DISTRIBUTION LICENSE 22-19422-02G

APPLICATION FOR AMENDMENT

12 NOVEMBER 1984

CONTROL NO. 77823

Commercial Aviation Operations

Honeywell

EXHIBIT A

Supplement to Condition 12 of License 22-19422-02G Amendment

The document to which this exhibit refers is the Application for Amendment dated 19 January 1981 and identified by FQIS file number 8107-566. The NRC Form 313 which accompanies the referenced application is dated 15 January 1981.

The changed pages are a part of this exhibit. Changes are marked by an asterisk in the margin.

BASIS FOR REQUESTED CHANGES

1. The rationale for most of the changes is evident from the text and the basic request to allow airlines to own and install spare emitters.

2. Change of Paragraph VI B 2b (5) Page 36. Deletion of this paragraph is requested on the basis that it is un-necessary because:

   a. There is no reasonable mechanism for producing the isotope - release conditions which are presupposed in the paragraph (5) wording.

   b. Four year's experience with the FQIS system have disclosed no isotope leakage.

   c. Both the aircraft and the emitter have a very high degree of mechanical integrity.

3. Paragraph VIII, Page 43. Deletion of the last four sentences of the first paragraph is requested, on the same basis as the request for deletion of paragraph (5) on page 36. That is, there is no reasonable cause for release of the isotope from its four levels of encapsulation and containment (fused ceramic matrix, stainless-steel encapsulation, isolation by sleeve inside of emitter casting, and containment within sealed emitter unit).

EXHBIT A SEPT. 1984

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I. Description of Product and Intended Use. (See Appendix A for Drawings)

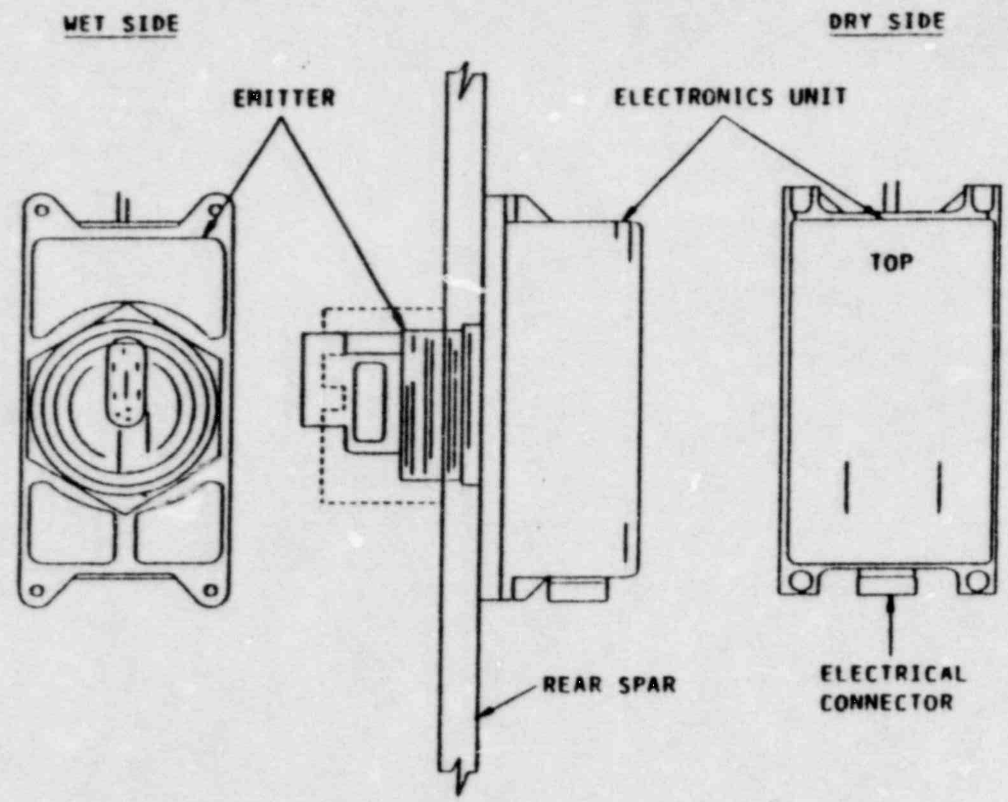
* The LG 1136AA01, WG1136 fuel densitometer is a two-piece component of an aircraft fuel gauging system, consisting of an emitter package containing the radioactive source and an electronics package. The emitter package is permanently installed through the wall of the fuel tank and contains lugs for mounting the external electronics package. The emitter casting is arranged to have two different fuel path lengths interfering with the stream of gamma rays (at 60 kev) emitted by the Americium 241 source. Only the gamma rays are used, so the source is sealed with no alpha particles accessible to the handler.

Two proportional counter gamma detectors in the electronics package process the charge pulses, utilizing a low level discriminator to block noise pulses. The pulse trains are transmitted to a microprocessor which is used to manipulate the pulse trains to obtain an accurate measure of density. The ratio method is used so that common-mode effects such as high voltage changes, source decay, etc., cancel out, leaving only the true ratio of counts as the determining quantity.

The drawing shows the most important mechanical features, along with relative position in the fuel tank. The need for a separate fuel density gauge in future commercial aircraft is emphasized by the errors of up to 4% now being seen by standard fuel gauging systems because of recent changes in fuel characteristics. The airplanes must carry extra fuel to provide an adequate safety margin. Virtually all aircraft fuel gauges now in use utilize a capacitance type sensor and depend on a linear relationship between dielectric constant and density, a deteriorating relationship with new fuels.

*Indicates September 1984 Revision

New Drawing Sept. 1984



FQIS DENSITOMETER ASSEMBLY
628-41-003-018

APR 7 1982 IGS

A capacitance type sensing device is used to measure volume and a compensator sensor, always fully wetted, provides dielectric constant (and therefore density) information. The output from the electronics represents fuel mass as long as the dielectric constant-density relationship holds.

In the new system, fuel volume is easily measured with capacitance sensors by using the dielectric constant of the fuel, determined by a compensator, to correct the capacitance reading completely, leaving only wetted sensing length (related to volume) as the output. A microprocessor then multiplies true volume by the predetermined density value (from the densitometer) to obtain true mass of fuel in the tanks within a small tolerance. This mass is then displayed to the flight crew in either kilograms or pounds.

Americium 241 was selected because it was the only source which had sufficient yield of gamma rays between 50 and 100 kev and a long half-life (458 years) to meet the application constraints. Higher energy x-rays or gamma rays would not be attenuated enough in the few centimeters of fuel in the path length, while lower energy x-rays or gamma rays would be attenuated by the casting itself and in particular by heavy element contaminants such as sulfur found in jet fuels. This unwanted attenuation by other than hydrocarbons produces errors in measuring density. The 60 kev photons from ^{241}Am are exactly right for the application. (The 27 kev photons also present in Am 241 are attenuated by the source capsule itself plus the aluminum in the casting).

The source activity level, 2 millicuries, was carefully selected after extensive sensitivity testing using a laboratory model densitometer. Accuracy is limited by the total number of detected events (counts) and to achieve a reasonable response time for this accuracy during aircraft refueling,

2 mCi source activity is required.

II. A. Type and Quantity of By-Product Material

The Honeywell Fuel Quality Indicating System emitter package contains a ^{241}Am source with nominal activity of 2.0 mCi. The sources will be obtained from Amersham Corp. (Model AMC63) 2636 S. Clearbrook Drive, Arlington Heights, Illinois 60005.

B. Chemical and Physical Form

^{241}Am is incorporated as a constituent of a ceramic (glass) matrix which is firmly bonded by high temperature firing to a metallic back shielded insert. This insert is further contained in a welded stainless steel capsule which is sealed by Argon arc welding (See Appendix B).

C. Prototype tests show this type source to be essentially insoluble in fuel and 0.1 N HCl (See Appendix B).

III. Construction and Design (See Appendix A for Drawings)

A. Handling and Use

Reference to the drawings shows the design details affecting device safety. The emitter package (WG1136) contains the source in a cavity which is cast as part of an aluminum investment casting. The Americium 241 sealed source is encapsulated in stainless steel and is staked into a copper collimator which in turn is staked in place in the aluminum casting assuring mechanical stability within the cavity. The minimum thickness of the casting is .04 inches directly under the collimator/source assembly.

*

An aluminum plate holding a fuel sensitive switch assembly extends approximately half way over the radioactive source capsule, collimator assembly, and is secured with a self-locking screw as shown in the sketch. This plate would retain a source if for any reason it should become loose in the assembly.

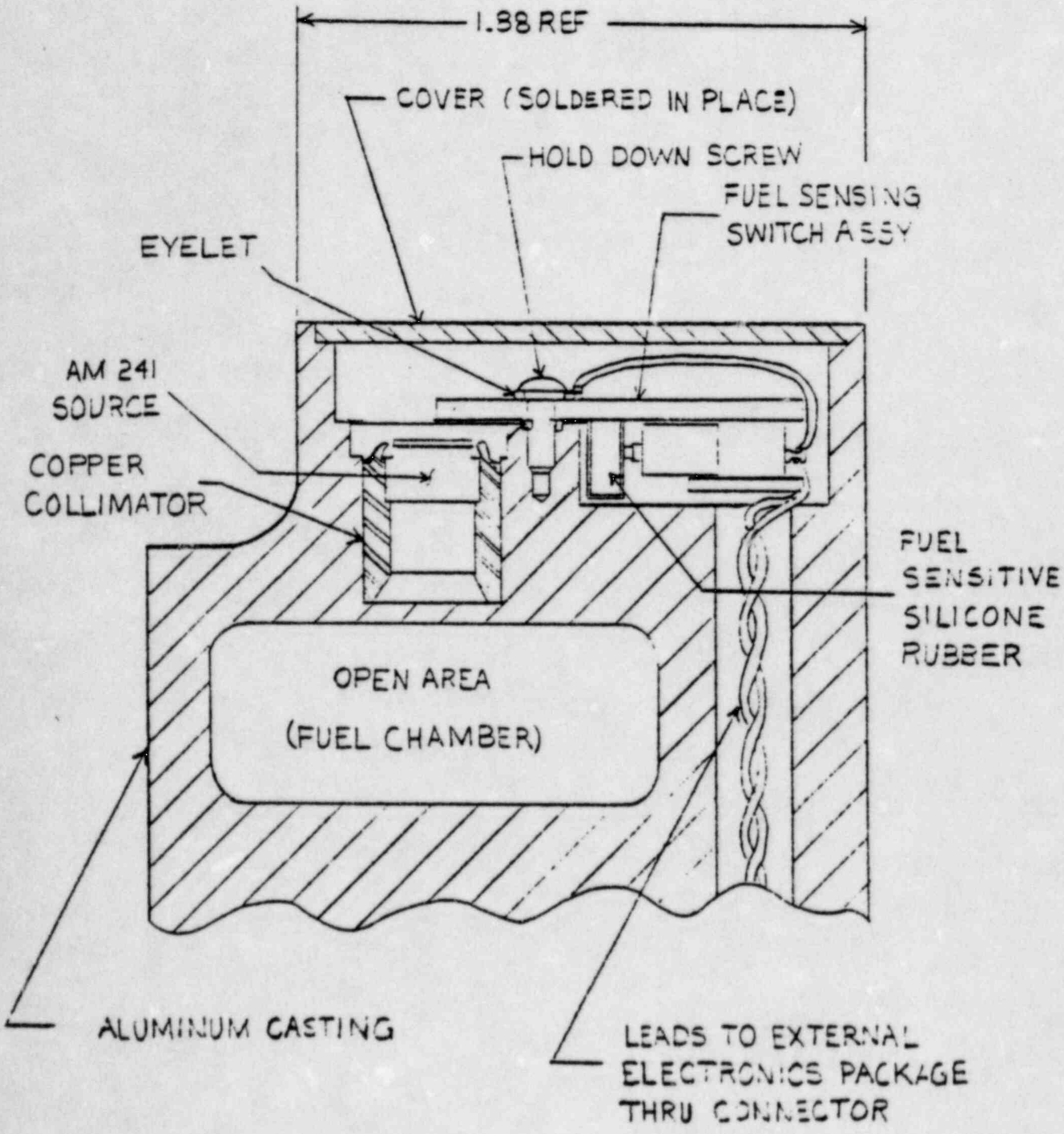
The cavity itself is sealed in two ways. The opening above the printed wiring board is sealed by a plated copper cover which is soldered in place, providing an air tight, fuel tight seal. The bored hole which carries lead wires to an interface connector is filled with stable epoxy, preventing moisture from entering the cavity and providing a semi-hermetic seal for the cavity.

