National Défense
Defence nationale

THE USE OF THE COMPUTER CODE ATR TO RELATE DREO EXPERIMENTAL RESULTS TO NUCLEAR BATTLEFIELD THREATS (U)

by

T. Cousins

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 89-10

Canada

February 1989
Ottawa

National Defence / Défense nationale

THE USE OF THE COMPUTER CODE ATR TO RELATE DREO EXPERIMENTAL RESULTS TO NUCLEAR BATTLEFIELD THREATS (U)

by

T. Cousins
Nuclear Effects Section
Electronics Division

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 89-10

PCN
041LS

February 1989
Ottawa

ABSTRACT

The computer code ATR allows quick reliable predictions of the neutron and gamma-ray radiation environments to be expected on the battlefield. This report details how ATR output may be related to recent DREO experimental results, especially in the TREE (Transient Radiation Effects on Electronics) area. It is the conclusion of this work that the prompt gamma-ray dose rate effects will be the most serious on the battlefield.

RÉSUMÉ

Le code machine ATR nous permet de predire rapidement et surement le niveau de radiation neutron et gammas qu'il pourrait y avoir sur les champs de bataille. Ce rapport nous decrit la similitude entre les resultats ATR et les recents resultats obtenus au CRDO, specialement sur les effets transitoires de la radiation sur l'ellectronique. Nous concluons, que sur le champs de bataille, les effets d'un taux rapide de radiation seraient les plus endommageantes.

EXECUTIVE SUMMARY

DREO has recently acquired the computer code ATR which can be used to predict the effects of nuclear radiation arising from simulated weapon bursts. This report relates these predicted effects to a number of DREO experiments involving irradiation of electronics. It is the conclusion of this report that gamma-ray dose rate effects are the most severe on the nuclear battlefield.

TABLE OF CONTENTS

TABLES

FIGURE CAPTIONS

1.0 INTRODUCTION

The Nuclear Effects Section (NES) at DREO has recently expanded its computational capabilities with the acquisition and installation of the computer code ATR(1) (Air Transport of Radiation), versions 4 and 5. This code is an extremely fast and powerful tool in providing a plethora of radiation parameters arising from realistic nuclear weapon/battlefield scenarios. This report gives details on what is available from ATR, with the emphasis on the radiation effects predicted. Biological effects will be briefly discussed, but the emphasis will be on on Transient Radiation Effects on Electronics (TREE) - specifically showing how recent DREO experimental results may be related to expected threats.

2.0 BACKGROUND

2.1 ATR

The code ATR was developed to provide an easy-to-use means of determining the complete radiation environment from a nuclear weapon burst in the atmosphere. The code uses a compact data base which contains a parameterized set of the results of detailed calculations. The user inputs weapon type and spectrum (Standard Fission Weapon (SFW), Enhanced Radiation Weapon (ERW), user defined or any mix), weapon height-of-burst, weapon yield and also receptor range and height. ATR 5 also allows meteorological parameters and ground altitude to be varied.

The ATR output is very extensive but here the concentration is on integral parameters such as tissue kerma, 1 MeV equivalent fluence in Si, and ionizing Si dose. However, complete energy and angular fluence data is available - from which virtually any parameter may be determined (i.e. Rads (GaAs), predicted dosimeter response, etc.).

The main advantage of ATR over other (perhaps more accurate) codes is its speed and availability. All problems solved here were run on an IBM PS-2 Model 60 Personal Computer (PC), and none took more than 15 minutes from setup to result.

2.2 DREO TREE Experiments

In the establishment of its TREE program, DREO has conducted several experiments at both on and off-site facilities. These have included the Chalk River Nuclear Laboratories (CRNL) (2)

LINAC, the Royal Military College (RMC) (3) Slowpoke II reactor and the DREO ^{60}Co gamma-ray source. Recently DREO carried out actual system irradiations on military equipment at the Aberdeen Proving Ground (APG) GODIVA reactor (RX) and flash x-ray machine (FX) facilities. These APG results, which have not previously been reported are presented here in more detail. All results are related to ATR calculations.

3.0 RESULTS

Although ATR has the capability to handle any yield weapon at any height of burst, and perform the calculations out to virtually any range, for many scenarios the radiation fields are of minimal importance when compared to blast and shock, or thermal effects. Thus the calculations here are for low yield ($\leq$100 kT) weapons for ranges of $\leq$2 km. For these conditions, biological effects of radiation are of paramount importance. The height of burst for each weapon was determined as that which would maximize blast effects, i.e.:

$$H = 60\ Y^{1/3}$$

where H = height of burst (m)
Y = weapon yield (kT)

3.1 Biological Effects

Figure (1) shows the results of the ATR calculations for a 10 kT SFW burst at 129 m height. The source normalization used here (and for all fission calculations in this report) was 2.0 x 10^{23} neutrons per kT and 5.0 x 10^{22} gamma rays per kT. Results are presented in Rads (Tissue), for neutron, prompt gamma ray and secondary gamma ray (arising from neutron interactions with air and ground atoms). Note the increasing importance of neutron-generated gamma rays at increasing ground range (typical of all fission weapons). Also notice that the prompt gamma ray contribution to the total dose is insignificant at all ranges - when only biological effects are considered. This statement, as will be shown later, is not true when the effects of radiation on electronics are considered.

