broad scope NRC license issued for ThF_4 optical coatings. This approach eliminates analysis of each separate system and further analysis for compliance to AR 200-2 prior to implementation of future night vision systems. The NRC license stipulates maximum permissable quantities of ThF_4 per system to be 2.00 grams (gm) with a total possession limit of forty kilograms at any one time.

5. As indicated above, assessments were performed assuming the maximum quantity of 2.00E+02 microcuries (uCi) per system contained in a single optical element. External exposure levels, inclusive of both beta and gamma energies, indicated for continuous presence during a forty-hour work week at a distance of one foot a total of 5.30E-03 Sieverts (Sv) per year (5.30E-01 rem per year). Calculations yield conservative (high) dose estimates for the handling of individual optical elements to completely identify insignificant radiological levels to the primary handling maintenance personnel and authorized user. Hypothetical incidents involving the storage or transportation of optical elements are based upon a fifteen pound limit per activity to identify conceivable internal exposure levels presented to the general public or environ subsequent to fire or vehicle accident. It is inconceivable that any activity will exceed a fifteen pound possession limit at any one time. The determination of compliance with environmental standards for radioactive release is assessed in Section C predicting the environmental transport and subsequent dose associated with ThF_4 released during accident situations. Uncertainties associated with the assumptions lead to over-estimates of actual environmental concentrations or doses which are acceptable when prediction leads to estimates of environmental concentrations or doses that are no cause for concern. The maximum internal dose was determined for an occupational worker who ingested ThF_4 from optical coating damage resulting in 1.41E-02 Sv (1.41E+00 rem) to the bone surface. This remains below the International Commission on Radiological Protection (ICRP)[2] limit recommendations of 5.00E-01 Sv (5.00E+01 rem) for non-stochastic effects as specified in ICRP 30. Table A-1 summarizes potential individual and population doses to bone surface as calculated under assumptions provided in this assessment.

6. Presently no alternative for substitution of ThF_4 in optical coatings offers comparable environmental stability or performance compliant to specifications as detailed in Section B and D. Assessment involving the use of Night Vision Systems incorporating ThF_4 coated optical elements has not defined any radiological impact or concern warranting discontinuation of usage or exclusion of ThF_4 from optical coatings. The overall advantages offered the systems incorporating thorium coated optics outweigh the insignificant to non-existent consideration of radiological hazard or environmental impact which when assessed continually results in external or internal dose levels magnitudes below required air/water concentrations or exposure levels stipulated in 10 CFR Part 20.

TABLE A - 1

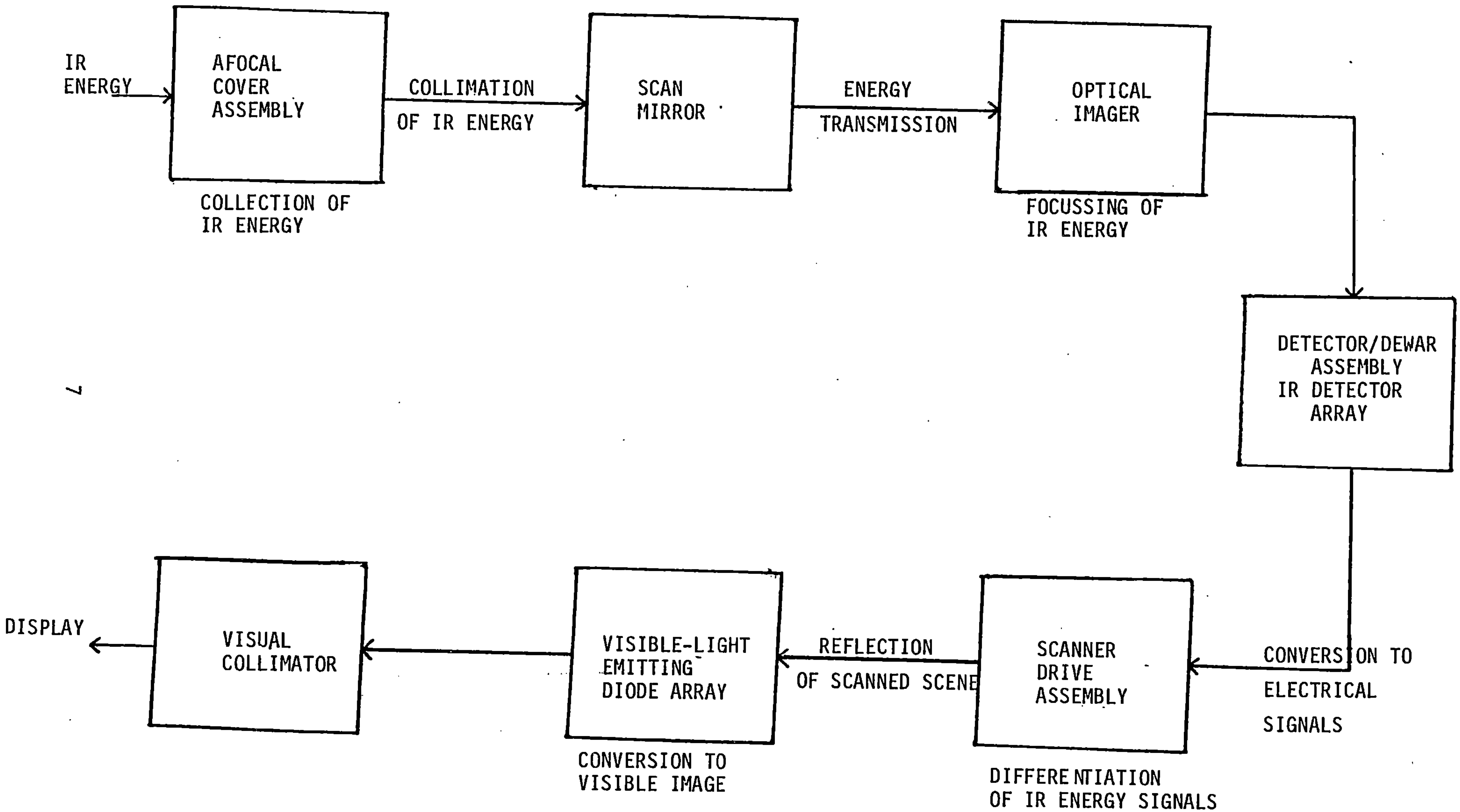
SUMMARY OF COMMITTED DOSE EQUIVALENT LIMITS TO BONE SURFACE SUBSEQUENT TO HYPOTHETICAL INCIDENT

INCIDENT	Sv (rem)
CONTAMINATION	1.41E-02 (1.41E+00)
INSTALLATION FIRE	7.46E-03 (7.46E-01)
SOURCE INCINERATION	7.55E-07 (7.55E-05)
TERRESTRIAL TRANSPORT	4.05E-05 (4.05E-03)
TRANSPORTATION	1.10E-02 (1.10E+00)

B. General Description and Control of Night Vision Systems.

1. Night Vision Sights (NVS) are integral components of major weapon systems. The NVS is a passive thermal imaging assembly providing night viewing capabilities. The night vision assemblies are electro-optical systems including both infrared and visible light optics. The optical elements of night vision systems are composed of infrared transmitting substrates such as Germanium or Silicon with a single or multilayer antireflective (SLAR/MLAR) coating. These coatings are designed to increase substrate transmission and reduce reflection losses associated with substrate materials having a high index of refraction within specific wavelength intervals. Antireflective coatings contain radioactive ThF_4. Several considerations for the incorporation of the ThF_4 in antireflective coatings are detailed in Section D identifying ThF_4 as the primary coating component for producing optimal transmission and durability for optical element performance required by government contract specifications. The total quantity of ThF_4 contained in each complete night vision system varies dependent on specific system characteristics and requirements for necessary field of view, magnification or final visual display. Current night vision equipment and those within developmental stages proposed for future deployment contain radioactive quantities ranging from 3.69E+01 bequerels (Bq) (9.97E-04 uCi) to 5.77E+03 Bq (1.56E-01 uCi) of ThF_4.