There are no known or expected means for the source or even loose radioactive material to escape from the cavity, short of a catastrophic accident which would break the cavity. Prototype tests (Appendix B) produced no visible damage or loss of source capsule integrity under extreme conditions. Shock and vibration tests produced no observable damage to source containment.

The gamma activity levels outside the cavity, documented in the next section, are low enough to ensure the safety of even untrained persons coming in contact. A standard "Caution-Radioactive Materials" sign with Logo are cast into the part to warn unauthorized persons to be cautious.

New Page Number Sept. 1984
Revised January, 1981

SOURCE ASSEMBLY



B. Degree of Access to the Source Under Normal Use

The source is completely sealed in its own capsule (qualified to ANSI requirements) and is additionally completely sealed again into the device during manufacture of the emitter package. The source does emit gamma radiation at low levels (60 kev) but as shown in the next section, the dosage is low enough to prevent harm to the handlers.

Once the emitter package is installed in the aircraft fuel tank, the source is almost inaccessible. To get near the source cavity, a small hatch must be opened in the bottom of the tank after draining and purging the fuel tank. This hatch is entered by specially trained aircraft technicians only, and only when absolutely required. The caution sign and logo are visible from inside the tank as a further precaution.

C. Expected Useful Life

The useful life of the emitter package is the same as that of the aircraft. The specifications for the 757/767 Boeing airplane where the device will be used state that the useful life is 20 years. If the aircraft life is extended, Honeywell will recommend checking or possibly replacing the emitter package at that time, based on experience gained. It is highly likely that the useful life is much longer than the required 20 years, based on the results of the prototype tests. No maintenance of the emitter package is anticipated for these devices.

IV. External Exposure Rates

A. The exposure rates at all accessible surfaces of the Honeywell densitometer unit for the Fuel Quantity Indicating System were measured using a Precision Instruments 111B scintillometer. The scintillometer was calibrated with a ^{241}Am source with an effective activity of 1.6 mCi. The source is nominally 2 mCi, however, encapsulation reduces the gamma emission rate by 20%.

Exposure rates at 5 cm and 25 cm from accessible surfaces of the units were measured using the same system.

The exposure rate was calculated for one surface which, while not accessible for measurement could be a point of exposure to the fingers of a worker installing the units.

These exposure rates are shown in Table 1 and Figures 1-3.

The maximum exposure rate measured for any accessible surface of the unit was 0.9 mR/h. The maximum measured exposure rate at 25 cm was 0.1 mR/h. Dose calculations are based on these values.

Calculated exposure rate:

Thickness of Al - 0.1 cm

Distance from source to surface - 1.0 cm

μ/ρ (Al) - 0.28 cm^2/g

ρ (Al) - 2.7 g/cm^3

$$I = I_o E^{-\mu/\rho \times \rho}$$

$$I_o = (1.6 \text{ mCi})(4.9 \text{ mR/h-mCi at 5 cm})^* \left(\frac{5 \text{ cm}}{1 \text{ cm}}\right)^2 = 200 \text{ mR/h}$$

$$I = 200 \text{ mR/h } e^{-(0.28)(2.7)(0.1)} = 180 \text{ mR/h}$$

$$I = 180 \text{ mR/h}/60,/\text{h} = 3.0 \text{ mR/m}$$

*Exposure rate = Φ (energy fluence) x μ/ρ (mass absorption coefficient)

$$\text{Energy fluence} = \frac{1.0 \text{ mCi} \times 2.2 \times 10^9 \text{ d/m-mCi} \times 0.36\ \gamma/\text{d} \times 60 \text{ KeV}/\gamma \times 60 \text{ m/h}}{4\pi(5\text{cm})^2 \times 6.24 \times 10^8 \text{ KeV/erg} \times 86.9 \text{ erg/g-R}}$$

$$= 1.69 \times 10^{-1} \text{ R-g/h-cm}^2$$

μ/ρ for air - 60 KeV = 0.0292 cm^2/g (1970 edition, Radiological Health Handbook

$$\text{Exposure rate} = (1.69 \times 10^{-1} \text{ R-g/h-cm}^2\text{-mCi})\ (0.0292 \text{ cm}^2/\text{g})$$

$$= 4.93 \times 10^{-3} \text{ R/h-mCi} = 4.93 \text{ mR/h-mCi at 5 cm}$$

TABLE 1

External Radiation Levels

Exposure Rate (mR/h)

	surface	5 cm	25 cm
Circumference of fuel chamber	0.08	0.04	Less than 2 x background
	0.11		
	0.10	0.08	
	0.13		
	0.06	0.04	
	0.10		
	0.10	0.07	
	0.13		
Average	0.10	0.06	
Surface Capsule area	0.08	0.03	
	0.19	0.07	
		0.02	
	0.13	0.11	
	0.19		
	0.15		
	0.06	0.02	
In Beam (through empty fuel chambers)	0.85	0.64	0.10 0.05
	0.65	0.53	0.09 0.07
Directly adjacent to source (calculated value)	180		

FIGURE 1 Page 10

EXTERNAL RADIATION LEVELS (MR/hr)

SURFACE OF UNIT WITH COLLIMATOR REMOVED

New Sketch
SEPT 1984

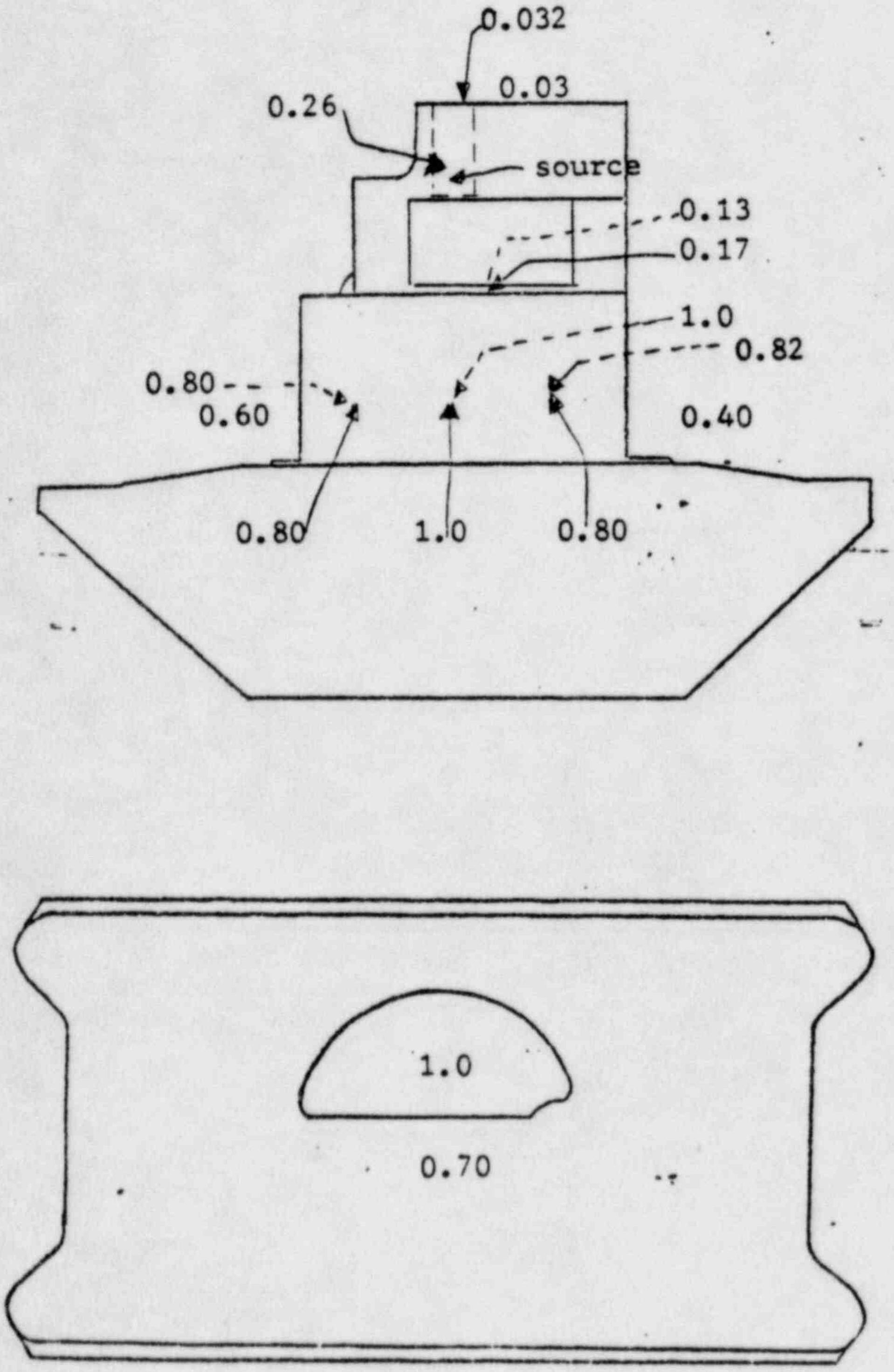
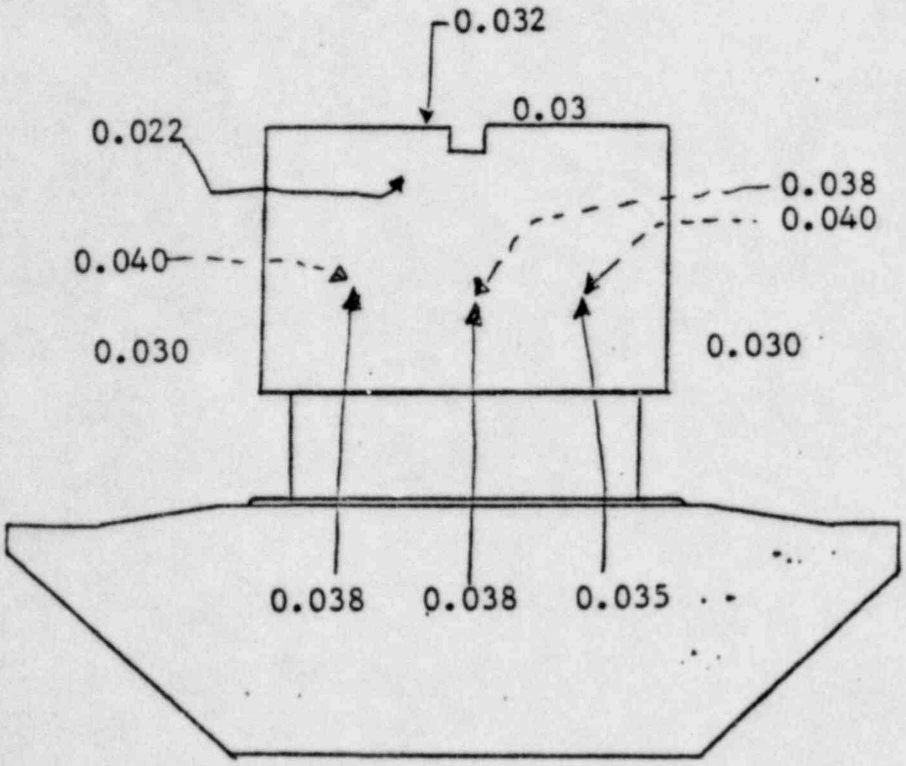