Figure (2) details the ATR calculations for total dose (neutron plus prompt gamma ray plus secondary gamma ray) for four weapon yields (1 kT, 5 kT, 10 kT and 100 kT) at optimum height of burst. Drawn on the figure are horizontal lines corresponding to LD50 (dose required to kill 50% of normal, healthy adult males = 450 Rad (Tissue)) and ITI (dose required to cause immediate transient incapacitation = 2200 Rads (Tissue)). Thus this graph is extremely useful in predicting radiation effects on troops for the weapon yields. Note, for instance, that increasing weapon yield by a factor of 100 results in a rough factor of two increase in ITI range.

Figure (3) compares SFW and ERW weapons in terms of neutron tissue kerma for identical weapon yields and heights of burst (10 kT at 129 m). An ERW is known to cause greater biological damage from neutrons that an SFW because of a higher release of neutrons per fission, and the fact that its 14 MeV neutrons have a higher kerma-fluence factor (in terms of rad cm^2) and a longer mean free path in air than fission neutrons. These facts are demonstrated in Fig (3). Note this the advantage of the ERW increases with increasing range.

3.2 Aberdeen Proving Ground Experiments

In January 1989 DREO staff conducted fission neutron and flash x-ray experiments on two pieces of military equipment - the PRC 77 man pack radio transmitter/receiver and the HP41CV calculator/EPROM-howitzer emulator artillery range finder.

The radio tests consisted of exposures at 20, 50 and 80 cm from the FX face plate. TLD's (both from APG and DREO) were placed on the front and rear faces of the radio to monitor total dose. The APG FX pulse is nominally 80 ns wide, so dose rates could easily be ascertained.

The PRC77 comes equipped with a BNC cable antenna output. Thus this output could be easily measured before, during and after the pulse. This testing procedure (which was also applied to the neutron irradiations) is capable of determining only the output transmission power and frequency of the radios. No attempts were made to monitor other parameters such as receiving capabilities and voice-communication capabilities, due to lack of time. This is illustrative of the complexities involved in performing complete radiation hardness tests.

Table (1) and Figs (4-7) summarize the FX/Radio results.

TABLE 1

Results of PRC77 Exposure to FX Shots

Shot #	d (cm)	Trans Freq (mHz)	Front Face Dose Rate (Rads(Si)/s)	Rear Face Dose Rate (Rads(Si)/s)	Recovery Time (s)
8910	80	63.70	$(2.4 \pm 0.3) \times 10^{9}$	$(1.4 \pm 0.2) \times 10^{9}$	1.2×10^{-5}
8911	50	63.70	$(6.2 \pm 1.0) \times 10^{9}$	$(3.2 \pm 0.2) \times 10^{9}$	1.5×10^{-5}
8912	20	63.70	$(2.4 \pm 1.2)^{*} \times 10^{10}$	$(8.1 \pm 2.5)^{*} \times 10^{9}$	2×10^{-5}
8916	20	40.00	$(2.9 \pm 1.2)^{*} \times 10^{10}$	$(1.0 \pm 0.4)^{*} \times 10^{10}$	10^{-2}

* The large errors at 20 cm represent an extremely non-uniform field when close to the FX face plate.

All tests here showed a protracted recovery time following pulse cessation. This is typical of transistor responses, which were observed by DREO at the CRNL LINAC. An example of this appears in fig (8). Thus there would appear to be some correlation between device and system responses to dose rate. The radios themselves seem to show a dose rate dependent recovery time, and a large frequency dependence. (In fact the 40 and 63.7 MHz frequencies represented two physically distinct bands on the radios.)

The recovery times here (even 10^{-2} s) would not present a problem for voice-communication, but similar technologies, if used in computers, could be affected when data transmission, calculational capabilities, etc. are considered.

The HP41CV/Howitzer Emulator tests involved visual (on camera) observation of the calculator display at the time of the pulse. The EPROMs were checked for functionality before and after the pulse.

The EPROMs proved completely immune to dose rate damage. The HP41CVs however, responded as shown in table (2).

TABLE 2

HP41CV Response to FX Pulses

Dist from face plate (cm)	front face dose rate (Rads(Si)/s)	back face dose rate (Rads(Si)/s)	Response
80	2.7×10^{9}	$(2.6 \pm .3) \times 10^{9}$	Calculator turned off at Pulse, had to be "hard started"
129	$(1.0 \pm 0.2) \times 10^{9}$	$(9.9 \pm 1.4) \times 10^{8}$	" "
305	$(1.94 \pm .1) \times 10^{8}$	1.90×10^{8}	Calculator remained on at pulse, but after automatic shutdown, had to be "hard started"
1000	3.75×10^{7}	$(3.13 \pm .3) \times 10^{7}$	no effect

The HP41CV was observed to "latch up" because of the radiation pulse. After the pulse the calculators could not be turned on (using the on/off switch). Rather a "hard start" was required (manually removing and physically re-inserting the batteries). Following the hard start, the calculators were functional. This latch-up behaviour is typical of CMOS technology, and has been observed by DREO at CRNL (2).

