DECLASSIFIED

[redacted]
Atomic Energy Act - 1954

MASTER

WANL - TME - 005

This document consists of 7 (pages)
Number 3 of 8 copies, Series ....

PAYLOAD DOSE RATE FROM DIRECT BEAM RADIATION AND EXHAUST GAS FISSION PRODUCTS

By M. A. Capo
R. Mickle

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

Classification cancelled ~~or changed to~~ ________
by authority of TID-1400-S?
by [signature] DTIE, date 7-14-75

[redacted]
Atomic Energy Act - 1954

DECLASSIFIED

A study was made to determine (1) the dose rate at the payload in the NERVA System due to direct beam radiation, and (2) the possible effect of fission products contained in the exhaust gases.

1. PAYLOAD DOSE RATE

The configuration used in this analysis was obtained from the George C. Marshall Space Flight Center, Drawing No. 91-0107, "C - 4/NERVA Upper Stage Layout for Shielding Calculations". All vehicle components shown in the drawing except the upper stage nozzles were included in this analysis. These components are: the liquid hydrogen propellant used in the nuclear stage, the hemispherical liquid hydrogen and oxygen bulkheads in the second stage, and the nitric acid sphere in the third stage. In addition to these components, a shield was placed above the top support plate of the KIWI B-1 core. This shield, consisting of 63% lithium hydride, 27% stainless steel, and 10% void for coolant flow (by volume) is 31.4 cm. in thickness at the core midplane and is tapered in the radial direction to the beryllium reflector. It is prese[illegible] believed that this is the maximum shield required to reduce the over all hydrogen propellant heat input by 90% for a 37.5° half angle tank. An inch thick aluminum pressure vessel was included. The current Aerojet General turbopump, gimbal, and tank shut-off valve were also approximated in this configuration. The turbopump, consisting of aluminum and stainless steel, was described as a cylinder (weight, 300 lb.) along the axis of symmetry. The gimbal, consisting of titanium, was described as an annulus rotated about the axis of symmetry. The aluminum tank shut-off valve was described in a similar manner.

Shielding Computer Program 14-0, which evaluates point-to-point attenuation functions and integrates over a cylindrical source, was used to calculate the core gamma ray and fast neutron dose rates at various positions along the centerline of the configuration. Detector points were located at the bottom of the tank, at several positions inside the tank, at the center of the liquid oxygen and the liquid hydrogen upper stage bulkheads, at the center of the nitric acid sphere in the third stage, and at the payload.

Three different problems were run: (1) with no liquid hydrogen propellant, (2) with 50% (by length) of the propellant in the tank, and (3) with the tank filled.

Throughout this study it was assumed that a KIWI B-1 core would be operating for 20 minutes at 1120 MW. The radial power distribution was assumed flat. The axial power distribution was described as a cosine function. About 800 source points were located in one-half the volume of the reactor core.

Presented in Table 1 are the core gamma ray and fast neutron dose rates for each of the three cases described previously at each detector location. The center of the cylindrical coordinate system was located at the bottom of the core.

Figure 1 graphically illustrates the gamma ray dose rate at the payload as a function of per cent propellant in the tank. Since the fast neutron dose rate at the payload is insignificant, it is not presented here.

Table 2 lists the gamma ray fluxes at the payload for various energy groups due to core gamma rays only. The core gamma source includes prompt gammas, short half-life gammas, delayed gammas, and those due to neutron capture in U^{235}.

2. EFFECT OF FISSION PRODUCTS

Fission products will be entrained in the hydrogen coolant as it passes through the active core. As this coolant is exhausted into space at the nozzle, it will expand to form a radioactive cloud. This cloud represents a radioactive source which might add appreciably to the radiation dose at the payload.

In order to make an estimate of the radiation impinging on the payload due to fission products in the exhaust coolant the following assumptions were made:

(1) 1% burst-loss of the fission products existing after 20 minutes full power operation.

(2) Fission products form disc source at nozzle exit.