FIGURE 1A Page 10A

EXTERNAL RADIATION LEVELS (MR/hr)

SURFACE OF UNIT WITH COLLIMATOR SLEEVE

New Sketch
SEPT 1984



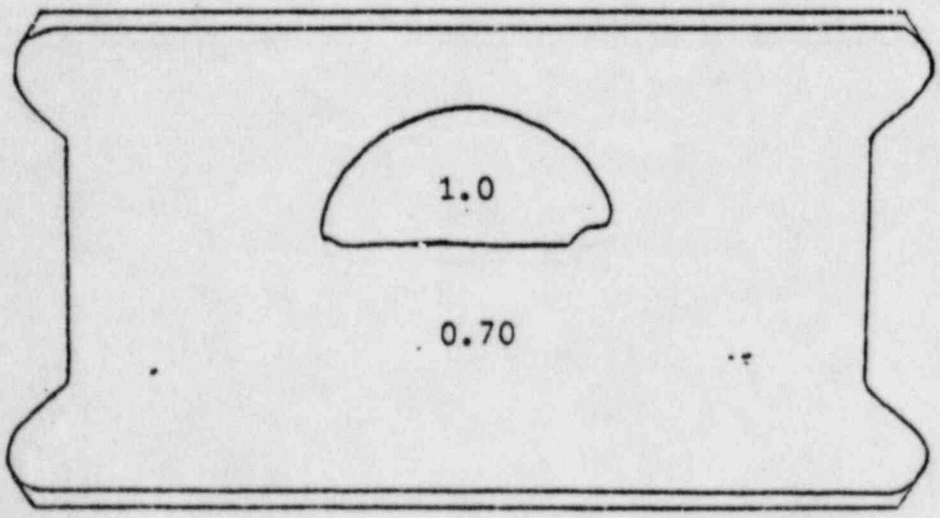
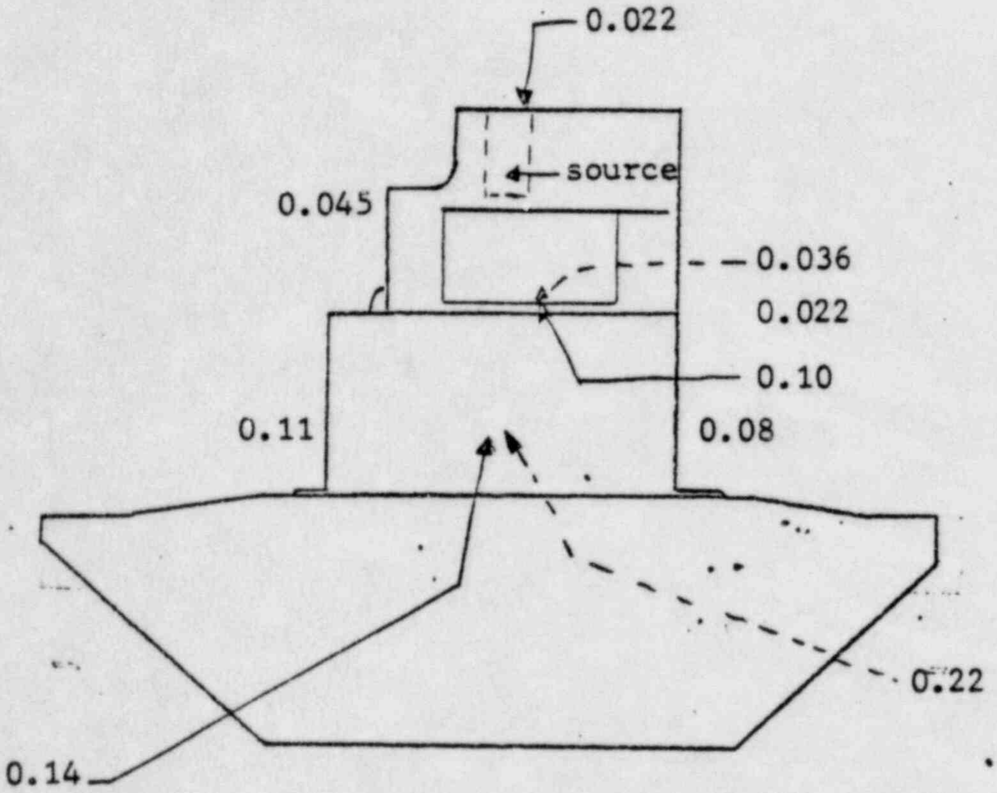


FIGURE 2

EXTERNAL RADIATION LEVELS (MR/h)

5 cm FROM UNIT WITH COLLIMATOR REMOVED

New Sketch
SEPT 1984



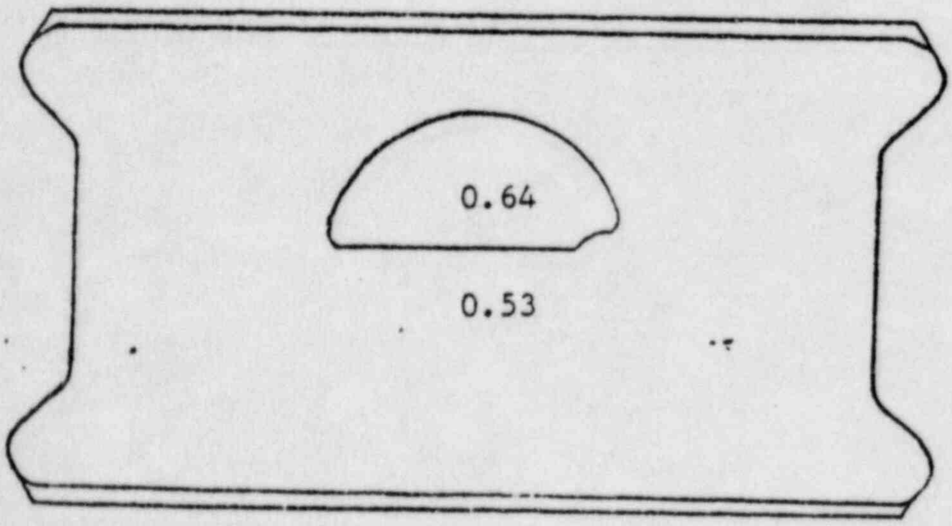
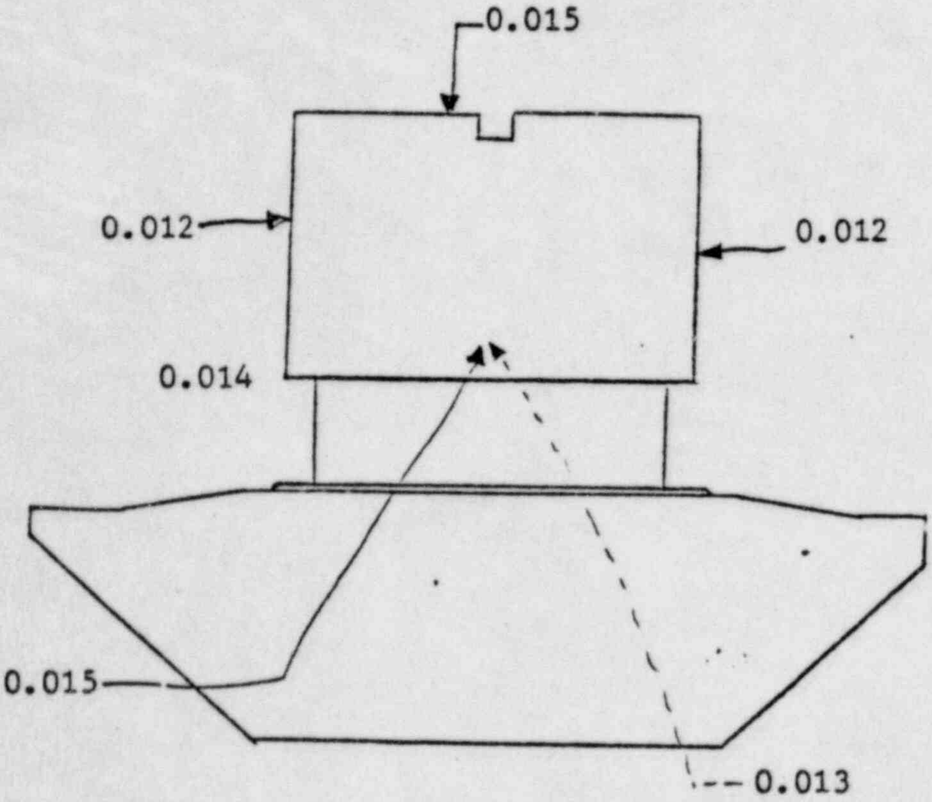


FIGURE 2A

EXTERNAL RADIATION LEVELS (MR/h)