The neutron tests showed that the radios, calculators and EPROMs were immune to neutron damage up to fluences of $\sim 10^{13}$ n/cm^2 (1 MeV equivalent Si) - as determined by APG sulphur pellet activation techniques. This hardness criteria would be typical of CMOS techniques in the calculators, and can be attributed to the use of high f_T, high gain transistors in the PRC77.

Relation of these effects to weapons criteria appears in the following sections.

3.3 Neutron Fluence Effects

The quantification of the effects of neutron irradiation on electronics uses the so-called 1 MeV equivalent fluence Si, defined as

$$\Phi_n = \int \frac{\Phi(E)\ KD(E)\ dE}{KD(1\ MeV)}$$

where $\Phi(E)$ = neutron fluence energy spectrum
$KD(E)$ = kerma-energy displacement factor in Si
$KD(1\ MeV)$ = Si kerma displacement factor at 1 MeV.

The 1 MeV equivalent factor is available from ATR, and fig (9) plots this along with neutron tissue kerma for the 10 kT yield at 129 m HOB. Note the horizontal line from a 1 MeV equivalent of 10^{12} n/cm^2, a suggested hardening target. Note that at the corresponding range the tissue kerma is roughly 3000 Rads - well above the ITI dose. Thus equipment hardened to 10^{12} n/cm^2 will generally survive while troops will not.

DREO experiments (3) have shown that the major effect of neutron irradiation is gain degradation in bipolar transistors consistent (for most tested) with the Messenger-Spratt equation:

$$\frac{1}{\beta} - \frac{1}{\beta_o} \quad \frac{\Phi_n}{2\pi\ f_T\ K}$$

where β = transistor gain after irradiation
β_o = original gain
f_T = gain-bandwidth product
and K = semi-empirical constant ($\sim$1.6 x 10^6 s cm^{-2})

The DREO tests at RMC yielded the values for 50% loss in transistor gain which are plotted on the 1 MeV equivalent fluence plot in fig (10). The intersection of the transistor name with the curve may be extrapolated down to arrive at the range for this effect. Comparison with figs (1) and (2) will give tissue kermas at these ranges.

3.4 Dose Rate Effects

ATR does not give gamma-ray dose rates directly. However the prompt gamma-ray total dose is available. Thus knowledge of the gamma-ray pulse width will give the dose rate. Information on these does rates is classified, however an estimation can be made from below (following (4)).

A nuclear detonation occurs when fissionable material can be contained for a certain time, corresponding to a certain number of "generations". Here each generation represents the capture of a neutron and subsequent release of (an average of 2.3 for ^{235}U) fission neutrons. The generation time, although energy-dependent, is roughly 10^{-8} s or 1 "shake".

The neutron-production from the chain reaction is simply

$$N = No \exp(n)$$

where N = number of neutrons present after n generations
and No = original number of neutrons.

If we assume (4) that 1.45 x 10^{23} neutrons are required to produce 1 kT equivalent, then the time (in shakes) necessary to produce certain yields is given in table (3).

TABLE 3

Time Requirements for Weapon Yields

Yield	Time (shakes)
0.1 kT	51.0
1 kT	53.3
10 kT	55.6
100 kT	57.9
1 MT	60.2

Clearly, from the table, most of the energy release occurs near the end of the chain reaction. In fact, about 90% of the yield occurs in the last 2 shakes. Thus, for the purpose of this discussion, a gamma-ray pulse width of 2 shakes is assumed.

One should note that the above argument makes no attempt to address any increase in time due to containment problems. This may be expected to increase with yield, and for the 10 kT weapon used here the approximation may have validity.

Using this assumption, fig (11) shows the expected dose rates arising from the 10 kT burst at 129 m. Some DREO experimental results also appear on the graph. They represent,

MCM2708 - data corruption of MCM2708 EPROM at CRNL LINAC

74HC00 - latch up of 74HC00 NAND gate at CRNL LINAC

HP41CV - latch up of HP41CV calculator at APG FX

2N4861A - sensitivity of 2N4861A JFET at CRNL LINAC.

Referring back to fig (2) the corresponding tissue kermas for the same ranges may be determined. For instance the HP41CV will latch up at ∿30 Rads (Tissue) total dose - not enough to cause performance decrement, and barely measurable on military dosimeters.

Except for the JFET, the effects shown here are permanent. However every device tested by DREO has shown some response for dose rates out to 2000 m - where no significant biological effects occur. These effects are typically protracted saturation in transistors from µs to ms or longer.

This would tend to amplify comments made to DREO by Friedman (5) stating that dose rate effects are the most severe on the battlefield, and the most difficult to guard against. This may considered as palpable proof that a LINAC should be the first purchase made in the DREO TREE program.