2. The basic modules within the night vision systems which contain ThF_4 coated optical elements are the optical imager and the detector/dewar assembly. Ancillary equipment containing ThF_4 coatings are the infrared (IR) window, afocal cover assembly and the boresight collimator. Generally, the thermal imagery modules receive IR energy (heat emission) from the viewing or target area. The IR energy is converted to electrical signals which are then transformed to visible light displayed as a real-time scene for viewing. The IR energy is initially collected in the afocal cover assembly consisting of a two-field-of-view telescope with an objective lens, made of IR passive material, common to both fields of view inclusive of interchangeable lens sets providing various magnifications of view. Typically, the narrow field of view consists of two IR lenses and the wide field of view is composed of a single IR lens. After collection of IR energy, it is collimated to a mechanical scan mirror which transmits the energy to an optical imager. The optical imager assembly is composed of IR imaging lenses and a folding mirror. The optical imager focuses the IR energy into the IR detector array in the detector/dewar assembly. The IR detector array converts incident energy into electrical signals. The scanned scene focussed on the IR detector array is reflected by a scanner drive assembly which senses differences in the IR energy. Electrical signals are converted to visible images which are then transmitted from a visible-light emitting diode array through a visual collimator into a display for viewing through an eyepiece or upon a video screen. Figure B-1 provides a block diagram of system conversion of IR energy to visible viewing. The afocal cover assembly, optical imager and detector/dewar subassemblies are contained within a cast aluminum housing which is then enclosed within an exterior metal housing/ Thus, only the exterior window of the afocal cover assembly is exposed for collection of IR energy in the night vision system.



BLOCK DIAGRAM OF SYSTEM CONVERSION OF IR ENERGY

FIGURE B-1

3. The remaining assembly containing ThF_4 coated optical elements associated with some night vision systems is the boresight collimator. The collimator is a precision electro-optical device attached to the NVS for provision of boresight alignment between the NVS and other assemblies such as the tube-launched, optically tracked, wire-guided (TOW) weapon system (TWS) or laser rangefinder dependent on the major system. Collimated beams of energy generated by the boresight collimator enter the day/night sight collimator producing an alignment image in the night sight.

4. For all procurements of night vision optical elements incorporated into modular subassemblies, the Army requires that the contractor test the thorium coated optics to insure that all elements comply with specifications for radiation (Incl 1) and environmental (Incl 2, 3, 4 and 5) requirements. Radiation requirements specify compliance with the following:

a. Control for lens element traceability to insure required testing is performed for each lot.

b. Screening of optical elements for detectable levels of radiation.

c. Provision of technical drawings, operational and cleaning instructions to insure future maintenance of the night vision program.

d. X-ray fluorescence analysis for first element and suspect element (actinides) of the visible lenses (eyepiece) to insure compliance to 10 CFR Part 40.

e. Environmental durability specifications to insure proper operation and coating adherence under severe environmental conditions.

5. The following environmental tests in a prescribed sequence or equivalent must be performed to identify conformance to optical coating specifications:

a. A witness sample from each coating run shall be subjected to the adherence and hardness tests as specified in MIL-M-13508 (Incl 2).

b. A witness sample from each coating run shall be subjected to the twenty-four hour or five day salt spray (fog) test, respectively dependent on whether it is an internal or external lens element. Testing is outlined in MIL-STD-810 (Incl 3), ANSI/ASTM B 117-73 (Incl 4) and MIL-C-675 (Incl 5).

c. A witness sample from each coating run shall be subjected to the cyclic twenty-four hour or ten-day humidity test dependent on whether it is an internal or external lens element. Procedural testing is described in MIL-M-13508.

Each lot does not proceed for further testing until each witness sample has satisfied environmental test requirements. In addition, the durability of all IR coatings is tested to insure that a sample from every lot of coated optical elements meets or exceeds the scotch tape, eraser rub abrasion and environmental tests as specified in Inclosures 3 and 5 or MIL-C-48497 (Incl 6).

Any witness sample or lot not meeting test standards will not be incorporated into the appropriate subassemblies for night vision devices.

6. Warning notices are contained in all technical manuals for both the operator or maintenance personnel involved with equipment containing ThF_4 optical elements stating:

RADIATION HAZARD

> The antireflective coating on all infrared optics contain thorium fluoride which is slightly radioactive. The only potential hazard involves ingestion (swallowing or inhaling) of this coating material. Dispose of broken lenses, etc, in accordance with AR 385-11[3].

The operating instructions emphasize that the equipment is an electro-optical instrument which must be carefully handled. The maintenance instructions for the various preventative maintenance for both eyepiece and external lens requires the inspection for any disfiguration such as abrasion, blemish, flaking or fissure. If any of these conditions which will effect the overall operation are discovered, the item is returned to various Direct Support/General Support (DS/GS)* maintenance levels. Specific instructions for cleaning of optical lenses outlines cleansing solutions and procedures emphasizing the lens surface coating is easily damaged. The operator's maintenance is limited to the replacement of the battery or coolant cartridge and cleaning of the external lens. The DS/GS personnel are authorized to replace common modules such as the Detector/Dewar and Optical Imager. All other maintenance functions pertaining to night vision devices are performed at Sacramento Army Depot (SAAD) for worldwide activities. Within eighteen months, maintenance for night vision equipment for European theater will be performed at Mainz Army Depot, Germany. All maintenance functions are exclusive of any grinding or removal of the ThF_4 coatings.

7. The program for control of the various night vision devices is similar to control of supply items as prescribed in AR 700-64, Radioactive Commodities in the Department of Defense (DOD) Supply Systems[4] and AR 385-11, Ionizing Radiation Protection, which establishes requirements for NRC licenses and Department of the Army (DA) authorizations for radioactive material possession, requirements for controlled items of supply, transportation, and disposal of radioactive materials. Regulatory guidance is implemented by the various Major Subordinate Command (MSC) or Project Manager (PM) governing the life-cycle management of the assigned materiel, logistics management/support, procurement, maintenance, storage, and transportation including packaging and disposal.

8. Headquarters (HQ) DARCOM has assigned HQ CECOM the responsibility of NRC license management for possession and use of FLIR imaging systems inclusive of all radiation protection management responsibilities within DA installations

* The DS/GS function also refers to the comparable aircraft maintenance echelon, i.e. Aviation Unit Maintenance and Aviation Intermediate Maintenance.

and worldwide activities. CECOM has established Memorandums of Understanding (MOU) with other effected MSC's and/or PM's having the individual logistical control based on the type of system incorporating thermal imaging devices as a component subassembly. These agreements stipulate command responsibilities for compliance to the NRC license and coordination of responsibilities for item assignments, procurement, future revisions, engineering, product assurance, technical data packages and international logistics. CECOM maintains Primary Inventory Control Activity (PICA) responsibilities for the various thermal imaging subsystems while other MSC's maintain PICA responsibilities for the entire system.

9. CECOM life cycle management control is inclusive of the following:

a. Coordination with the National Inventory Control Point (NICP), an element of CECOM at Fort Monmouth, to assure that requisitioning elements are authorized to and technically capable of receiving the item and that procurements do not exceed the quantity or use limitations imposed by the license.

b. Performance of pre- and post- award health physics reviews and surveys of contractors.

c. Provision of health physics advice to be included in instructions for disposal of radioactive waste, and serve as headquarters for notification, investigation and preparation of reports required in the event of accidents/ incidents in which radioactive items may be involved.

d. Annual quality assurance testing of a random sampling of at least six FLIR assets by the inspection of the ThF_4 assessable lenses. Lenses are inspected for flaking and/or pitting of the ThF_4 MLAR coatings.