Shielding Computer Program 14-0 was used to compute the gamma flux at the payload due to a disc source at the end of the nozzle. Three disc sources, each having a different outer radius, were considered. For the case where no hydrogen is in the tank, the results of this preliminary analysis for disc sources due to 1% fission products are shown in Figure 2.

It was previously noted that the gamma ray flux at the payload due to core gamma rays (Table 2) for the case where no liquid propellant is in the tank is 2.55×10^3 Mev/cm^2-sec. Under the assumptions made in these calculations, the exhaust gas will contribute 10% to the gamma flux at the payload if the gas expands to a radius of 170 cm. at the nozzle exit. At a radius of 250 cm., the contribution to the payload will be approximately 25%.

[redacted]
Atomic Energy Act - 1954

WANL - TMB - 003
Astronuclear

TABLE 1
DOSE RATES AT VARIOUS AXIAL POSITIONS ALONG CENTER LINE
(Z Axis = 0 at Bottom of Core)
RADS/HOUR

Reactor Operating Power: 1120 MW
Operating Time : 20 Minutes

	0% Liquid Hydrogen		50% Liquid Hydrogen		100% Liquid Hydrogen	
Axial Location, cm.	Gamma Ray	Fast Neutron	Gamma Ray	Fast Neutron	Gamma Ray	Fast Neutron
436.88 (Tank Bottom)	8.75 (5)*	3.15 (5)	———	———	———	———
450.88 (Inside Tank)	8.61 (5)	3.09 (5)	8.06 (5)	1.26 (5)	———	———
502.92 (Inside Tank)	3.70 (5)	1.45 (5)	2.68 (5)	3.24 (2)	———	———
800.0 (Inside Tank)	2.98 (5)	1.11 (5)	5.83 (4)	1.47 (-2)	———	———
1500.0 (Inside Tank)	8.52 (4)	3.19 (4)	3.83 (3)	5.95 (-8)	1.09 (3)	5.79 (-12)
2464.22 (Center of Liquid Oxygen Bulkhead)	3.26 (2)	2.55 (1)	1.88 (1)	4.77 (-11)	1.57 (0)	4.22 (-19)
2743.38 (Center of Liquid Hydrogen Bulkhead)	6.86 (0)	1.55 (-4)	5.76 (-1)	9.49 (-15)	4.40 (-2)	1.68 (-22)
3329.94 (Center of Nitric Acid Sphere)	5.78 (-2)	3.21 (-10)	5.87 (-3)	1.69 (-19)	6.61 (-4)	5.96 (-27)
3476.76 (Payload)	2.69 (-3)	9.76 (-13)	2.99 (-4)	6.63 (-22)	3.61 (-5)	2.54 (-29)

*Read 8.75 (5) as 8.75×10^5

[redacted]
Atomic Energy Act - 1954

[redacted]
Atomic Energy Act - 1954

Astronuclear
WANL - TME - 005

TABLE 2

GAMMA RAY FLUXES AT PAYLOAD

$Mev/cm^2 - sec$

GAMMA RAY FLUXES

E_γ Mev	0% L H_2	50% L H_2	100% L H_2
0.3	———	———	———
0.7	———	———	———
1.0	———	———	———
1.5	1.00 (-3)	———	———
2.0	7.17 (-2)	8.31 (-4)	9.62 (-6)
2.5	1.18 (0)	2.29 (-2)	4.47 (-4)
2.8	3.65 (0)	9.16 (-2)	2.29 (-3)
3.5	8.54 (1)	3.49 (0)	1.43 (-1)
4.5	4.57 (2)	3.02 (1)	1.99 (0)
5.5	7.01 (2)	6.63 (1)	5.99 (0)
6.5	5.52 (2)	6.84 (1)	7.97 (0)
7.5	5.04 (2)	7.56 (1)	1.09 (1)
9.0	2.42 (2)	4.62 (1)	8.73 (0)
TOTAL	2.55 (3)	2.90 (2)	3.57 (1)