4.0 CONCLUSIONS

The computer code ATR has greatly expanded and enhanced NES computer capabilities to the point where reliable radiation effects criteria arising from any nuclear weapon's detonation may be achieved quickly and accurately. The code has been demonstrated relevant to both biological and TREE effects and will be invaluable in the planning and analysis of future NES experiments.

The analysis presented here shows that, for TREE effects, gamma-ray dose rate effects are of paramount importance and thus LINAC and Flash X-ray experiments will be emphasized in the future.

ATR will continue to play a role in NES work in the future, such as the development of the vehicle shielding code VPF (6).

A typical ATR output (for some of this work) appears in the appendix.

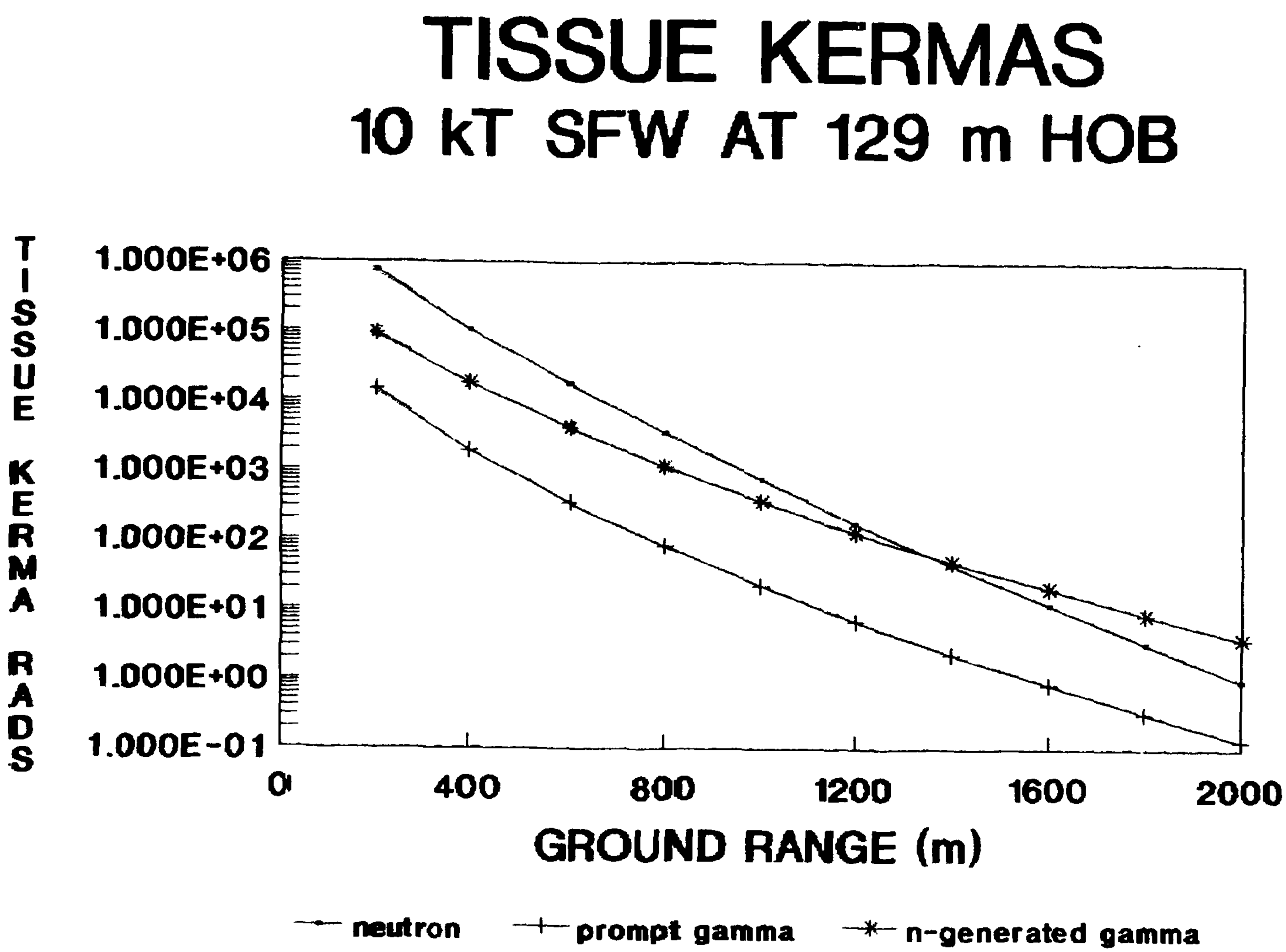

Figure (1) Tissue kermas arising from a 10 kT SFW burst at 129 m height out to a ground range of 2000 m. Note that secondary gamma rays play an increasingly important role as distance from the burst is increased.