10. The NICP has adopted special procedures for individually controlled radioactive items that are in addition to standard Army supply practices used for all type-classified items through the following:

a. Record maintenance of procurements, receipts, storage locations, shipments, and using locations.

b. Authorization and provision of items assuring adequate supply.

c. Review of the submitted requisition and upon approval, the NICP will issue material release orders to the designated storage depots for shipment of the material directly to the requisitioner. The control point bases requisition approval on previously established authorization of the requisitioner to receive the item from supply standpoint. Reports of excess items are submitted through various command channels to the NICP for review of serviceability, turn-in, or disposal as radioactive material. The NICP, in conjunction with assistance and directive provided by health physicists at the CECOM Safety Office, determines disposition of excess items.

11. Bulk storage, maintenance, serviceability, surveillance and issue of the various night vision devices are provided by the designated Depot Systems Command (DESCOM) storage activity when approved by the NICP. Primary DESCOM storage activities are New Cumberland Army Depot (NCAD), Red River Army Depot (RRAD), and Sharpe Army Depot (SHAD). SAAD only provides maintenance and serviceability of night vision assets. Where radioactive materials are involved, DESCOM activities have established warehousing facilities and handling procedures which are governed by a formal radiation protection program administered by a qualified Radiation Protection Officer (RPO). Items are inspected when received, at intervals during storage, and immediately before shipment. Warehouse facilities are fire resistant buildings posted with appropriate radiation warning signs and secured for protection against unauthorized removal. Facilities at DESCOM storage activities are constructed of 36 inch poured concrete and protected by fire sprinkler systems encompassing one hundred percent of the area. Fire-fighting personnel are available within short time intervals at all activities in the event additional fire control is necessary. Installations are surrounded by chain-linked fence with patrols eliminating the possibility of unauthorized possession.

12. Shipment from depots/activities of night vision assemblies containing ThF_4 are excepted from specification packaging, markings and labeling. They are also excepted from the provisions of Department of Transportation (DOT) regulations, 49 CFR Part 173.393, testing for removable exterior package surface contamination. The shipper is advised to include the following notice on shipments:

> "This shipment is exempt from DOT specification packaging, marking, and labeling requirements IAW Title 49 CFR 173.391."

13. If any of the ThF_4 components are beyond repair, they will be disposed of as radioactive waste in accordance with AR 385-11. The Defense Logistics Agency assures that designated and identified radioactive materials are not sold, transferred or donated to non-licensed recipients through a computerized system.

C. Radiological Exposure and Environmental Considerations Proposed for Night Vision Systems.

1. Optical elements coated with ThF_4 contained within night vision devices incorporate from 3.69E+01 Bq (9.97E-04 uCi) to 5.77E+03 Bq (1.56E-01 uCi) for the total system quantity (Table C-1). The external dose calculations were performed assuming a total quantity of 7.40E+03 Bq (2.00E-01 uCi) in foresight of future systems incorporating an additional lens element and in further demonstration of insignificant exposure levels. The Thorium series decay chain is inclusive of alpha, beta and gamma emission.[5] External dosimetric calculations accounting for gamma and beta contributions have assumed the following:

a. A disc source measuring 2.74 centimeters (cm) in diameter (R_o=1.37 cm) containing 7.40E+03 Bq (2.00E-01 uCi) of Thorium-232 (Th-232) yielding an

TABLE C - 1

End Article Application (EAA) and Total System Quantity

	EAA	Bq (uCi)
1.	AN/TAS-4 (TOW*)	2.11E+03 (5.70E-02)
2.	AN/TAS-5 (DRAGON)	9.99E+02 (2.70E-02)
3.	AN/TAS-6 (NODLR*)	2.11E+03 (5.70E-02)
4.	AN/VSG-2 (TTS*) M60A3*	5.55E+03 (1.50E-01)
5.	NIGHT CHAPARRAL SUBSYSTEM M48	5.77E+03 (1.56E-01)
6.	ISU* IFV*(M-2)*/CFV*(M-3)*	2.11E+03 (5.70E-02)
7.	TIS* M-1*	2.11E+03 (5.70E-02)
8.	TADS/PNVS* AAH*	5.44E+02 (1.47E-02)
9.	Thermal Driver Viewer M-1, M-2, M-3	3.69E+01 (9.97E-04)

* Abbreviations are clarified at the beginning of this Report.

activity concentration per unit area (C_A) of 1.26E+03 Bq/cm^2 (3.40E-08 Ci/cm^2).

b. Determination of external exposure resultant from gamma energies associated with the decay scheme employed the following equations[6]:

(1) The gamma flux (I_0) at a distance of 30.5 cm directly above the source is given as:

$$I_0 = 2.96E{+}09\ E' C_A \pi \ln\left(\frac{R_0^2 + h^2}{h^2}\right)$$

(2) The absorbed dose rate for tissue is then determined incorporating values of I_0 into the general formula:

$$\text{Gray/hour (Gy/h)} = 5.76E{-}05\ \mu I_0/100$$

where μ = mass absorption coefficient (cm^2/gm) or the equivalent mass energy absorption coefficient for various energies in a tissue medium, i.e., H_2O with a density of 1.0 g/cm^3.

Table C-2 summarizes resulting values for gamma flux and the associated absorbed dose rate. Calculations employing point source geometry yield identical absorbed dose rates due to the distance at which exposure levels are determined with regard to source diameter.

c. The external absorbed dose rate contribution from beta particle energies is assessed incorporating Loevinger point source attenuation[6]:

$$Gy/h = \frac{KC}{(vr)^2}\left\{c\left[1 - \frac{vr}{c}\ e^{1-(vr/c)}\right] + vre^{1-vr}\right\} \div 100$$

where K = normalization constant

$$= \frac{1.70E{+}05\,\rho^2 v^3 E_{av}}{3c^2 - e(c^2-1)}\quad \text{(rads/hr/Ci)}$$

C = Curies

r = Distance from source (g/cm^2)

ρ = Mass density of the absorbing medium

$$c_{tissue} = \begin{array}{ll} 2.00 & 0.17 \leq E_{max} < 0.50\ \text{MeV} \\ 1.50 & 0.50 \leq E_{max} < 1.50\ \text{MeV} \\ 1.00 & 1.50 \leq E_{max} < 3.00\ \text{MeV} \end{array}$$

v_{tissue} = Apparent absorption coefficient (cm^2/g)

$$= \frac{18.6}{(E_{max}-0.036)^{1.37}}\left[2 - \frac{E_{av}}{E_{max}}\right]$$

TABLE C - 2

INDIVIDUAL GAMMA FLUX VALUES WITH RESULTANT ABSORBED DOSE RATES

Isotope	E(MeV)	Gamma Intensity [2]	E'(MeV/disintegration)	I_o(MeV/cm^2/sec)	μ(cm^2/g)	Gy/h(rad/hr)
^{228}Ac	3.40E-01	1.50E-01	5.10E-02	3.22E-02	3.20E-02	5.94E-10(5.94E-08)
	9.08E-01	2.50E-01	2.27E-01	1.43E-01	3.13E-02	2.58E-09(2.58E-07)
	9.60E-01	2.00E-01	1.92E-01	1.21E-01	3.10E-02	2.16E-09(2.16E-07)
^{228}Th	8.40E-02	1.60E-02	1.34E-03	8.47E-04	2.54E-02	1.24E-11(1.24E-09)
	2.14E-01	3.00E-03	6.42E-04	4.06E-04	2.99E-02	6.99E-12(6.99E-10)
^{224}Ra	2.41E-01	3.70E-02	8.92E-03	5.64E-03	3.05E-02	9.91E-11(9.91E-09)
^{220}Rn	5.50E-01	7.00E-04	3.85E-04	2.43E-04	3.27E-02	4.58E-12(4.58E-10)
^{212}Pb	2.39E-01	4.70E-01	1.12E-01	7.08E-02	3.05E-02	1.24E-09(1.24E-07)
	3.00E-01	3.20E-02	9.60E-03	6.07E-03	3.17E-02	1.11E-10(1.11E-08)
^{212}Bi	4.00E-02	2.00E-02	8.00E-04	5.06E-04	6.77E-02	1.97E-11(1.97E-09)
	7.27E-01	7.00E-02	5.09E-02	3.22E-02	3.19E-02	5.92E-10(5.92E-08)
	1.62E+00	1.80E-02	2.92E-02	1.85E-02	2.75E-02	2.93E-10(2.93E-08)
^{208}Ti	5.11E-01	8.28E-02	4.23E-02	2.67E-02	3.27E-02	5.03E-10(5.03E-08)
	5.83E-01	3.10E-01	1.81E-01	1.14E-01	3.26E-02	2.14E-09(2.14E-07)
	8.60E-01	4.32E-02	3.72E-02	2.35E-02	3.15E-02	4.26E-10(4.26E-08)
	2.61E+00	3.60E-01	9.41E-01	5.95E-01	2.37E-02	8.12E-09(8.12E-07)
					TOTAL =	1.89E-08(1.89E-06)