[redacted]
Atomic Energy Act - 1954

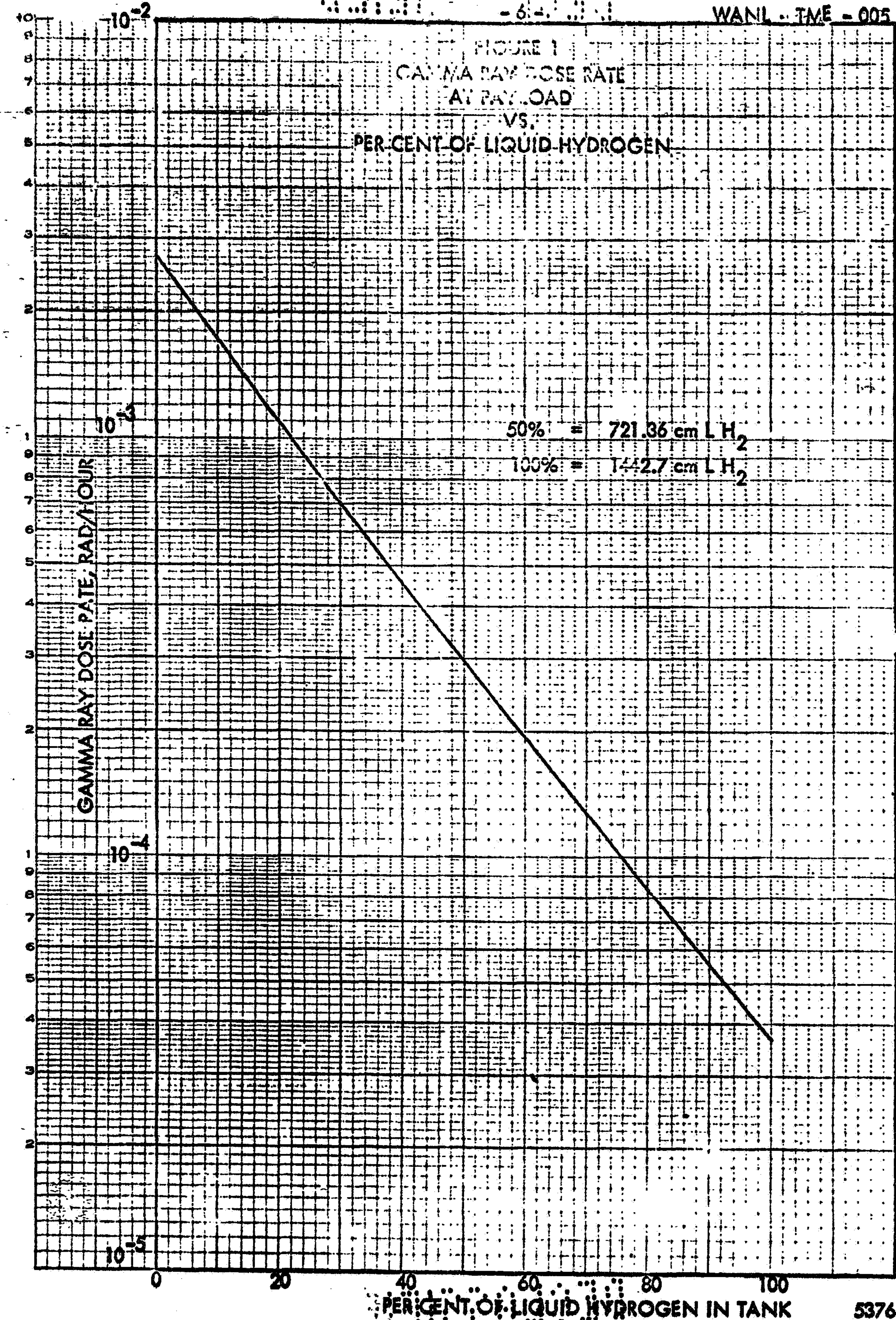
FIGURE 1
GAMMA RAY DOSE RATE
AT PAYLOAD
VS.
PER CENT OF LIQUID HYDROGEN
50% = 721.36 cm L H_2
100% = 1442.7 cm L H_2
GAMMA RAY DOSE RATE, RAD/HOUR
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
20
40
60
80
100
PER CENT OF LIQUID HYDROGEN IN TANK