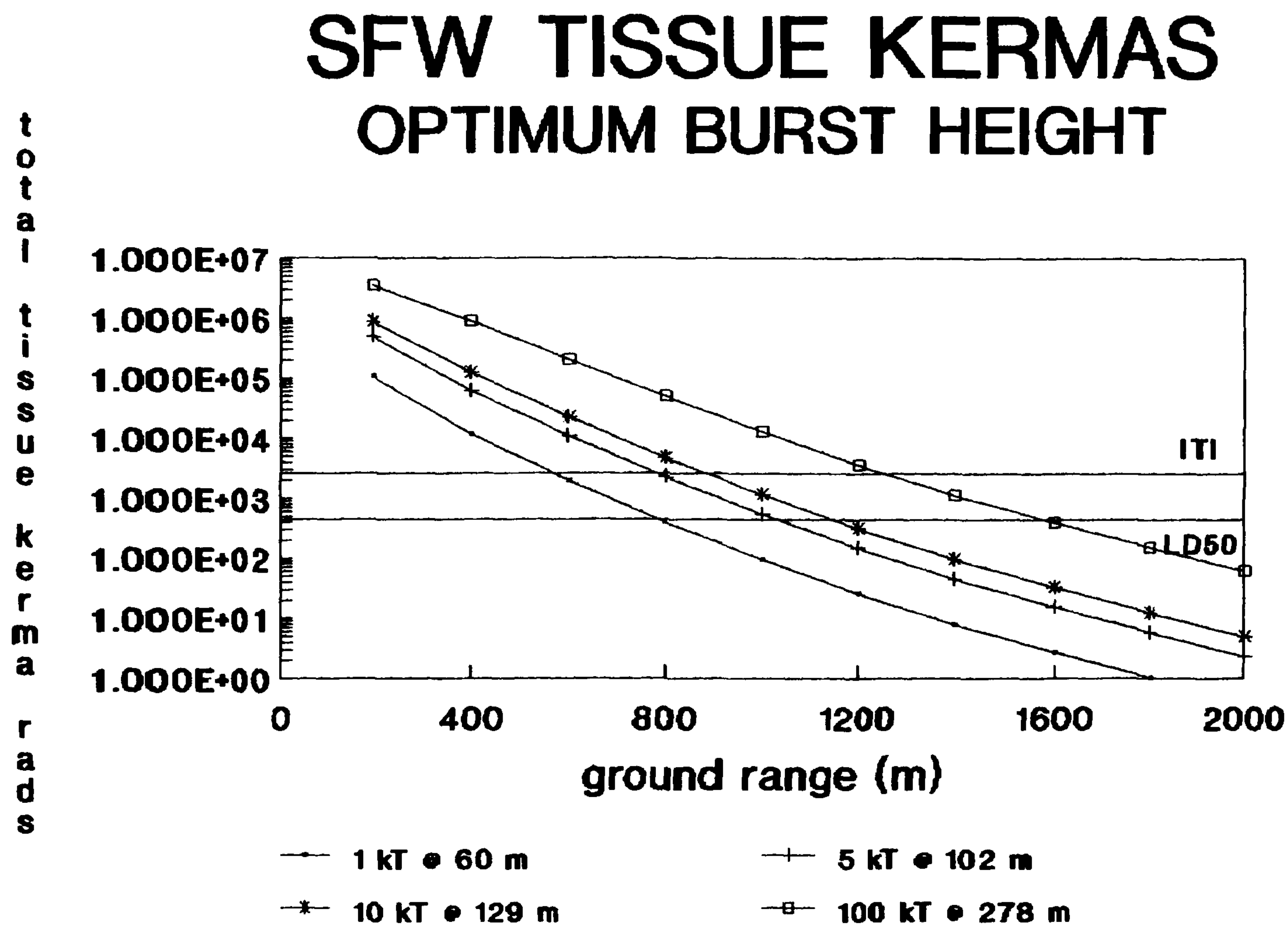

Figure (2) Total tissue kerma from 4 different bursts at optimum height. The LD50 and ITI ranges for each weapon may be determined.