5 cm FROM UNIT WITH COLLIMATER

New Sketch
SEPT 1984



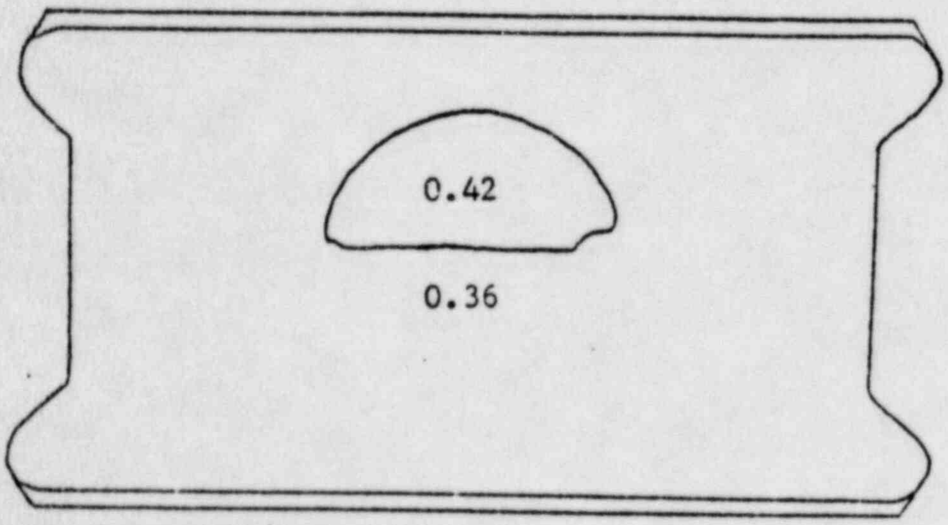
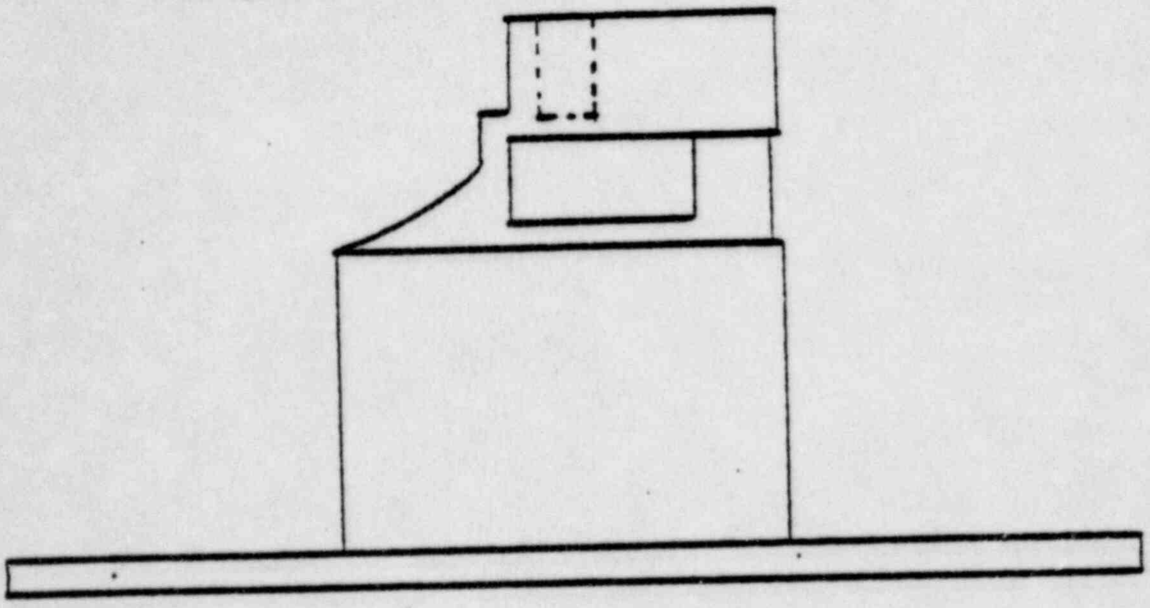


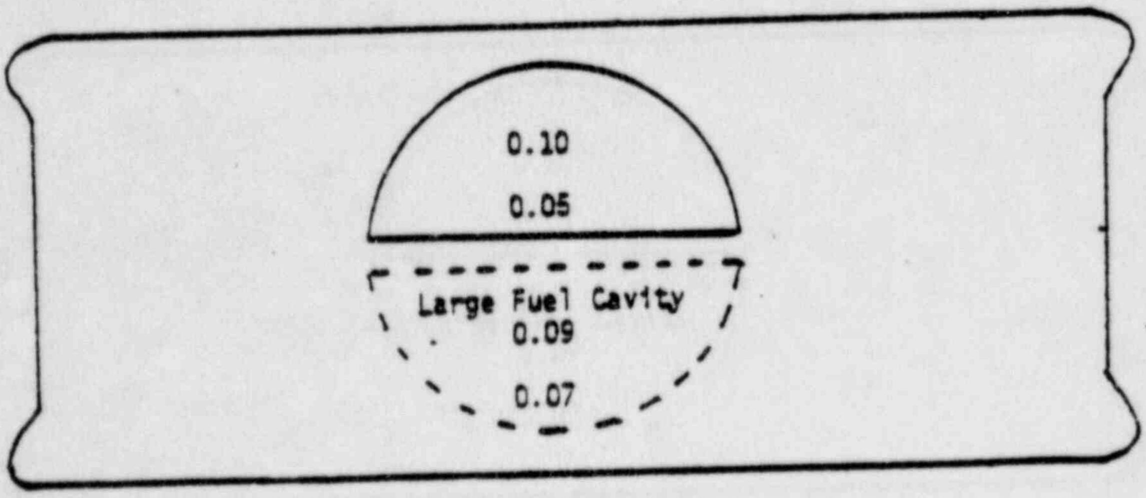
FIGURE 3

External Radiation Levels (mR/h)

25 cm from unit

All readings from sides of device were less than twice background (0.007 mR/h)





B. Calculated Exposure Rate from Packaged Unit

(Minimum package size* = 15 cm x 17 cm x 24 cm)

1. Exposure rate at surface of packing box

   Maximum measured exposure rate at surface of densitometer unit - 0.9 mR/h

   Distance from source to surface - 7 cm

   Surface of packing box 3 cm from densitometer surface (assume no effective shielding by packing material)

   Exposure rate at surface of box:

   $(0.9 \text{ mR/h}) \left(\frac{7 \text{ cm}}{10 \text{ cm}}\right)^2 = 0.5 \text{ mR/h}$

2. Maximum exposure rate at 25 cm from packing box:

   Measured exposure rate at 25 cm from surface of densitometer - 0.10 mR/h

   Exposure rate at 25 cm from packing box:

   $(0.10 \text{ mR/h}) \left(\frac{25 + 7 \text{ cm}}{3 + 25 + 7 \text{ cm}}\right)^2 = 0.08 \text{ mR/h}$

3. Exposure rate at 1 m from single packing box:

   $(0.10 \text{ mR/h}) \left(\frac{25 + 7 \text{ cm}}{100 + 3 + 7 \text{ cm}}\right)^2 = 0.008 \text{ mR/h}$

4. Exposure rate at 1 m from stacked array of 100 packing boxes:

   The contribution from each of the 100 packing boxes was calculated based on inverse square law (neglecting any shielding value of packing).

   Total maximum exposure rate at 1 m - 0.6 mR/h

*Package size may be increased, reducing exposure rates at package surface.

V. Prototype Testing

Prototype testing on the ^{241}Am encapsulated source and the source assembly was carried out at Amersham Corp. and at Honeywell. The procedures and results of these tests are documented in Appendix B.

A. Accelerated aging test.

An encapsulated source was exposed to a 1% SO_2 atmosphere for 10 days then to a 1% H_2S atmosphere for 10 days. The source was wiped for contamination and visually inspected for damage. The maximum activity wiped from the source after each corrosion test was 0.25 nCi. No visual damage to source was noted.

B. Fire test.

The source was installed into the source holder portion of the FQIS emitter package. The unit was placed in a silica crucible and heated to 1200 C during a two hour period then left at that temperature for one hour. The unit was solidified into a solid mass with the source not exposed. The total activity released during this test was less than 10 nCi. A wipe test of the crucible indicated 8.3 nCi; the crucible lid, 0.23 nCi and the solid aluminum mass, 0.65 nCi.

C. Fuel leach test.

The encapsulated source was immersed in 300 ml commercial jet fuel and maintained at a temperature of 57 C for 17 days. A sample of the fuel was analyzed for ^{241}Am contamination and the source wiped for removeable contamination. The wipe and a 5 ml aliquot of the fuel were counted in a single channel NaI well type detection system. No activity above background was detected on either the wipe or an aliquot of the fuel system. Minimum detectable activity level in fuel

$$= 7 \times 10^1 \text{ pCi} \times \frac{300 \text{ ml}}{5 \text{ ml}}$$

$$= 4 \text{ nCi}$$

Efficiency of the counting system = 0.025 c/

Fraction of gamma/dis. - 0.36

Count time - 10 m

Background - 1 c/m

Lower limit of detection = $\frac{4.66 \sigma_{R_h}*}{(E)(2.22)}$

$(0.36) = \frac{4.66 \sqrt{\frac{1}{10}}}{(0.025)(2.22)} = 7 \times 10^1$ pCi

D. Acid leach test.

A source was immersed in 0.1 N HCl at a temperature of 38 C for 24 hours to simulate digestive tract conditions. The source was wiped and the hydrochloric acid was evaporated to dryness. The wipe and the hydrochloric acid residue were counted in a NaI well-type detection system. LLD - 7×10^1 pCi. No significant activity was detected.

E. Vibration test.

The source was installed in the emitter package and subjected to a total of fifteen hours of random vibration five hours along each of three axes. A wipe test was performed after five hour segment. The source was visually inspected for damage. The wipes were counted in the gamma scintillator system with a lower limit of detection of 7×10^1 pCi.

No significant activity was detected on two of the wipes. The third wipe contained 20 pCi (not statistically significant) activity. No visual damage was noted.

F. Shock test.

The source was installed in an emitter package mock-up and subjected to 40 drops from a height of eight feet onto a concrete surface.

*USNRC Reg Guide 4.14

The emitter package was monitored by alpha detector during and after the drop test. The source was removed from the emitter package mock-up for inspection after 20 drops and after 40 drops. The wipes were counted using a gamma scintillation system with a lower limit of detection of 7×10^1 pCi. No significant activity was detected on either wipe. No visual damage to the source was noted.

VI. A. Estimated External Radiation Dose

1. Normal conditions.

During normal use of the device there is no possibility of radiation exposure or access to the source. The FQIS densitometer source assembly is mounted inside the fuel tank. The only radiation exposure under non-accident conditions occurs during manufacturing, packaging, shipping, initial installation and removal of the device. (The dose to Honeywell personnel in manufacturing and packaging the densitometer unit is covered by the manufacturing license application, Appendix D).

a. Dose to worker handling packaged units in storage at
* Honeywell or general licensee.