d. Beta dosimetric calculations summarized in Table C-3 result in maximized dose rates due to difficulties presented when attempting within mathematical models to consider the characteristics of continuous energy spectrum and scattering interactions which would yield significant change in resultant values. No inclusion of beta energies less than 5.00E-02 MeV or alpha particle consideration is incorporated in absorbed dose rates due to the short distance of less than three (3.00) centimeters traveled in air.

e. Total absorbed dose rates resultant from gamma and beta energies is 2.47E-06 Gy/h (2.47E-04 rad/hr). It should be noted that no consideration has been given to system shielding of the radioactive elements, actual quantity, distance and duration of operation which would further reduce resultant levels. Assuming continuous exposure during a forty hour work-week, the total absorbed dose for a one year period results in 5.13E-03 Gy/yr(5.13E-01 rad/yr). The dose equivalent value is 5.13E-03 Sv/yr(5.13E-01 rem/yr) assuming a quality factor and dose modifying factor of one (1) for associated energies. These values assume whole body irradiation and do not account for the absorption of beta energies within the first centimeter of tissue.

f. The NRC occupational exposure limits, as specified in 10 CFR Part 20, allow for an occupational whole body dose of 5.00E+00 rem per year. The Metric System (SI) equivalent value would be 5.00E-02 Sv per year as an equivalent exposure limit for uniform irradiation of the whole body. The external exposure presented under normal usage does not demonstrate excessive occupational exposure levels and is similar to non-occupational exposure levels set forth in 10 CFR Part 20.

2. In determining possible internal dose from ThF_4 as a result of incidental inhalation or ingestion, maximum quantities of 7.40E+03 Bq (2.00E-01 uCi) per optical element are assumed. Metabolic data for Th-232 indicates that the bone surface has the highest fractional deposition factor upon translocation of the element following ingestion. For inhalation specific classes have been assigned by the ICRP based upon associated retention in the pulmonary region. ThF_4 is assumed to have a retention half-time from ten to one hundred days (CLASS W). All committed dose equivalents as assessed are below recommendations and regulatory standards. The described incidents are highly improbable but reveal that there would not be significant harm to occupational/non-occupational individuals or degradation to the quality of the environ. Internal exposure was considered the primary risk presented excluding complete assessment of total exposure which would include external exposure contribution. External exposure assessment due to submersion within a semi-infinite cloud was performed only for the hypothetical scenario involving installation fire to illustrate minimal external exposure presented in comparison to internal exposure consideration.

a. Damage of Optical Elements Resulting in Ingestion:

(1) During use of night vision devices, optical elements coated with ThF_4 may become scratched during inspection or cleaned improperly leading to personnel contamination and subsequent ingestion. The following assumptions are considered:

TABLE C-3

Individual Beta Energies with Resultant Absorbed Dose Rates

Isotope	E_{max}(MeV)[7]	E_{avg}(MeV)[7]	c_{tissue}	K	v	Gy/h (rad/hr)
^{228}Ra	3.89E-02	9.90E-03	2.00	--	--	--
^{228}Ac	2.08E+00	3.75E-01	1.00	4.35E+07	1.27E+01	4.26E-07 (4.26E-05)
^{212}Pb	5.73E-01	9.90E-02	1.50	2.53E+09	7.97E+01	6.30E-07 (6.30E-05)
^{212}Bi	2.25E+00	7.17E-01	1.00	4.70E+07	1.05E+01	6.71E-07 (6.71E-05)
^{208}Tl	1.79E+00	5.58E-01	1.00	9.64E+07	1.45E+01	7.27E-07 (7.27E-05)
					TOTAL =	2.45E-06 (2.45E-04)

(a) During the inspection of an afocal cover assumed to contain a maximum quantity of 7.40E+03 Bq (2.00E-01 uCi), the coating becomes scratched removing ten percent of the total activity (7.40E+02 Bq or 2.00E-02 uCi).

(b) Fifty percent of the removed activity is assumed personnel contamination.

(c) Ten percent of the personnel contamination is ingested yielding a total intake of 3.70E+01 Bq (1.00E-03 uCi).

(2) The committed dose equivalents to various organs using internal dosimetry data provided in ICRP 30 and NUREG/CR-1962 [8] are tabulated in Table C-4. The total ingested activity is 1.23E-01 percent of the given Annual Limit on Intake (ALI) for ingestion, which is given as 3.00E+04 Bq.

(3) Even under the assumption that the entire ten percent of the removed activity is entirely consumed, the total ingested activity remains below the recommended ALI for ingestion identifying minimal quantities non-substantive of significant radiological health hazard to individuals involved in the handling of these devices. Committed dose equivalents are presented in Table C-4 for comparison of both hypothetical situations.

(4) The possibility of damage to optical elements leading to removal of source activity is highly unlikely due to specific handling and cleaning instructions provided in technical manuals and bulletins as described in Section B. It should be noted that assumed quantities are extremely overstated in comparison to actual quantities present in any single element of the system.

b. Installation Fire:

(1) The proposed incident involves installation/depot warehouse fire occurring during storage at SAAD in which night vision devices/replacement parts awaiting maintenance are enveloped releasing Th-232. The warehouse facility is equipped with complex sprinkler systems inclusive of pressure monitors and automatic alert to firefighting units which have a minimum response time. The quantity of fifteen pounds is assumed stored in the warehouse resulting in the following scenario with the additional assumptions:

(a) The specific activity of the radioactive material is assumed to be for the pure form yielding a total activity of 2.75E+07 Bq (7.42E+02 uCi) for a fifteen pound storage limit.

(b) Ten percent of the total activity in various units is involved releasing one percent to the warehouse area (2.75E+04 Bq or 7.42E-01 uCi) prior to extinguishment.

TABLE C-4

Committed Dose Equivalents to Various Organs Resultant from Ingestion
Following Contamination/Source Damage

Incident	Activity Ingested	Bone Surface	R. Marrow	Liver*	Gonads*
CONTAMINATION	3.70E+01 Bq	7.03E-04 Sv	5.55-05 Sv	3.77E-07 Sv	4.55E-08 Sv
	(1.00E-03 uCi)	(7.03E-02 rem)	(5.55-03 rem)	(3.77E-05 rem)	(4.55E-06 rem)
SOURCE DAMAGE	7.40E+02 Bq	1.41E-02 Sv	1.11E-03 Sv	7.56-06 Sv	9.11E-07 Sv
	(2.00-02 uCi)	(1.41+00 rem)	(1.11E-01 rem)	(7.56E-04 rem)	(9.11E-05 rem)

* Internal dosimetry data from NUREG/CR-1962.

Remaining committed Dose Equivalents are assessed using ICRP 30 Data.

(c) The volume of air in the warehouse is 1.23E+04 m^3 yielding 2.24E+00 Bq/m^3 (6.03E-05 uCi/m^3).