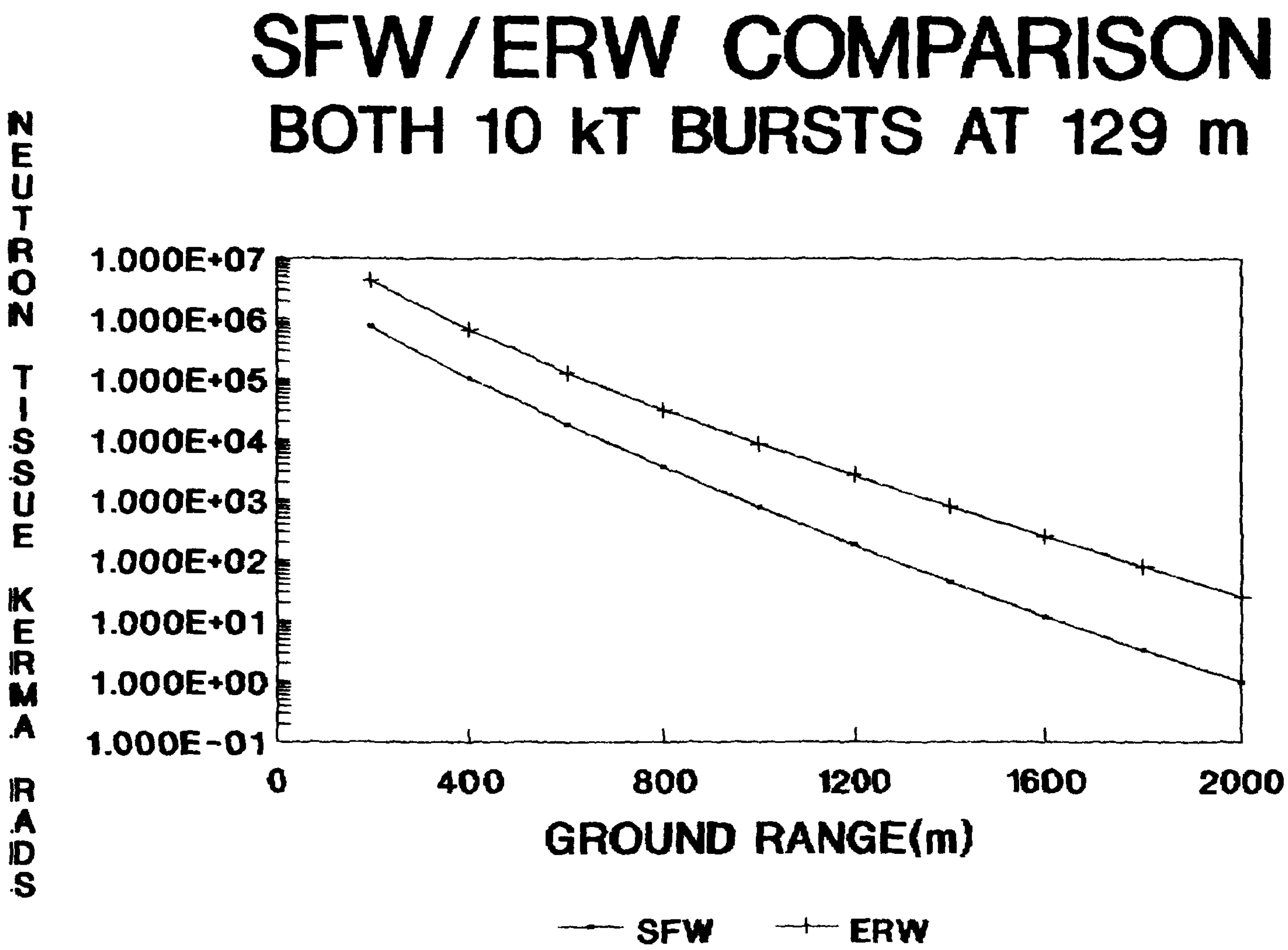

Figure (3) Comparison of neutron tissue kermas from the same ERW and SFW burst yeild and height. Note the large advantage of the ERW increases with range.