1) Whole body dose from handling packaged units.

Calculated maximum exposure at 25 cm from a single packaged unit - 0.08 mR/h

Assume worker handles 100 packaged units per month a total of 15 minutes per unit (See Table 2).

Maximum quarterly radiation does:

0.08 mR/h x 0.93 rem/R x 100 units/month x 0.25 b/unit x 3 months/qtr. = 6 mrem/quarter

2) Whole body dose from stacked array of packaged units

Exposure rate at 1 m from stacked array of 100 units - 0.6 mR/h

Assume worker spends 25 hours/month at 1 m from stacked array.

Maximum quarterly radiation does:

0.6 mR/h x 0.93 rem/R x 25 h/month x 3 months/quarter = 4×10^{1} mrem/quarter.

It is highly unlikely that a warehouse worker would spend 25 hours per month handling packaged densitometer units.

3) Dose to hands from andling packaged units.

Calculated exposure rate at surface of packaged unit - 0.5 mR/h.

Assume worker handles 100 package units per month a total of 15 minutes per package.

Maximum quarterly radiation dose:

0.5 mR/h x 0.93 rem/R x 100 units/month x 0.25 h/unit x 3 months/quarter = 3×10^{1} mr

It is unlikely that a worker's hands would be in direct contact with each packaged unit handled for fifteen minutes.

TABLE 2

Time Schedule

Personnel Handling of Source Assembly

		Honeywell Storage Boeing	Service Center
1.	Receiving and Unpacking	15 minutes	15 minutes
2.	Installation	30 minutes	30 minutes
3.	Removal	15 minutes	15 minutes
4.	Packing for shipment	15 minutes	15 minutes
	Frequency	100/month	1/month

* b. Dose to general licensee or Honeywell employee leak testing source assembly.

1) Whole body dose.

Assume individual is 25 cm from source assembly during leak test and that wipe test procedure requires less than one minute.

Maximum exposure rate at 25 cm - 0.1 mR/h

(0.1 mR/h)(I h/60 m)(100 units/mo)(1 m/unit)(3 mo/qtr)

(0.93 mrem/mR) = 0.5 mrem/quarter

2) Dose to fingers.

Maximum measured exposure rate at surface of unit = 0.9 mR/h.

Assume total wipe test procedure requires one minute per unit.

0.9 mR/h x 1 h/60 m x 1 m/unit x 100 units/mo x 3 mo/qtr x

0.93 mrem/mR = 4 mrem/quarter

3) The area directly adjacent to the source will be protected by a screen or tape until the densitometer unit is completely installed. Removal of this protective tape will be the last segment of the installation procedure. However, in the event the tape is removed prematurely during the wipe test procedure the dose to the individual's fingers would be no greater than 0.09 mrem.

Assume the individual's fingertips are in contact with the surface adjacent to the source for 2 seconds.

Calculated exposure rate - 3 mR/m

(3 mR/m)(1m/60s)(2s/unit) x 0.93 mrem/mR = 0.09 mrem

In the event the precautionary barrier is circumvented each time a wipe test is performed, the quarterly dose to the individual's fingertips would be 3×10^1 rem/quarter.

(0.09 mrem)(100 units/mo)(3 mo/qtr) = 3×10^1 mrem/qtr

This would require deliberate disregard or ignorance of safety instructions.

* c. Dose to general licensee.

1) Whole body dose.

. Maximum measured exposure rate at 25 cm - 0.1 mR/h

Assume worker is 25 cm from the unit for thirty minutes during installation and that the same individual installs 100 units per month.

Quarterly whole body radiation dose

= 0.1 mR/h x 0.5 h/unit x 100 units/mo x 3 mo/qtr x

0.93 mrem/mR = 0.014 rem/quarter

It is unlikely that any individual would receive this exposure. The unit will be shielded during part of the installation time. The average distance from the unit during installation will be greater than 25 cm.

2) Dose to hands.

Assume worker's hands are in direct contact with the densitometer unit for 30 minutes during installation and that the same individual installs 100 units per month. Maximum measured exposure rate at the surface of the unit - 0.9 mR/h.

Quarterly radiation dose to hands:

0.9 mR/h x 0.5 h/unit x 100 units/mo x 3 mo/qtr x 0.93 mrem/Mr = 126 mrem/qtr = 0.13 rem/qtr

3) Calculated dose to fingers of worker improperly installing densitometer.

The surface of the densitometer directly adjacent to the source will be protected during installation of the densitometer by a tape or screen to prevent accidental access to this area. However it is possible that a worker contrary to instructions could remove the tape for convenience in installing the unit. The worker's fingers could, if placed directly against the source holder, receive a radiation exposure rate of 3 mR/m. Assuming the worker's hands remain in this position for one minute while installing the unit and that this same worker installs 100 units per month using this technique specifically prohibited by instructions, the maximum quarterly dose to the fingertips would be 0.8 rem.

(3 mR/m)(1 m/unit)(100 units/mo)(3 mo/qtr)(0.93 rem/mR) = 8×10^2 mR/quarter

A worker could only receive this exposure by deliberately circumventing safety precautions.

d. Dose to worker removing densitometer source assembly for maintenance.

1) Whole body dose

Assume worker is 25 cm from the unit for 15 minutes during removal of the densitometer source assembly. It is estimated that removal of a source assembly may be required a maximum of once per month. Maximum measured exposure rate at 25 cm from densitometer source assembly - 0.1 mR/h.

Quarterly whole body radiation dose:

0.1 mR/h x 0.25 h/unit x 1 unit/mo x 3 mo/qtr x 0.93 mrem/mR = 0.07 mrem/quarter.

2) Dose to hands

Assume worker's hands are in direct contact with densitometer source assembly for 15 minutes during removal and that one such removal is required monthly. Maximum measured radiation exposure rate at surface - 0.9 mR/h

Quarterly dose to hands:

0.9 mR/h x 0.25 h/unit x 1 unit/mo x 3 mo/qtr x 0.93 mrem/mR = 0.6 mR/qtr.

3) Calculated dose to fingers of worker improperly removing densitometer.

Assume worker's hands directly in contact with the surface adjacent to the source for one minute per unit.

3 mR/m x 1 m/unit x 1 unit/mo x 3 mo/qtr x 0.93 mrem/mR = 8 mrem/qtr.

2. Accident conditions

* a. Fire in Honeywell, Boeing, or Airline Storage Area.

1) The gamma radiation dose to Honeywell or Boeing employees in the event of fire in the storage or

installation ar as would be no greater than the gamma dose under normal conditions. Employees would be evacuated from the building and would have no contact with the units. If fire in an area not associated with the source assemblies required immediate removal of the packaged units the dose to employees involved in this activity would be minimal. Assuming all units in Honey-
* well or Boeing storage (500 units) were removed in a fifteen minute period the dose to workers would be approximately 0.2 mrem to hands, less than 0.2 mrem whole
* body. Airline inventory would probably not exceed 10 units, with proportional reduction in dosage.

2) Firemen fighting a fire in the storage area would be in close proximity (1 meter) to a stacked array of packaged units for only a short period of time, probably less than fifteen minutes. The maximum whole body radiation dose would be 0.2 mrem.

3) A fire test on the source assembly showed that under extreme heat conditions (1200 C) the unit melted into a solid mass with the source not exposed (See Prototype Tests, Appendix B). This would indicate that the solidified units would pose no significant hazard to any individual involved in a clean-up after a fire. The mass of aluminum would probably shield the source so that the exposure rates would be minimal. The solidified mass would also preclude the possibility of an individual accidentally removing or picking up a source.

* b. Honeywell or general licensee Service representative responding to Fuel Sensor "Failure" indication.

In lieu of 6 month leak testing of the installed densitometer device, a continuous fuel leakage indicator is used (Section VIII and Appendix C). In the event of a failure * indication Honeywell or general licensee personnel will remove the densitometer unit for repair or replacement. The * gamma radiation dose to these workers, assuming no more than one such incident per month* would be no greater than that calculated in this section, Part A.1.d.

Whole body dose - 0.07 mrem/qtr

Dose to hands - 0.6 mrem/qtr

Even in the event that the source had disintegrated and contaminated the inside of the fuel tank the external gamma dose would not be significant.

*Reliability of source package is such that no more than six incidents per year of any type requiring removal are anticipated.

B. Internal Dose Commitment

1. Normal conditions. The source is completely contained within the densitometer source assembly. Under normal conditions there is no access to the source. In addition wipe tests on the source itself under extreme conditions indicate a very high degree of source integrity. Removable contamination is well below the limit of 5 nCi (Prototype Tests, Appendix B). Therefore it is highly improbable that internal radiation dose commitment from these units would be significant under normal conditions.

2. Accident conditions.

a. Ingestion.

Acid leach tests by simulating digestive tract conditions performed by Honeywell on the sealed source indicated no significant loss of activity to a 0.1 N HCl solution at 38° C for 24 hours. The minimum detectable activity for the system used in the prototype test was 7×10^1 pCi.

Under "worst case" conditions the dose commitment to an individual ingesting a single 2 mCi source would be as noted in Table 3.

TABLE 3

LLD Activity Lost in Acid (μCi)	Organ of Reference	Committed dose equivalent per intake of unit activity (Sv/Bq)[1]	Committed dose equivalent per intake of unit activity (rem/μCi)	Committed dose equivalent (rem)
7×10^{-5}	Gonads	1.4×10^{-7}	5.2×10^{-1}	4×10^{-5}
	Red marrow	8.4×10^{-7}	3.1	2×10^{-4}
	Bone surface	1.1×10^{-5}	4.1×10^{1}	3×10^{-3}
	Liver	2.3×10^{-6}	8.5	6×10^{-4}

(7×10^{-5} Ci $\times$ 2.3×10^{-6} Sv/Gq $\times$ 3.7×10^{6} rem/ Ci/Sv/Bq = 6×10^{-4} rem)

[1] ICRP Publication 30, Supplement to Part 1, Limits for Intakes of Radionuclides by Workers, Pergamon Press (1979, p. 456).