(d) The breathing rate of persons involved is 1.20 m^3/hr.

(e) The total intake for each firefighter is 6.72E-01 Bq (1.81E-05 uCi) assuming no implementation of respiratory protective devices during a fifteen minute period following initial firefighting operations.

(2) The committed dose equivalents to various organs are given in Table C-5. Estimates are not considered for the general public due to conservative dose estimates indicated and consideration of dispersion parameters which would further decrease estimated committed dose equivalents. It should be noted that no consideration of standard operating procedures inclusive of respiratory devices or ventilation of the building during extinguishment were considered which would reduce estimated doses. The committed dose equivalent limit for bone surface remains below recommended non-stochastic dose equivalent limits. The total inhaled activity is 6.72E-01 percent of the ALI (1.00E+02 Bq) recommended for inhalation. The air concentration stated in 2.b.(1)(c) is equivalent to 2.24E+00 Bq/m^3 (6.03E-11 uCi/ml). The air concentration does not cause the inhalation of a quantity of radioactive material greater than the quantity which would result from inhalation for forty hours per week for thirteen (13) weeks at uniform concentrations of radioactive materials in air as specified in 10 CFR Part 20 for restricted areas.

(3) Although it is highly improbable that a total of fifteen pounds of ThF_4 incorporated into various night vision devices are stored at any one time in a depot or that envelopment could occur of these units prior to containment of the fire, the incident is demonstrative of levels which do not present significant radiological health impact. Additionally, operations of fire-fighting would be conducted with awareness of the potential hazard leading to measures for respiratory protection. Finally, as previously indicated, warehouse facilities are constructed for prevention of fire leading to envelopment of stored materials. Additional areas such as replacement facilities ("clean rooms") at SAAD also contain sprinkler systems but would never possess quantities assumed within this assessment.

(4) For assessment of complete exposure presented to individuals during this hypothetical incident, the following calculations are performed to identify external exposure resultant from a one hour time frame:

(a) Assuming a homogenous cloud with dimensions establishing an equilibrium condition where the rate of energy absorption is equal to the rate of energy released within an equivalent unit volume, the following equations[9] are employed for resultant radiation absorbed doses from beta and gamma energies respectively:

TABLE C - 5

Committed Dose Equivalents to Various Organs Resultant from Inhalation Following Bulk Storage Installation Fire

Inhaled Activity	Bone Surface	Liver*	Lung*	R. Marrow
6.72E-01 Bq	7.46E-03 Sv	4.19E-06 Sv	9.68E-06 Sv	6.00E-04 Sv
(1.81E-05 uCi)	(7.46E-01 rem)	(4.19E-04 rem)	(9.68E-04 rem)	(6.00E-02 rem)

* Internal Dosimetry Data from NUREG/CR-1962.

Remaining committed Dose Equivalents are assessed using ICRP 30 Data.

$$\text{Gy/sec} = 2.29\text{E-03}\ \bar{E}_{\beta}\chi$$
$$\text{Gy/sec} = 2.54\text{E-03}\ \bar{E}_{\gamma}\chi$$

where χ = Curies/m^3.

(b) Tables C-6 and C-7 give resulting values assuming a constant concentration as stated in b.(1)(c) within a semi-infinite cloud whose radius is equal to or greater than the range of any beta or gamma energy. The receptor was assumed centrally located to exclude media of different absorbing characteristics. It should be noted absorbed dose rate variation for beta energies due to field perturbation from the individual is excluded. The total absorbed dose is approximated to be 2.86E-09 Gy/h (2.86E-07 rad/hr) or equivalent to 2.86E-09 Sv (2.86E-07rem) within a one hour time frame. It can be seen that the external dose consideration with the given assumptions in view of the fifty year internal committed dose equivalent is minimal and will not be included in following hypothetical incident assessments.

c. Source Loss Leading to Improper Disposal to an Incinerator:

(1) SAAD procures replacement parts to different night vision systems. The following incident assesses transfer to a commercial incinerator, a package containing twenty elements for night vision systems assuming a maximum activity of 7.40E+03 Bq (2.00E-01 uCi) per element. Transfer of these components to unauthorized areas is considered highly inconceivable based on stringent inventory controls imposed on the item, physical size, and monetary values of these devices. The assessment is presented to identify levels below regulatory standards for unrestricted areas and to demonstrate that there would be no significant resultant environmental impact or radiological hazard to the surrounding public. The assumptions[10] used to evaluate the amount of Th-232 in incinerator emissions are as follows:

(a) The initial activity (Q_i) from twenty optical elements is 1.48E+05 Bq (4.00E+00 uCi).

(b) The incinerator processes 300 tons of refuse per day at fifty percent excess air.

(c) The Th-232 released during the incineration process (f_s) is approximately one hundred percent of the total activity.

(d) The efficiency of the air pollution control systems for particulates is 90 percent (i.e. the fraction of Th-232 which escapes with stack gases, f_r = 0.1)

(e) The aerodynamic mean activity diameter of released particles is one micron.

TABLE C - 6

AVERAGE BETA ENERGIES AND ABSORBED DOSE RATES

RESULTANT FROM SUBMERSION WITHIN A SEMI-INFINITE CLOUD

ISOTOPE	$\bar{E}_\beta$ (Mev)[7]	Gy/s (rad/sec)	Gy/h (rad/hr)
^{228}Ra	9.90E-03	1.36E-15 (1.36E-13)	4.91E-12 (4.91E-10)
^{228}Ac	3.75E-01	5.17E-14 (5.17E-12)	1.86E-10 (1.86E-08)
^{212}Pb	9.90E-02	1.36E-14 (1.36E-12)	4.91E-11 (4.91E-09)
^{212}Bi	7.17E-01	9.88E-14 (9.88E-12)	3.56E-10 (3.56E-08)
^{208}Tl	5.58E-01	7.69E-14 (7.69E-12)	2.77E-10 (2.77E-08)
		TOTAL =	8.73E-10 (8.73E-08)

TABLE C - 7

AVERAGE GAMMA ENERGIES AND ABSORBED DOSE RATES

RESULTANT FROM SUBMERSION WITHIN A SEMI-INFINITE CLOUD

ISOTOPE	$\bar{E}_\gamma$(Mev)[7]	Gy/s (rad/sec)	Gy/h (rad/hr)
^{228}Ac	9.48E-01	1.45E-13 (1.45E-11)	5.23E-10 (5.23E-08)
^{228}Th	1.73E-01	2.65E-14 (2.65E-12)	9.54E-11 (9.54E-09)
^{224}Ra	4.65E-01	7.12E-14 (7.12E-12)	2.56E-10 (2.56E-08)
^{220}Rn	5.50E-01	8.42E-14 (8.42E-12)	3.03E-10 (3.03E-08)
^{212}Pb	1.77E-01	2.71E-14 (2.71E-12)	9.76E-11 (9.76E-09)
^{212}Bi	1.07E+00	1.64E-13 (1.64E-11)	5.90E-10 (5.90E-08)
^{208}Tl	2.24E-01	3.43E-14 (3.43E-12)	1.24E-10 (1.24E-08)
		TOTAL =	1.99E-09 (1.99E-07)

(f) The number of persons feeding one incinerator disposal route is also assumed to be the exposed population of 73,000 individuals.

(g) The entire activity of Th-232 is released within a twenty-four hour time frame.

(h) The inhalation of Th-232 occurs within twenty-four hours.

(i) Fifty percent excess of the theorectical volume of air required for complete combustion of one pound (lb) is 2.00E+06 cm^3/lb (V_a).

(j) The weight of the refuse incinerated (W_r) is 6.60E+05 pounds.

(k) The atmospheric dispersion coefficient (X/Q) is assumed to be 2.00E-05 seconds/m^3.