537644

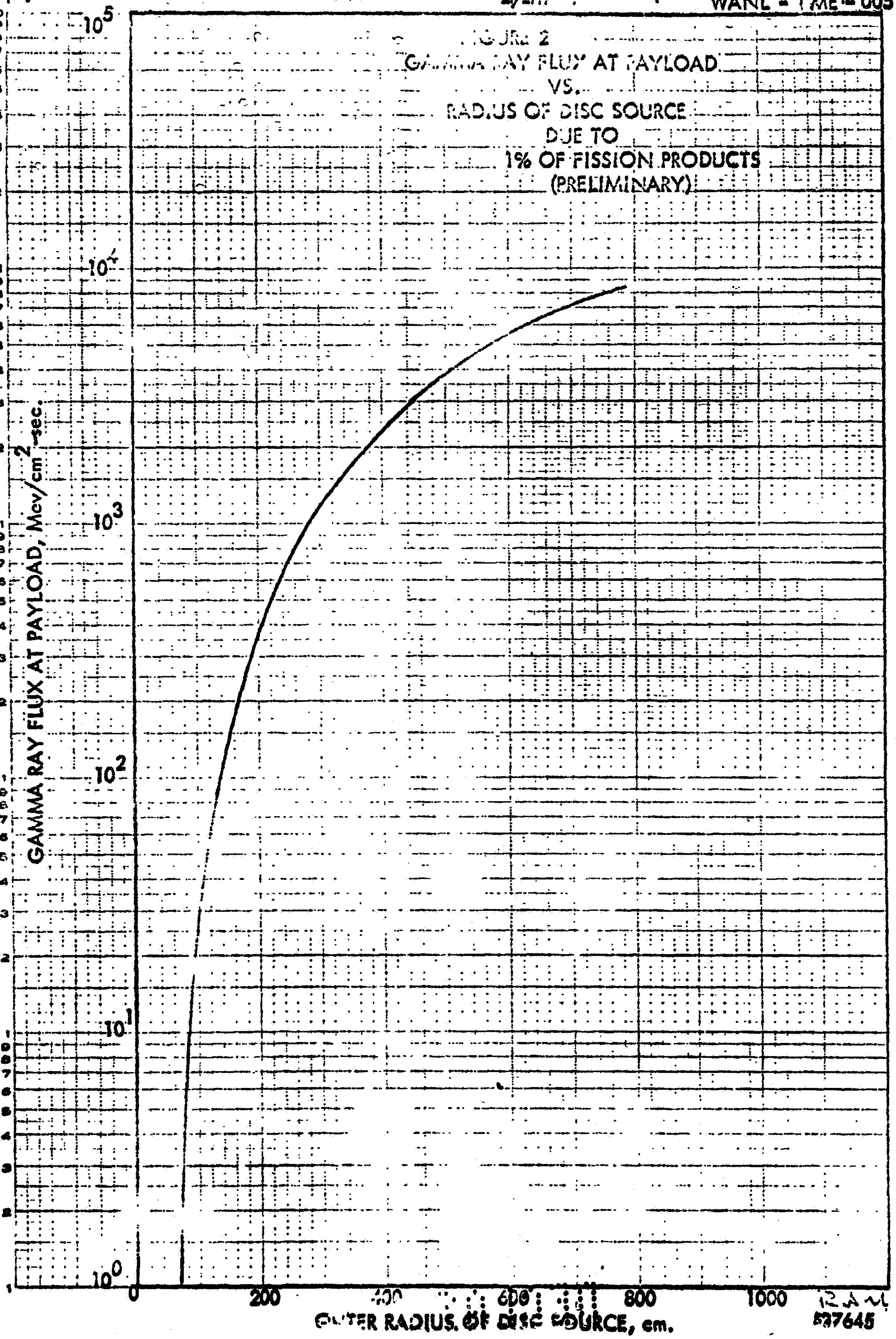

FIGURE 2
GAMMA RAY FLUX AT PAYLOAD
VS.
RADIUS OF DISC SOURCE
DUE TO
1% OF FISSION PRODUCTS
(PRELIMINARY)

537645