Sample calculation:

Dose to liver by ingestion:

Dose (rem) = 7×10^{-5} μCi x 2.2×10^{6} d/m-μCi x 5.7 MeV/d

$$\times 20 \text{ rem/rad}^{(a)} \times \frac{5 \times 10^{-4\ (b)} \times 0.45^{\ (c)}}{1.8 \times 10^{3} \text{ g}^{(d)}} \times \frac{1.6 \times 10^{-6} \text{ erg/MeV}}{10^{2} \text{ erg/g-rad}}$$

$$\times 5.26 \times 10^{5} \text{ m/y} \int_{0}^{50} e^{-\lambda t} dt$$

$\lambda = 0.693/T_{1/2}$ $T_{1/2} = 40 \text{ y}^{(e)}$ $T = 50$ y

$$\text{Dose (rem)} = 1.8 \times 10^{-5} \text{ rem/y} \left[\frac{(1-e^{-\lambda t})}{\lambda}\right] =$$

1.8×10^{-5} rem/y (33.5 y) = 6×10^{-4} rem

(a) Quality factor for alpha particles (ICRP 26)

(b) Fraction Am absorbed from GI tract (ICRP 30)

(c) Fraction of absorbed Am to Liver (ICRP 30)

(d) Mass of liver (ICRP 23)

(e) ^{241}Am half life in liver (ICRP 30)

The hydrochloric acid leach test was performed on the encapsulated source. The source was subjected to other severe prototype tests. In no case was the source capsule breached. The maximum removable activity found to result from any prototype test (other than the fire test) done at Honeywell was less than 20 pCi, (LLD-70 pCi). A corrosion test performed by Amersham resulted in a maximum removable activity of 250 pCi. If it is assumed that this entire amount was ingested and soluble the dose commitment to any organ would not exceed 0.010 rem (Dose commitment to bone surface).

$250 \text{ pCi} \times 10^{-6} \mu\text{Ci/pCi} \times 4 \times 10^{1} \text{ rem}/\mu\text{Ci} = 0.010 \text{ rem}$

The fire test indicated that under accidental (fire or explosion) conditions involving a single aircraft less than 10 nCi would be released per source. Assuming three source assemblies per aircraft a total of 30 nCi could be lost. The probability of such an incident occurring is $<2 \times 10^{-6}$ per flight. Under such conditions it is unlikely that any activity would escape from the aircraft to the environment. Therefore the probability of any individual ingesting ^{241}Am from such an incident is very low.

Ingestion of the entire 30 nCi would result in a dose commitment of 1 rem to the bone surface assuming complete solubility of the ^{241}Am released.

It is highly improbable that any condition could exist under which an individual could receive a significant dose

commitment from ingestion. Even under extreme accident conditions the limits specified in Column IV of the Table in 10CFR 32.24 would not be exceeded.

b. Inhalation.

TABLE 4 (1)

	Committed Dose Equivalent Per Intake of Unit Activity	
Organ of Reference	(Sv/Bq)	(rem/ Ci)
Gonads	$3.2x10^{-5}$	$1.2x10^{2}$
Red Marrow	$2.0x10^{-4}$	$7.4x10^{2}$
Bone Surface	$2.5x10^{-3}$	$9.3x10^{3}$
Liver	$5.5x10^{-4}$	$2.0x10^{3}$
Lung (calculated value)	$1.8x10^{-5}$	$6.7x10^{1}$

Conversion factor - $3.7x10^{6}$ (Sv/Bq) = rem/μCi

(1) ICRP Publication 30, p. 456.

Sample calculation of Committed Dose Equivalent Per Intake of Unit Activity.

Liver:

$$\text{Dose (rem/}\mu\text{Ci)} = 1.0\mu\text{Ci} \times (0.12)^{(a)}(0.45)^{(b)}\ 2.22 \times 10^{6}\text{d/m-}\mu\text{Ci} \times$$

$$5.7\ \text{MeV/d} \times \frac{1.6 \times 10^{-6}\ \text{erg/MeV}}{1.8 \times 10^{3}\ \text{g}} \times 10^{-2}\ \text{erg/g-rad} \times 20\ \text{rem/rad}$$

$$\times\ 5.26 \times 10^{5}\ \text{m/y} \int_{0}^{50} e^{-\lambda t}dt$$

$t = 50\ y$ $\qquad\qquad$ $\lambda = 0.693/40\ y$

$$\text{Dose (rem/ Ci)} = 6.4 \times 10^{1}\ \text{rem/year}\quad (1-e^{-\lambda t})/\lambda$$

$$= 6.4 \times 10^{1}\ \text{rem/year (33.5 y)} = 2.1 \times 10^{3}\ \text{rem/}\mu\text{Ci}$$

(a) Fraction from lung to body fluids (ICRP 30)

(b) Fraction from body fluids to liver (ICRP 30)

Committed dose equivalent to lung from alpha emitter.

$H_{50,T} = 1.6 \times 10^{-10} \Sigma U_T \; \Sigma SEE (T \leftarrow T)_i$ (1)

Where: $H_{50,T}$ = committed dose equivalent to target organ (lung)

ΣU_T = sum of transformations in the target organ (lung)

$\Sigma SEE (T \leftarrow T)_i$ = specific effective energy absorbed in the target organ from radiation of type i emitted in the target organ.

$$\Sigma SEE (T \leftarrow T) = \frac{Y_i E_i AF(T \leftarrow T)_i Q_i}{M_T} \text{ MeV/g}$$

Y = yield of radiation of type i per transformation - 1.0

E_i = energy in MeV = 5.7 MeV

AF(T ← T) = fraction of energy absorbed in target organ - 1.0

Q_i = Quality factor = 20 (for alphas)

M_T = mass of target organ = 1000 g

(1) ICRP 30, p. 28.

$$H_{50,\ lung} = \frac{(1.6 \times 10^{-10})(5.7\ MeV)(1.0)(1.0)(20)}{1000\ g} \Sigma U_{lung}$$

$$= 1.8 \times 10^{-11} \Sigma U_{lung}\ Sv/Bq$$

$$\Sigma U_{lung} = U_{T-B} + U_P + U_L$$

U_{T-B} = transformations in the tracheo-bronchial region

U_P = transformations in the pulmonary region

U_L = transformations in the pulmonary lymphatic system

$$U_{T-B} = D_{T-B}\left[\frac{F_c}{\lambda_c + \lambda_R} + \frac{F_d}{\lambda_d + \lambda_R}\right] + \frac{D_P}{\lambda_d + \lambda_R}\left[\frac{\lambda_f F_f}{\lambda_f + \lambda_R} + \frac{\lambda_g F_g}{\lambda_g + \lambda_R}\right]$$

D_{T-B} = fractional deposition in the tracheo-bronchial region - 0.08

D_P = fractional deposition in the pulmonary region - 0.25

λ_R = radioactive decay constant

λ_c, λ_d, λ_f, λ_g = biological clearance rates

F_c, F_d, F_f, F_g = fraction of material associated with various compartments of the lung model

$$\lambda_R = \frac{0.693}{458\ y \times 3.15 \times 10^7\ s/y} = 4.8 \times 10^{-11}\ s^{-1}$$

(2) $\lambda_c = 0.693/(86{,}400\ s/d)\ (0.01\ d) = 8.0 \times 10^{-4}\ s^{-1}$

$\lambda_d = 0.693/(86{,}400\ s/d)\ (0.2\ d) = 4.0 \times 10^{-5}\ s^{-1}$

$\lambda_f = 0.693/(86{,}400\ s/d)\ (1.0\ d) = 8 \times 10^{-6}\ s^{-1}$

$\lambda_g = 0.693/(86{,}400\ s/d)\ (50\ d) = 1.6 \times 10^{-7}\ s^{-1}$

(2) All values taken from ICRP 30, p. 25.

λ_R is very small compared to λ_c, λ_d, λ_f and λ_g therefore can be dropped from the equation.

$F_c = 0.5$

$F_d = 0.5$

$F_f = 0.4$

$F_g = 0.4$

$$U_{T-B} = 0.08 \left[\frac{0.5}{8.0\times10^{-4}} + \frac{0.5}{4.0\times10^{-5}} \right] + \frac{0.25}{4.0\times10^{-5}} \left[0.4 + 0.4 \right]$$

$$U_{T-B} = 5.1\times10^3$$

$$U_P = D_P \left[\frac{F_e}{\lambda_e + \lambda_R} + \frac{F_f}{\lambda_f + \lambda_R} + \frac{F_g}{\lambda_g + \lambda_R} + \frac{F_h}{\lambda_h + \lambda_R} \cdot \lambda_R \right]$$

F_e, F_f, F_g, F_h - fraction of material associated with various compartments

λ_e, λ_f, λ_g, λ_h - biological clearance rates

λ_R - radioactive decay constant

λ_R is small compared to λ_e, λ_f, λ_g and λ_h, therefore drops out of the equation.

$\lambda = 0.693/(86{,}400 \text{ s/d})(T_{1/2}(d)$

$$U_P = (D_P)\left(\frac{86{,}400}{0.693}\right) (F_e T_e + F_f T_f + F_g T_g + F_h T_h)$$

$F_e = 0.15$	$T_e = 50$ d
$F_f = 0.4$	$T_f = 1.0$ d
$F_g = 0.4$	$T_g = 50$ d
$F_h = 0.05$	$T_h = 50$ d
$D_p = 0.25$	

$$U_p = (0.25(1.25\times10^5)(7.5 + 0.4 + 20 + 2.5) = 9.5 \times 10^5$$

$$U_L = \frac{D_p\, F_h\, \lambda_h\, F_i}{(\lambda_h + \lambda_R)(\lambda_i + \lambda_R)} \qquad F_i = 1.0$$

$$\lambda_i = 0.693/(86,400)(50)$$

$$U_L = \frac{(0.25)(0.05)(0.693/86,400)(50)\quad(1.0)}{[0.693/(86,400)(50)]\ [0.693/(86,400)(50)]} = 7.8 \times 10^4$$

$$\Sigma\, U_{lung} = 5.1 \times 10^3 + 9.5 \times 10^5 + 7.8 \times 10^4 = 1.0 \times 10^6$$

Committed dose equivalent to lung = $(1.8 \times 10^{-11})(1.0 \times 10^6)$

$= 1.8 \times 10^{-5}$ Sv/Bq

$$(1.8 \times 10^{-5}\ \text{Sv/Bq})\ (3.7 \times 10^6\ \frac{\text{rem}/\mu\text{Ci}}{\text{Sv/Bq}}) = 6.7 \times 10^1\ \text{rem}/\mu\text{Ci}$$

Dose commitment from inhalation could occur only under conditions of fire or explosion in a closed area.

* (1) Fire in storage area.

Prototype tests on the source assembly performed by Amersham Searle showed the total loss of activity of a 2 mCi source subjected to a one hour burn test at 1200 C was 10 nCi (See Appendix B).

The maximum number of source assemblies in storage at either Boeing or Honeywell (Minneapolis) will be 500 units. If a fire occurred in either place it is unlikely that all units would burn.

However, assuming all units burned the maximum activity released would be (500 units) (10 nCi/unit) = 5 µCi.

It is highly unlikely that the entire amount of activity released would become airborne.