FX8910_S1 17 Jan 1989

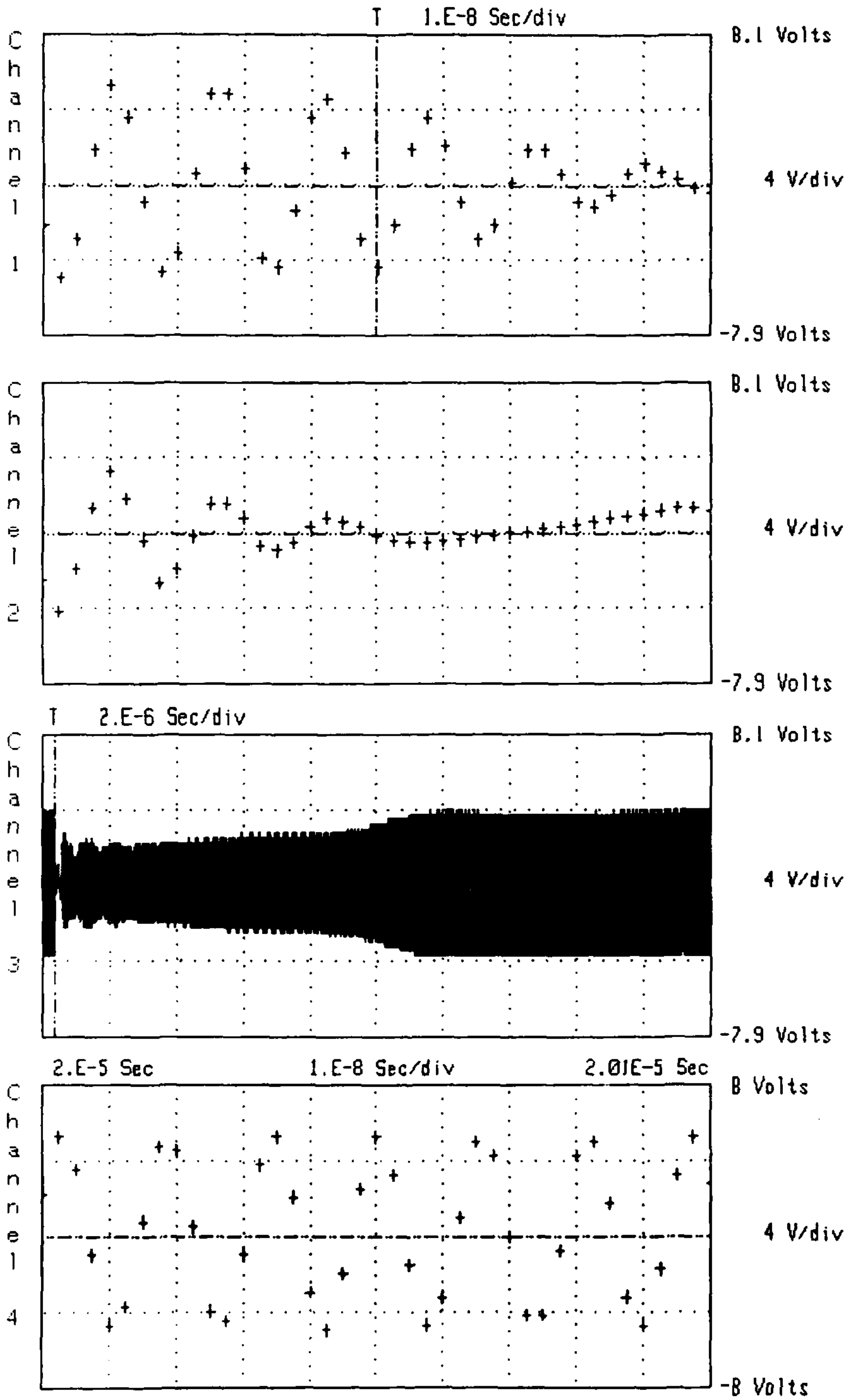

Figure (4) Response of PRC77 transmitter/receiver to APG FX at 80 cm (f = 63 MHz). The third figure shows the protracted response following 80 ns pulse (note time scale).