(2) The total activity released in a day (Q) would be:

$$Q = Q_i \; f_s \; f_r$$

Incorporating values specified in b.(2)(b, c and d), calculations yield 1.48E+04 Bq (4.00E-01 uCi) released from incineration. The continuous release rate (Q') over twenty-four hours is 1.71E-01 Bq/s (4.63E-06 uCi/sec).

(3) The concentration of Th-232 in the stack gas (X_s) is given by $X_s = Q/V_a V_r$. Substituting values indicated in b(1)(i and j) and B(2), the average 24 hour concentration of Th-232 is 1.12E-08 Bq/cm^3 (3.03E-13uCi/cm^3).

(4) The wind speed is assumed constant at 1.0 m^2/sec under stable meteorological conditions.

(5) The maximum downwind concentration (X) substituting values from 2.c(1)(k) and 2.c(2) into the general formula X = Q' (X/Q) is estimated to be 3.43E-06 Bq/m^3 (9.26E-11 uCi/m^3) or equivalent to 3.43E-06 Bq/m^3 (9.26E-17 uCi/ml). The air concentration limits specified in 10 CFR Part 20 for unrestricted areas is stated as 3.70E-02 Bq/m^3 (1.00E-12 uCi/ml).

(6) The average daily breathing rate of 20.0 m^3 per day is assumed. Therefore, the maximum exposed individual would inhale approximately 6.86E-05 Bq (1.85E-09 uCi).

(7) The average person is assumed to inhale an amount of Th-232 equal to one third the total activity yielding 2.29E-05 Bq (6.17E-10 uCi). Approximation of committed dose equivalents to various organs using ICRP 30 and NUREG/CR-1962 are summarized in Table C-8.

TABLE C - 8

COMMITTED DOSE EQUIVALENTS TO VARIOUS ORGANS RESULTANT FROM INHALATION

FOLLOWING SOURCE INCINERATION

EFFECTED GROUP	ACTIVITY INHALED	BONE SURFACE	LIVER*	LUNG*	R. MARROW
Maximum Exposed Individual	6.86E-05 Bq	7.55E-07 Sv	4.27E-10 Sv	9.88E-10 Sv	6.11E-08 Sv
	(1.85E-09 uCi)	(7.55E-05 rem)	(4.27E-08 rem)	(9.88E-08 rem)	(6.11E-06 rem)
Average Exposed Individual	2.29E-05 Bq	2.52E-07 Sv	1.43E-10 Sv	3.30E-10 Sv	2.04E-08 Sv
	(6.17E-10 uCi)	(2.52E-05 rem)	(1.43E-08 rem)	(3.30E-08 rem)	(2.04E-06 rem)

* Internal dosimetry data from NUREG/CR-1962.

Remaining committed Dose Equivalents are assessed using ICRP 30 Data.

(8) Realistic consideration of the above incident is eliminated based on user ability to maintain proper authorized possession and accountability.

d. Source Loss Resulting in Improper Disposal Directly to a Public Landfill:

(1) The quantity of Th-232 incinerated in c.(1)(a) is assumed transferred to a public solid waste landfill. Surrounding populations may be exposed through ingestion of contaminated groundwater. The following parameters are assumed for complete assessment:

(a) Leaching of the total activity of 1.48E+05 Bq (4.00E+00uCi) is one hundred percent (A_t).

(b) One hundred percent is assumed to contaminate groundwater without any dispersion (f_{L1}).

(c) The total volume (V_L) of leachate generated per year from an average 25 acre landfill based on US Environmental Protection Agency (EPA) estimates is 6.76E+06 gallons (2.57E+10ml) accounting for only the average precipitation infiltrate of ten inches per year.

(d) There is no further dilution in the zone of contamination (f_{L2}) is equivalent to one).

(e) One percent is assumed withdrawn for domestic water supply (f_{d1}) and five percent for public drinking water (f_{d2}).

(2) The total activity in the leachate is determined by:

$$A_L = A_t f_{L1} f_{L2} / V_L$$

The activity substituting proper values is estimated to be 5.76E-06 Bq/ml (1.55E-10 uCi/ml).

(3) In determining the activity ingested by surrounding populations the equation $A_{ing} = V_L f_{d1} f_{d2} A_L$ is employed.

The dietary intake by the entire population (73,000) surrounding the landfill would be 7.40E+01 Bq (2.00E-03 uCi). The average dietary intake would be 1.01E-03 Bq (2.74E-08 uCi).

(4) The dose commitment to the maximally exposed individual is assessed with the assumption that the annual dietary intake of water (I_w) is 370 liters (l) and consists entirely of drinking water contaminated with Th-232 at the same concentration as calculated for leachate (5.76E-06 Bq/ml)

incorporated into the formula: $A_{ing} = I_w A_L$. This yields an ingestion of 2.13E+00 Bq (5.75E-05 uCi). The Th-232 intake and committed dose equivalents to various organs are summarized in Table C-9.

(5) The maximum permissible concentrations for unrestricted areas as specified in 10 CFR Part 20 are 7.40E+04 Bq/m^3 (2.00E-06 uCi/ml) for soluble forms and 1.48E+06 Bq/m^3 (4.00 E-05 uCi/ml) for insoluble forms. The concentration of the radionuclide in the leachate is approximately 7.78E-03 percent of the soluble limits and 3.88E-04 percent of the insoluble limits.

(6) The maximum exposed individual ingests 7.10E-03 percent of the ICRP recommended ALI (3.00E+04 Bq) for ingestion. The resulting committed dose equivalent to bone surface is 8.10E-03 percent of the recommendations for non-stochastic effects (5.00E-01 Sv).

e. Transportation Incidents:

(1) A transport incident involving an assumed maximum quantity of Th-232 is proposed to demonstrate levels below regulatory limits for unrestricted areas. Transportation of night vision devices having a total of fifteen pounds within a single shipment would never occur. The assessment considers inhalation risk as the primary immediate mode of exposure to individuals in the vicinity of an incident under the assumptions:

(a) A maximum quantity of fifteen pounds is transported yielding a total activity of 2.75E+07 Bq (7.42E+02 uCi).

(b) Fifty percent of the total activity is instantaneously and uniformly spacially distributed within a hemispherical volume whose radius equals 200 meters yielding a total volume of 1.67E+07 m^3 and whose activity concentration per unit volume is 8.23E-01 Bq/m^3 (2.22E-05 uCi/m^3).

(c) Assuming no change in activity per unit volume from dispersion during a one hour time period, an individual with a breathing rate of 1.2 m^3/hr remaining for an hour would inhale an activity of 9.88E-01 Bq (2.67E-05 uCi). The concentration when averaged over a one year period is 2.25E-03 Bq/m^3 (6.08E-14 uCi/ml). Based on the calculations, this value is shown to be several orders of magnitudes below NRC air concentration specifications for restricted (1.11E+00 Bq/m^3 or 3.00E-11 uCi/ml) or unrestricted (3.70E-02 Bq/m^3 or 1.00E-12 uCi/ml) areas stated for insoluble/soluble forms.

(2) The total quantity inhaled is approximately 2.47E+00 percent of the recommended ALI (4.00E+01 Bq) for inhalation. The resulting dose equivalent to bone surface is 2.20E+00 percent of the yearly dose equivalent limit (5.00E-01Sv) recommendations for non-stochastic effects. Table C-10 summarizes committed dose equivalent limits to various organs.

TABLE C - 9

COMMITTED DOSE EQUIVALENTS TO VARIOUS ORGANS RESULTANT FROM INGESTION OF CONTAMINATED DRINKING WATER

Effected Group	Activity Ingested	Bone Surface	Liver *	R.Marrow	Gonads *
Total Public	7.40E+01 Bq (2.00E-03 uCi)	1.41E-03 Sv (1.41E-01rem)	7.55E-07 Sv (7.55E-05rem)	1.11E-04 Sv (1.11E-02rem)	9.10E-08 Sv (9.10E-06rem)
Maximum Exposed Individual	2.13E+00 Bq (5.75E-05 uCi)	4.05E-05 Sv (4.05E-03rem)	2.17E-08 Sv (2.17E-06rem)	3.19E-06 Sv (3.19E-04rem)	2.62E-09 Sv (2.62E-07rem)
Average Exposed Individual	1.01E-03 Bq (2.74E-08 uCi)	1.92E-08 Sv (1.92E-06rem)	1.03E-11 Sv (1.03E-09rem)	1.52E-09 Sv (1.52E-07rem)	1.24E-12 Sv (1.24E-10rem)

* Internal dosimetry data from NUREG/CR-1962.