However, assuming uniform distribution in an area 5000 ft^2 with 10 ft ceilings the concentration would be

$1 \times 10^{-4}\ \mu Ci/ft^3$ or $3.5 \times 10^{-9}\ \mu Ci/cm^3$

If an individual, either an employee of Boeing or Honeywell or a firefighter, remained in the area for ten minutes without respiratory protection the dose commitment to various organs would be as follows:

Assume twice normal breathing rate -

Dose to gonads:

$4.2 \times 10^5 cm^3 \times 3.5 \times 10^{-9}\ \mu Ci/cm^3 \times 1.2 \times 10^2\ rem/\mu Ci = 0.18\ rem$

Dose to red marrow:

$4.2 \times 10^5 cm^3 \times 3.5 \times 10^{-9}\ \mu Ci/cm^3 \times 7.4 \times 10^2\ rem/\mu Ci = 1.1\ rem$

Dose to bone surface:

$4.2 \times 10^5 cm^3 \times 3.5 \times 10^{-9}\ Ci/cm^3 \times 9.3 \times 10^3\ rem/\ Ci = 14\ rem$

Dose to liver:

$4.2 \times 10^5 cm^3 \times 3.5 \times 10^{-9}\ Ci/cm^3 \times 2.0 \times 10^3\ rem/\ Ci = 2.9\ rem$

Dose to lung:

$4.2 \times 10^5 cm^3 \times 3 \times 10^{-9}\ Ci/cm^3 \times 6.7 \times 10^1\ rem/\ Ci = 0.11\ rem$

It is highly improbable that an individual could remain in the vicinity of a fire hot enough to cause the release of activity from the source assemblies.

In the event a fire did occur the probability of all of the activity becoming airborne is very small.

In no case does the calculated dose commitment exceed the limits set in Column IV 10CFR 32.24 for accident conditions.

* AIRLINE STORAGE ASSUMES A MAXIMUM OF 10 UNIT INVENTORY. THEREFORE, AIRLINE PERSONNEL DOSAGE WILL NOT EXCEED 2% OF BOEING OR HONEYWELL DOSAGE.

* (2) Honeywell service centers.

A maximum of five units will be stored in a locked metal * cabinet in the Honeywell service centers. In the event of fire, occupants of the area would be evacuated before the units could reach a high enough temperature to cause release of radioactivity. The dose commitment to a firefighter would be less than 1 rem. The maximum dose commitment is to bone surfaces.

Assume:

Storage area - 10000 ft^3 ($2.8 \times 10^8 cm^3$)

Firefighter stays in area 10 minutes

Volume of air breathed - $4.2 \times 10^5 cm^3$

^{241}Am activity released - 0.010 Ci x 5 units

$$\text{Dose commitment} = \frac{0.05\ \text{Ci} \times 4.2 \times 10^5 cm^3}{2.8 \times 10^8 cm^3} \times 9.3 \times 10^3\ \text{rem/ Ci} = 0.7\ \text{rem}$$

Dose commitment to all other organs is well below bone surface value.

Gonads - 0.009 rem

Red Marrow - 0.06 rem

Liver - 0.15 rem

Lung - 0.005 rem

* (3) Fire in aircraft equipped with Honeywell FQIS.

a) Dose to occupants.

The probability of an incident involving fire in the wing is less than 2×10^{-6} per flight.

Assume:

One fuel tank containing the densitometer unit burns releasing 10 nCi ^{241}Am.

The airborne contamination enters the cabin.

Volume of the cabin - $10^8 cm^3$

Occupants remain in cabin for five minutes with twice normal breathing rate.

$$\text{Dose to bone surface (rem)} = \frac{0.010\ \text{Ci}}{10^8 cm^3}$$

$$\times 2.1 \times 10^5 cm^3 \times 9.3 \times 10^3\ \text{rem/ Ci} = 0.2\ \text{rem}$$

Dose commitment to all other organs is well below the dose commitment to bone surfaces.

Gonads - 0.003 rem

Red Marrow - 0.02 rem

Liver - 0.04 rem

It is highly unlikely that the airborne ^{241}Am under such conditions would enter the cabin.

It is presumed that in the case of more than one fuel tank burning, the radiation dose commitment is of little concern.

* (4) Clean-up of fire debris.

The prototype tests indicated that the source assembly would melt into a solid mass under extreme fire conditions. The probability of any ^{241}Am becoming airborne during clean-up operations is very low. If a fire occurs wipe tests will be performed in the area to determine the extent of ^{241}Am contamination if any exists. Clean-up of the area will be conducted taking all necessary precautions to insure that the doses to clean-up workers do not exceed 10% of the quarterly dose limits set in 10CFR 20.101.

* (5) Hazard to the General Public from Accident Conditions.

Due to rapid dilution the concentration of airborne ^{241}Am outside the immediate accident area would be minimal. Therefore, there would be no radiation hazard to the general public from such an incident.

C. Hazard to General Public From Disposal of Source Assemblies.

* Source assemblies will be serviced by Honeywell or general licensee.
* Malfunctioning units will be replaced by Honeywell or general licensee personnel. All source assemblies removed from aircraft and units not used will be returned to Honeywell for eventual use or disposal. Therefore there will be no hazard to the general public from random disposal of units.

In the event a unit is disposed of to a sanitary landfill the source characteristics make it improbable that any radioactive material will be released into the environment. Prototype tests showed the stability of the source with regard to loss of activity under severe conditions and integrity of the source encapsulation.

Many years of disposal of smoke detectors containing ^{241}Am have not presented problems to the environment. The Honeywell densitometers will remain under the control of the airlines, Boeing or Honeywell during their useful life. The probability of random disposal of a unit is low.

In addition, the type of source used in the FQIS densitometer is more stable than the sources used in smoke detectors. The source is encapsulated in stainless steel and securely contained within the source assembly.

The probability of random disposal of a Honeywell FQIS densitometer source assembly is very low. The environmental hazard from such disposal is also very low.

D. Summary of Estimated Radiation Dose

1. Normal handling and installation.

a. External Gamma Radiation Dose

1) Handling packaged units for shipment

a) Whole body dose - 0.006 rem/quarter

b) Dose to hands - 0.03 rem/quarter

2) Whole body dose from stacked array of packaged units - 0.04 rem/quarter

3) Leak testing of units prior to installation

a) Whole body dose - 5×10^{-4} rem/quarter

b) Dose to hands - 4×10^{-3} rem/quarter

c) Dose to fingertips from surface adjacent to source - 0.03 rem/quarter

4) Installation of unit.

a) Whole body dose - 0.014 rem/quarter

b) Dose to hands - 0.13 rem/quarter

c) Dose to fingers from improper installation technique - 0.8 rem/quarter

5) Removal of unit for servicing

a) Whole body dose - 7×10^{-5} rem/quarter

b) Dose to hands - 6×10^{-4} rem/quarter

c) Dose to fingers from improper removal technique - 0.008 rem/quarter

b. Internal dose

Due to the fact that the source is completely contained and inaccessible there will be no significant internal dose from handling completed source assemblies during packaging, shipping or installation.

c. All of the above values* are well below the requirement stated in 10CFR 32.51 of 10% of the quarterly limit specified

*These doses were calculated using maximum measured exposure rates and time estimates. Since average exposure rates are approximately 10 percent of maximum, probable radiation doses will be less than 10 percent of those listed above.

in 10CFR 20.101 (1.25 rem/quarter, whole body; 18.75 rem/quarter, hands).

2. Accident conditions

a. External gamma dose

1) Honeywell or Boeing employees - same as for normal conditions.

2) Fireman fighting fire in storage area - 0.2 mrem

b. Internal dose commitment

1) Ingestion

a) Ingestion of a single encapsulated source

(1) Gonads - 4×10^{-5} rem

(2) Red marrow - 2×10^{-4} rem

(3) Bone surface - 3×10^{-3} rem

(4) Liver - 6×10^{-4} rem

b) Dose commitment to members of general public from ingestion of ^{241}Am released by aircraft fire - not significant.

c) None of the calculated dose commitments exceeds the limits specified in Column IV of the table in 10CFR 32.24. Even under the most extreme accident conditions it is highly improbable that an individual could receive a significant dose commitment from ingestion.

2) Inhalation

a) Fire or Explosion at Honeywell or Boeing storage area.

(1) Gonads - 0.18 rem

(2) Red marrow - 1.1 rem

(3) Bone surface - 14 rem

(4) Liver - 2.9 rem

(5) Lung - 0.10 rem

* b) Fire at a service center.

(1) Gonads - 0.009 rem

(2) Red marrow - 0.06 rem

(3) Bone surface - 0.7 rem

(4) Liver - 0.15 rem

(5) Lung - 0.005 rem

c) Aircraft fire.

(1) Gonads - 0.003 rem

(2) Red marrow - 0.02 rem

(3) Bone surface - 0.2 rem

(4) Liver - 0.04 rem

(5) Lung - 0.001 rem

d) Clean-up of fire debris - no significant dose.

e) Fuel Sensor "Failure" indication - no significant dose.

f) All of the above values are well below the limits set in Column IV 10CFR32.24.

According to ICRP 30 the bone surface would receive the greatest radiation dose from inhaled and ingested ^{241}Am. The risk associated with dose to bone surfaces is small compared to risk associated with dose to other organs.

VIII. Leak Testing of Installed Densitometer

After installation of the densitometer in a fuel tank the source assembly is inaccessible under normal conditions. Therefore a continuous system for monitoring leakage of fuel into the source assembly will be used. (Appendix C). No leakage of radioactive material into the fuel system is possible unless the seal on the source assembly is broken and fuel enters the source cavity. The fuel leakage detector provides continuous assurance of the integrity of the source assembly seal. However, a "failure" signal from the fuel sensor would not necessarily indicate leakage of radioactive material. In fact, based on prototype tests of the source integrity under normal and extreme conditions such leakage is highly improbable.

* (Because of the low probability of a "failure" signal indicating significant radioactive source leakage and the low hazard associated with such leakage into the fuel system (see Section VI) the "failure" signal is not considered reasonable justification for immediate grounding of the aircraft).

IX. Labeling

A label, clearly visible to any individual involved in handling the source assembly will contain substantially the following information:

The receipt, possession, use and transfer of this device, Honeywell
* Fuel Quantity Indicating System Densitometer, Model WG1136, Serial No. _____, are subject to a general license or the equivalent and the regulations of the USNRC or of a State with which the NRC has entered into an agreement for the exercise of regulatory authority. This label shall be maintained on the device in a legible condition. Removal of this label is prohibited.

Honeywell Avionics Division
CAUTION RADIOACTIVE MATERIALS - ^{241}Am, 2mCi

Refer to Installation and Servicing manual for instructions.

* Continuous indirect radioactive source leak testing by fuel sensing device.

Due to space limitations, a condensed version, transmitting the above information, will be used, as shown on the label drawing in Appendix A.

X. Installation, Servicing, and Operating Instructions (related to Radiation Safety).

FQIS DENSITOMETER PROCEDURES

BOEING

1. Honeywell shall offer specific training to specific Boeing personnel on proper installation, removal, handling, storage and transportation of the Densitometer Source. This shall consist of classroom training and written procedures.
2. Honeywell shall provide detailed procedures for use by airlines in the event of a failed densitometer source. This material will be included in the Boeing Maintenance Manual which covers the fuel tank.

3. The label on the Densitometer Source shall identify documents to be consulted for removal, handling and installation of the source.
4. Procedures provided to Boeing shall identify extraordinary requirements in event of potential hazard, suspicion of release of material, damage, etc. This will include use of meters, clean-up, etc.
5. Boeing shall provide a locked storage area. This area may store up to 500 source assemblies, at one time.
6. Boeing receiving inspection shall perform survey, wipe test, or equivalent to assure no leakage prior to moving package to storage area. If leakage has occurred, appropriate clean-up measures shall be initiated.

* HONEYWELL SERVICE CENTERS

1. A minimum of two technical personnel at Honeywell Service Centers will be designated as able to handle, store and transport source assemblies.
2. The designated personnel shall attend the factory training classes on radiation safety and specific training on the Densitometer Source handling, installation, storage, and removal.
3. The Service Center will maintain a locked and labeled cabinet in which up to 5 source assemblies may be stored, either for spares stock or for interim storage prior to return to Minneapolis factory for repair. Only designated, trained personnel will have access to the cabinet keys.

4. No repair or disassembly work will be done on the source assemblies at this factory.

* 5. A survey meter will be employed at Honeywell Service Centers to monitor source assemblies during unpacking and packing operations, also storage area and surroundings when devices are moved.

6. No disposal will be done by field personnel. All material will be returned to Minneapolis factory for disposal.

7. The designated personnel will undergo a bioassay once per year, and when they leave the job, and immediately if a spill of material occurs.

8. The storage cabinet will be inspected with the survey meter at least quarterly.

9. The designated personnel will receive training to allow them to do removal and installation work on the aircraft, so as to assist airlines which elect not to have such capability.

10. Designated personnel will submit a radiation dose history to the company on an annual basis. A local log will be kept, as a memory aid, because activity will be infrequent and unscheduled.

* 11. An inventory of source assemblies in storage and in custody at the Service Centers will be maintained at all times.

AIRLINES

* 1. General licensee personnel may install or remove both the emitter and electronic parts of the FQIS assembly.

* 2. The Boeing aircraft manual specifies precautionary measures to be implemented by the airline in the event of accident or malfunc-
* tion.

* 3. Because of the extremely high reliability of the source package itself the frequency of Item 1 activity is expected to occur no more than approximately six times per year with respect to the entire fleet of aircraft.

XI. Total Quantities and Annual Distribution

A. Total number of source assemblies in storage at any time:

* 1. Honeywell - 500 (1.25 Ci ^{241}Am)

* 2. Honeywell Service Centers - (12.5 mCi maximum)
Source assemblies will be stored in a locked metal cabinet to which only designated, trained, personnel will have access.

* 3. Boeing (Seattle) - 500 (1.25 Ci ^{241}Am). Units will be stored in a locked parts "cage".

B. Annual distribution.

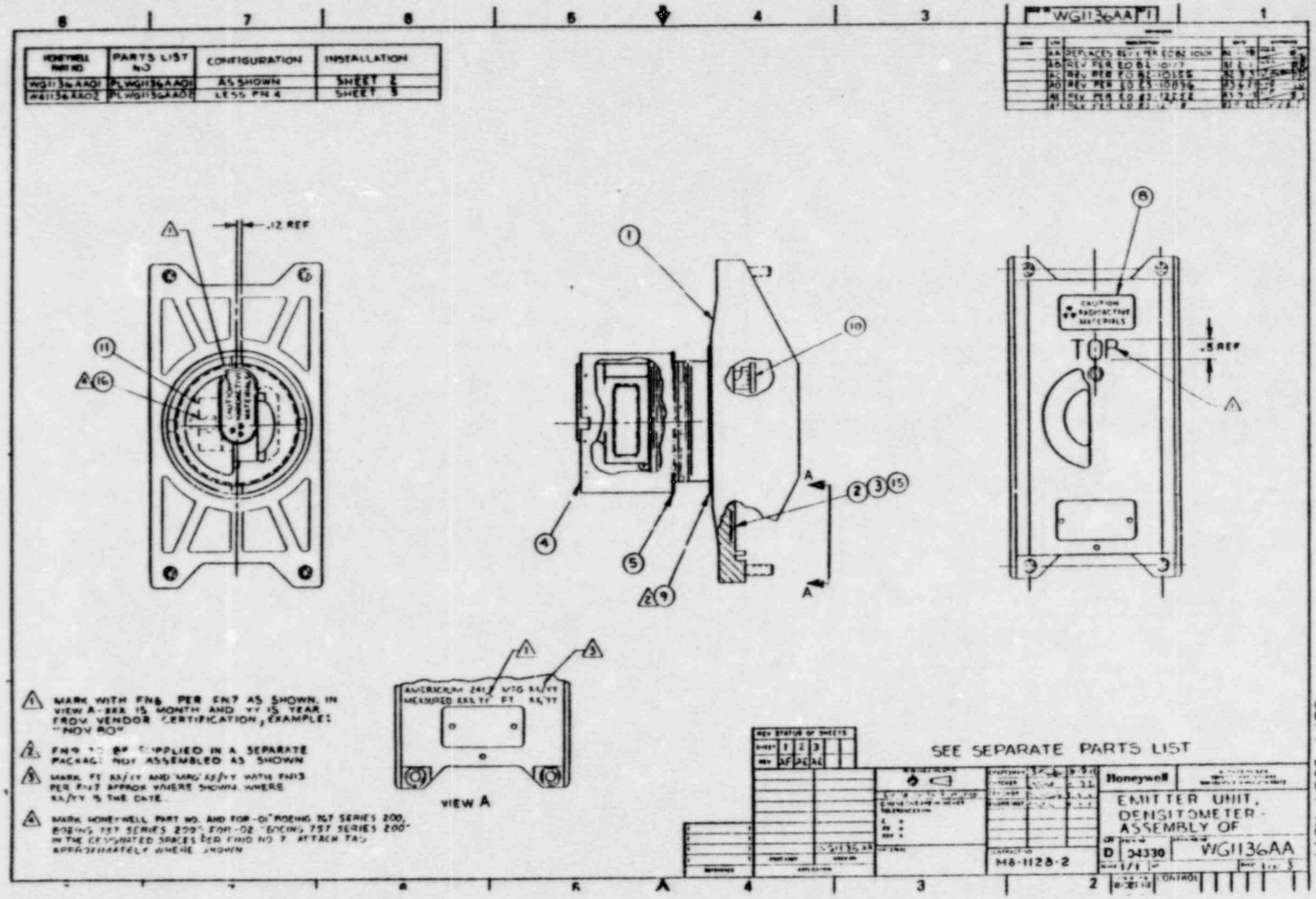
The estimated annual distribution will not exceed 1200 units (100
* units per month) (3.0 Ci ^{241}Am).

Revised 14 September 1984

APPENDIX A

This appendix contains the following drawings:

1. Amersham X.10 capsule outline drawing.
2. Densitometer emitter and electronics package shown mated and installed.
3. * Installation drawing for WG1136 densitometer emitter.
4. Densitometer source (emitter) case-casting drawing.
5. Densitometer emitter case-machined drawing.
6. Densitometer emitter Label drawing.



SEPT 1984 REV.

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APPENDIX C

METHOD OF MEETING LEAK TEST REQUIREMENT (of 10 CFR, paragraph 32, 51-b)

* The WG1136 emitter assembly, part of which is within an aircraft fuel tank, is specifically designed to eliminate the need for a six month wipe test. Monitoring is continuous, by means of an electronic circuit which signals a central processor unit that a condition exists which may allow a faulty sealed source to leak Americium 241 outside the normal containment. The basis for this method is that leakage of the source is a hazard only if the emitter package breaks open, allowing fuel to enter and spread the leakage. The failure code is stored in non-volatile memory for readout by airplane maintenance personnel after landing.

The Americium 241 by-product is sealed in a thoroughly tested capsule (prototype test report is part of this application). This capsule is mechanically staked into a copper cylinder which is further pressed and staked into
* a dead-end hole bored into a hollow cavity in the WG1136 casting. The hole is sealed on the bottom, but in case a break should occur in that area, the copper cylinder is shaped to pass fuel up to the top of the cavity in back of the sealed source. A cover is later soldered on to completely seal the cavity.

The electronic circuit which is always energized when the aircraft instrument power is on, consists of a microswitch in the source cavity connected through an interface connector to a transistor in the electronics package. Both the normally open and normally closed contacts are used for redundancy. That is, opening of the normally closed contacts will signal failure of the source cavity and closing of the normally open contacts will independently cause failure indication. The effect of switch operation is to disable one of the two pulse trains always being transmitted to the central processor, immediately indicating failure of the densitometer. Only 8 components are required for this function.

The switch is actuated by a very stable silicone rubber material which swells on contact with fuel and solvents. The specifications require a minimum amount of swelling (30%) which when combined with the calibration performed during assembly ensures tripping of the switch indicating failure.

The probability of an undetected fuel leak occurring using this detector is only 4.6×10^{-11} in the 20 year life of each densitometer unit.

The silicone rubber has been carefully selected for its stability. Honeywell and most avionics manufacturers have used this material successfully for padding and sealing purposes for 30 years. Federal spec ZZ-R-765, class 2B, grade 50 (methyl vinyl) covers the basic material. It is extremely resistant to age hardening at the temperatures the densitometer will see, and is not susceptible to damage from radiation and ozone and has a very

small temperature coefficient. The rubber (1/8 inch thick) is held captive against the switch by a soft aluminum holder which is shaped to bend when the rubber expands (when fuel is present).

Vibration and temperature tests have been successfully performed, and all design concerns have been thoroughly answered.

Figure 1C shows mechanical details.

The failure is instantly noted by the central processor unit and a "maintenance required" light is turned on. Maintenance personnel will later read out the failure code and follow through instructions provided to the airlines and aircraft manufacturer by Honeywell. These instructions will as-
* sure safe handling of the emitter package if indeed a double failure has occurred. That is, the failure of either the monitor or a breach of the emitter package allowing fuel to come into the source area, would signal the processor that a possible problem exists which could lead to contamination. However, a second failure would be required to actually cause contamination, a failure of the source capsule itself. In fact, most failures of the capsule would not be a problem since the Americium 241 is in a ceramic matrix which is fired into a tungsten insert. Any indication of fuel intrusion would trigger a trouble-shooting procedure which will verify a breach of the emitter package or isolate the failure to the monitor circuit only.

RELIABILITY

* The reliability of the fuel leak sensing circuitry in the WG1136 emitter assembly is very high, since only a few components are required - one transistor, one microswitch and a few resistors and capacitors. The probability of an undetected fuel leak with this continuous monitor is estimated to be 4.7×10^{-11} during the 20 year life. (This would require a monitor failure). The basic reliability of the design provides high confidence that no radiation leak will occur whether it is monitored or not. The probability of radiation leak from the emitter assembly is conservatively estimated to be 5.4×10^{-9} for the 20 year life of the units (even if no monitor).