Remaining committed dose equivalents are assessed using ICRP 30 data.

TABLE C - 10

COMMITTED DOSE EQUIVALENTS TO VARIOUS ORGANS RESULTANT FROM INHALATION SUBSEQUENT TO TRANSPORT INCIDENT

Activity Inhaled	Bone Surface	Liver *	Lung *	R. Marrow
9.88E-01 Bq (2.67E-05 uCi)	1.10E-02 Sv (1.10E+00 rem)	6.15E-06 Sv (6.15E-04 rem)	1.42E-05 Sv (1.42E-03 rem)	8.82E-04 Sv (8.82E-02 rem)

* Internal dosimetry data from NUREG/CR-1962.
Remaining committed dose equivalents are assessed using ICRP 30 data.

3. Hypothetical scenarios developed for environmental or radiological health assessment have not been identified to exceed recommended exposure levels for stochastic/non-stochastic dose limits of the ICRP or NRC regulatory requirements. Assumptions established for each incident are regarded as highly improbable. Resultant determinations even when assessed with extreme parameters do not pose significant health or environmental risk. Actual levels would be magnitudes below proposed inhalation or ingestion quantities and determined committed dose equivalents. Maximum safety controls in conjunction with contractual requirements are adequate to insure safe operation without regard to radiological or environmental impact from incorporation of ThF_4 optical coatings within night vision systems.

D. Alternatives

1. The use of optical coatings for obtaining superior spectral performance is achieved over wide wavelength ranges using SLAR/MLAR coatings free from the effects of temperature, angle of incidence shifts and coating non-uniformity. Both MLAR and SLAR coatings are designed to increase substrate transmission and reduce surface reflection for specific wavelength intervals. Typical substrates employed for optical elements are germanium or silicon. Without optical coatings, the transmittance performance of only forty-six percent is obtained in the eight to fourteen micrometer IR spectral region. The incorporation of ThF_4 as one of the multilayers in antireflective coatings produces a ninety-eight percent transmittance within the same spectral region. The development of optical elements for night vision devices with military specifications for an eight to fourteen micrometer IR region withstanding environmental degradation has necessitated the incorporation of ThF_4 as one of the multilayers for specified properties. Additional considerations for ThF_4 selection includes:

(a) The low index of refraction for antireflective coatings.

(b) The extreme stability exhibiting no appreciable decomposition in coating processes.

(c) The low water solubility lending to withstanding severe environmental conditions as an outer coating.

(d) The high transmittance offered due to the molecular lattice structure.

2. The coating for this system is important since there are as many as five lens elements within night vision assemblies. Without this coating, the inter-reflection losses within the lens system would significantly result in decreased performance. Incorporation of ThF_4 allows use of approximately ten coated elements without decrease in total reflective functions. Commercial laboratories have developed non-radioactive coatings which are capable of producing approximately ninety-four percent transmittance. The non-radioactive

coatings are typically inorganic dielectric type compounds. No material being prototype tested in research and development stages for objective (exterior) lenses assure or meet all military requirements. Research and testing for non-radioactive substitutes is ongoing for complete development of coatings producing higher transmission and durability characteristics.

3. In consideration of the negligible to non-existent exposure risk associated with the use of FLIR systems, alternative replacements decreasing performance are unacceptable. There is no demonstration for the need of immediate or future concern regarding the incorporation of ThF_4. Primary consideration should continue to surround provision of optimal systems for use by effected military organizations. ThF_4 antireflective coatings provide the only source for optimal characteristics/properties for use in night vision devices meeting requirements of Federal regulations, Army contracts and tactical implementation. These coatings are considered most advantageous in obtaining specified requirements for uniformly high transmission over required wavelength intervals and multiple reflectance reduction.

E. Status of Compliance

All night vision systems included under the CECOM NRC Source Material License No. SMB-1300 have been identified in Section B to comply to all regulations stipulated in 10 CFR, applicable Army regulations as specified in AR-385-11 and CECOM MOU's between other MSC's. In addition, CECOM provides assurance to compliance of regulations through annual health and safety inspections of depot areas inclusive of quality assurance testing. Further, this headquarters will assure that contractor facilities are inspected for compliance with statements and representations contained within NRC Source Material License No. SMB-1300. As previously stated in Section B, transportation of night vision thermal imagery equipment is exempted with regard to applicable DOT/NRC regulations.

F. Listing of Agencies and Persons Contacted:

1. Nado, George: IEL/SAL Laboratory Manager
Electro-Optics Division
Texas Instruments
Dallas, Texas

2. Olson, Valerie: Assistant Program Manager, FAS
Hughes Aircraft Corporation
Culver City, California

3. Vincent, Jerry: Safety Specialist
Safety Office
Sacramento Army Depot
Sacramento, California

4. Zmarzly, Frederick: Sales Manager
Government Aerospace
Optical Coating Laboratories, Incorporated
Santa Rosa, California

G. References:

1. Army Regulation 200-2, Environmental Quality: Environmental Effects of Army Actions, Headquarters, Department of the Army, Washington, DC, 1981.

2. International Commission on Radiological Protection, Publication 30, Limits for Intakes of Radionuclides by Workers, Pergamon Press, New York, adopted 1978.

3. Army Regulation 385-11, Ionizing Radiation Protection (Licensing, Control, Transportation, and Disposal), Headquarters, Department of the Army, Washington, DC, 1980.

4. Army Regulation 700-64, Radioactive Commodities in the DOD Supply System, Headquarters, Department of the Army, Washington, DC, 1976.

5. US Department of Health, Education and Welfare, Radiological Health Handbook, Public Health Service, Rockville, Maryland, 1970.

6. Fitzgerald, John J., Applied Radiation Protection and Control, Gordon and Breach Inc., New York, 1970.

7. Kocher, David C., Radioactive Decay Data Tables, National Technical Information Service, Springfield, Virginia, 1981.

8. Eckerman, K. F., et al., Internal Dosimetry Data and Methods of ICRP - Part 2, Volume 1: Committed Dose Equivalents and Secondary Limits, NUREG/CR-1962, Volume 1, ORNL/NUREG/TM-433/V1, National Technical Information Service, Springfield, Virginia, 1981.

9. Slade, David H., Meteorology and Atomic Energy, National Technical Information Center, Springfield, Virginia, 1968.

10. Belanger, R., Buckley, D.W., and Swenson, J.B., Environmental Assessment of Ionization Chamber Smoke Detectors Containing Americium-241, NUREG/CR-1156, Science Applications, Inc., California, 1979.

RADIATION REQUIREMENT

The Optical Elements shall contain no thorium or other source material as defined in Title 10, Code of Federal Regulations, Part 40, in excess of 0.05 percent by weight or other added radioactive material (See Definition A).

The contractor shall include the preceding requirement in all purchase orders for Optical Glass.

1. Optical Elements (Visible Lenses)

a. Inventory Control - Each lens element shall be traceable to a particular lot and vendor. Lots shall be separated according to date received, lens type and vendor. For accounting and control purposes, each lot will be documented as to the number in the lot, type of lens, source of supply and date received. Individual lots must be kept separated until unit testing has been completed and the lots are approved for use (see below). This inventory control system shall be open for Government inspection throughout the life of the contract and one copy of the applicable portion of the inventory records will be submitted along with each test report for Government retention.

* b. Screening Test - All completed glass elements will be individually screened for detectable radiation by using a Government approved radiation monitor (See Definition B). All glass elements will be unwrapped before screening and screening will be done on both sides of the glass. Each glass element will first be screened using an end window probe. All glass passing this test will then be screened by using an Alpha Probe. Any lens element which indicates a positive reading on the monitor, a steady reading twice background or greater, will be cause for rejecting the lot.

* c. X-Ray Analysis for First Element in Eyepiece - After screening the lots as described in part b, 10 percent of the accepted screen elements in each lot will be randomly selected and tested by X-Ray Fluorescence (See Definition C)for compliance with the test requirement (NOTE: At least one sample from each lot will be tested and all sample quantities will be rounded to the next higher integer). If the analysis shows a source material concentration greater than 0.05 percent by weight, 500 parts per million, for any sample, all glass elements in the lot associated with this sample will be rejected and replaced with acceptable glass elements at the contractors expense. Government prior approval of the test facility that will perform the X-Ray Analysis is required (See Definition C).

d. X-Ray Analysis for Suspect Elements in Eyepiece- After screening the lot as described in part b, one percent of the accepted screened elements in each lot will be randomly selected and tested by X-Ray Fluorescence (See Definition C) for compliance with the test requirement. (NOTE: At lease one sample from each lot will be tested and all sample quantities will be rounded to the next higher integer). If the analysis shows a source material concentration greater than 0.05 percent by weight, 500 parts per million, for any sample, all glass elements in the lot associated with this sample will be rejected and replaced with acceptable glass elements at the contractors expense. Government prior approval of

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the test facility that will perform the X-Ray Analysis is required, (See Definition C).

e. One glass sample which has not received the X-Ray fluorescence test from each lot associated with c and d above may be randomly selected by the Government QAR and sent as part of the test report for Government verification testing. If tests show a source material concentration greater than 0.05 percent by weight, 500 parts per million, all glass elements in the lots associated with the sample will be rejected and replaced with acceptable glass elements at the contractors expense. The sample will be returned fifteen (15) days after date of receipt.

f. The plan shall include a sample test report (see DD 1423 DI-T-1906)which demonstrates the ability to determine compliance with the requirement by examination of the report.

g. <u>Alternate Methods of Certification</u>. Equivalent alternate procedures may be submitted for Government approval at the time of and in addition to the submission of the Contractor test plan. The alternate plan must contain adequate documentation concerning the relative cost and difficulties of implementing this note and the alternate plan and of the equivalence of the alternate certification plan in terms of assuring compliance with paragraph a., while maintaining the contractual delivery schedule and minimizing additional costs.

2. Optical Elements IR Coated (Thorium Fluoride)

a. <u>Restriction of Optical Fluoride Coatings on IR Optics</u>. Thermal Imaging Systems, especially developed in the 8-14 um region, and delivered under this contract may have Infrared Optics containing thorium fluoride anti-reflective coatings. Since this material is radioactive, 10CFR requires the items using this coating material be controlled. All systems utilizing thorium fluoride coatings shall be tested to assure durability of the coatings. Furthermore, on all materials prepared in support of the equipment, as required by the contract, the Contractor shall inform the customer/reader of the existence of the thorium coatings and shall indicate that licensing authorization has been approved from the Nuclear Regulatory Commission (NRC) for their use. The prime Contractor shall assume full responsibility for the implementation of this note and shall include this note in all subcontracts.

(1) <u>Operating Instructions</u>. Manuals or other operating instructions shall state that the objective lenses are coated with indicated numerical value amount of radioactive material and that licensing authorization for its use has been obtained from NRC. Also, methods to be used in cleaning the lenses shall be defined in the manuals.

(2) <u>Testing</u>. IR coatings shall pass adherence and abrasion tests. IR coatings shall not flake, peel or pit when subjected to environmental requirements.

(3) Drawings. Drawings describing thorium coated elements shall indicate that the element is thorium fluoride coated. The amount of thorium compound per square centimeter in the total coating will be provided.

(4) Certification or Safety Statement. The contractor shall specifically provide the following information as a separate item or as part of another data item such as the safety statement, final report, or radioactive material data list:

(a) Part number of all optical elements with IR coatings.

(b) Diameter of each element with a radioactive IR coating.

(c) The amount of thorium compound per square centimeter in the total coating will be provided.

(This information is required under NRC Source Material License Number SMB-1300 issued to USACERCOM)

Definitions

A. Radioactive Material - Material requiring specific licensing, under the regulation issued pursuant to the Atomic Energy Act of 1954, as amended, and any other radioactive material not requiring specific licensing in which the radioactivity per gram is greater than 0.002 microcuries.

B. Radiation Monitor - Must have both audible and meter detection ability. The monitor must have capability to be used with both a thin window probe and a Alpha Probe (Equivalent to Eberline Model RM-15 or RM-19).

Minimum Requirements for Probes

1. Alpha Probe - Target surface must be of Aluminized Mylar no heavier than 1.5 mg/sq cm (Equivalent to Eberline Model AC-3-7/AC-3B-7).

2. Thin End Window Probe - End window must be Mica no heavier than 2 mg/sq cm (Equivalent to Eberline Model HP-230A).

C. Government Approval of Test Facility - Will be based on the ability to use X-Ray Fluorescence techniques to analyze glass with a minimum detectable level for thorium and other source material of at least 100 parts per million with an accuracy of ± 25 parts per million. Equipment to be used in performing the X-Ray Fluorescence must be calibrated and correlated against Government standards.

F-17-25

MIL-M-13508C
19 March 1973
SUPERSEDING
MIL-M-13508B
16 November 1966

MILITARY SPECIFICATION

MIRROR, FRONT SURFACED ALUMINIZED: FOR OPTICAL ELEMENTS

This specification is mandatory for use by all Departments and Agencies of the Department of Defense

1. SCOPE

1.1 Scope. This spe[illegible]n covers a mirror coating consisting [illegible] deposited aluminum refl[illegible]ive film overlaid with a transparent dielectric protective film applied on the front surface of optical elements.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issu[illegible] [illegible]ffect on date invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

* Federal

L-T-90	Tape, Pressure-Sensitive, Adh[illegible] (Cellophane and cellulose ac[illegible])
CCC-C-440	Cloth, Cheesecloth, Cotton, Bl[illegible]ched and unbleached

Military

MIL-O-13830	Optical Components for Fire Control Instruments; General Specification Governing the Manufacture, Assembly, and Inspection of

FSC 6650

THIS DOCUMENT CONTAINS 6 PAGES

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STANDARDS

Federal

Federal Test Method, Standard No. 151	Metals; Test Methods

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-1241	Optical Terms and Definitions

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Optical terms and definitions.- Reference shall be made to MIL-STD-1241 to define optical terms used.

3.2 Optical elements.- The supplier is responsible for the quality of the optical elements used as backing for a front surface mirrored finish. Optical elements shall have been manufactured, tested and approved for use in accordance with the applicable element drawing and referenced specifications prior to the coating process.

3.3 Coating process.- The coating process producing the front surface mirror finish shall cause no impairment to the optical element. Optical elements which have met the requirements of 3.2 shall not be rejected because of fine hair lines, scratches, digs or stains which are made more visible by the coating process.

3.3.1 Aluminum film.- The deposited film shall be of high quality aluminum. There shall be no visible discontinuities or blemishes that adversely affect the field of view as seen with the eye in the specified viewing position.

* 3.3.2 Protective film.- The front surface aluminum film shall be protected by a film of high quality uniform magnesium fluoride or silicon monoxide or as otherwise specified on the applicable drawing. The film shall be free from holes, foreign matter and perceptible variations in density.

3.4 Reflectance.- The finished coated surface, for visible use, shall have more than 86 percent luminous reflectance when measured at required angle of incidence, or a refelctance as otherwise specified on the applicable drawing.

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