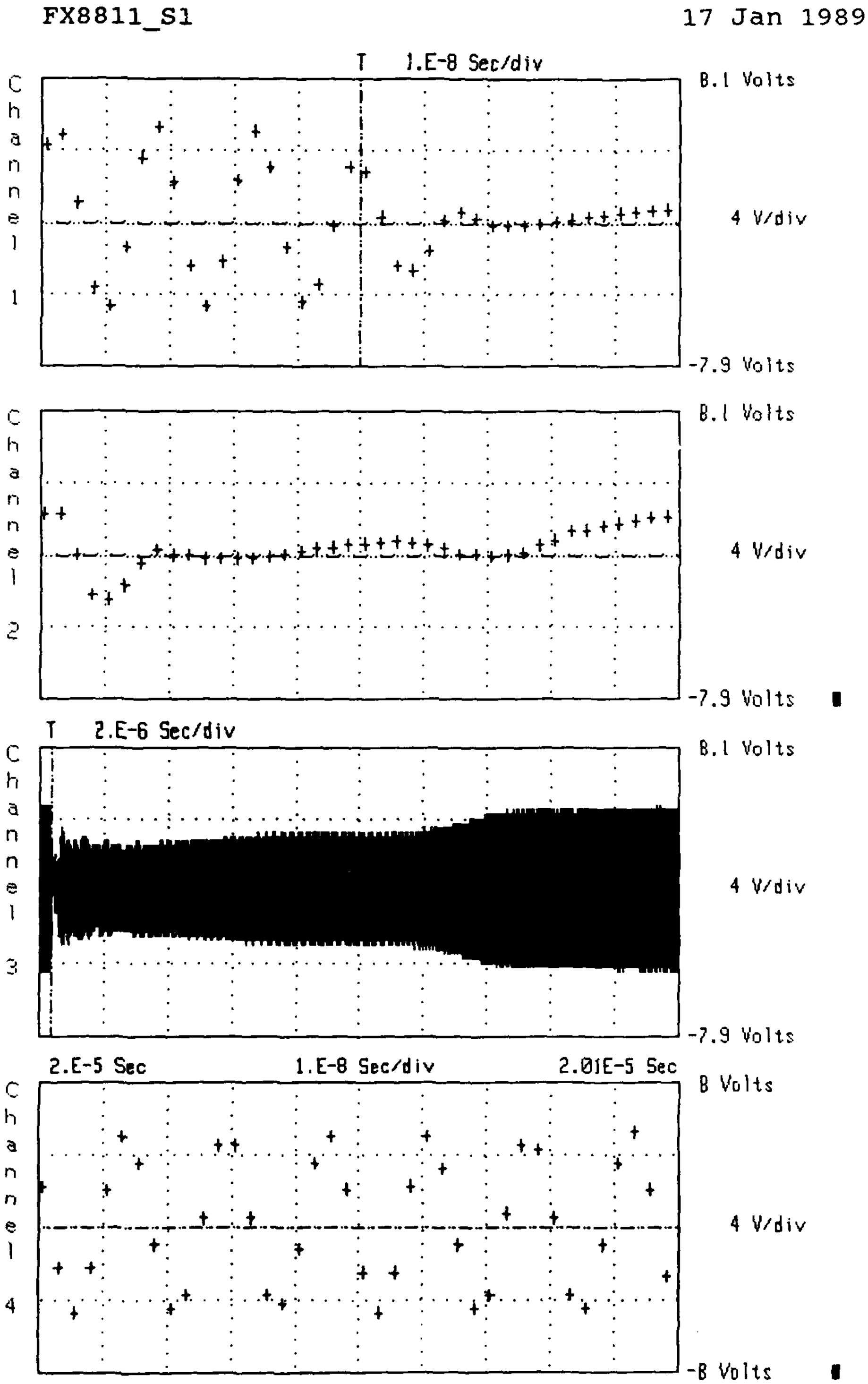

Figure (5) Same as fig (4), but radio at 50 cm.

FX8912_S1 17 Jan 1989

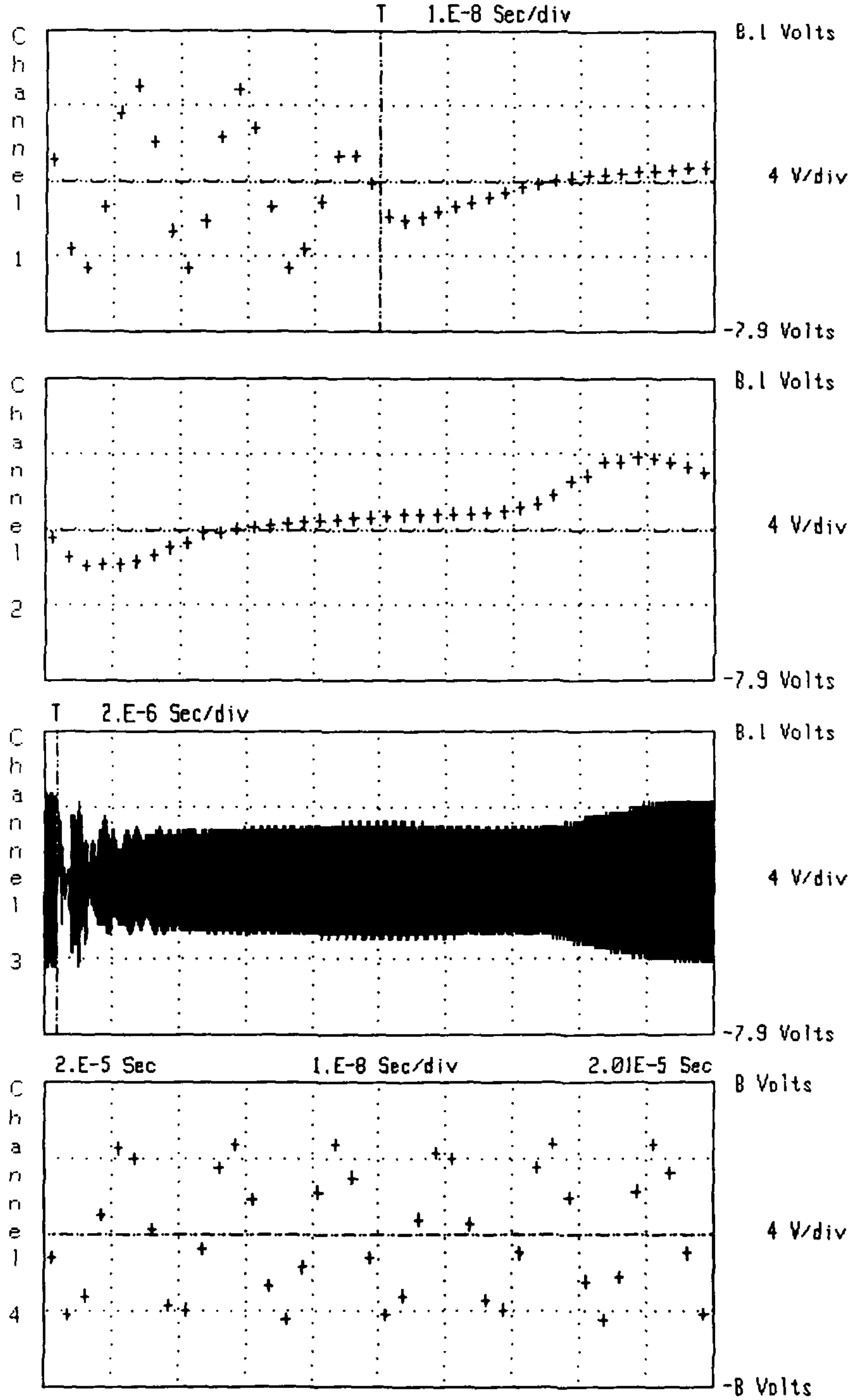

Figure (6) Same as fig (4), but radio at 20 cm.

FX8916_S1 17 Jan 1989

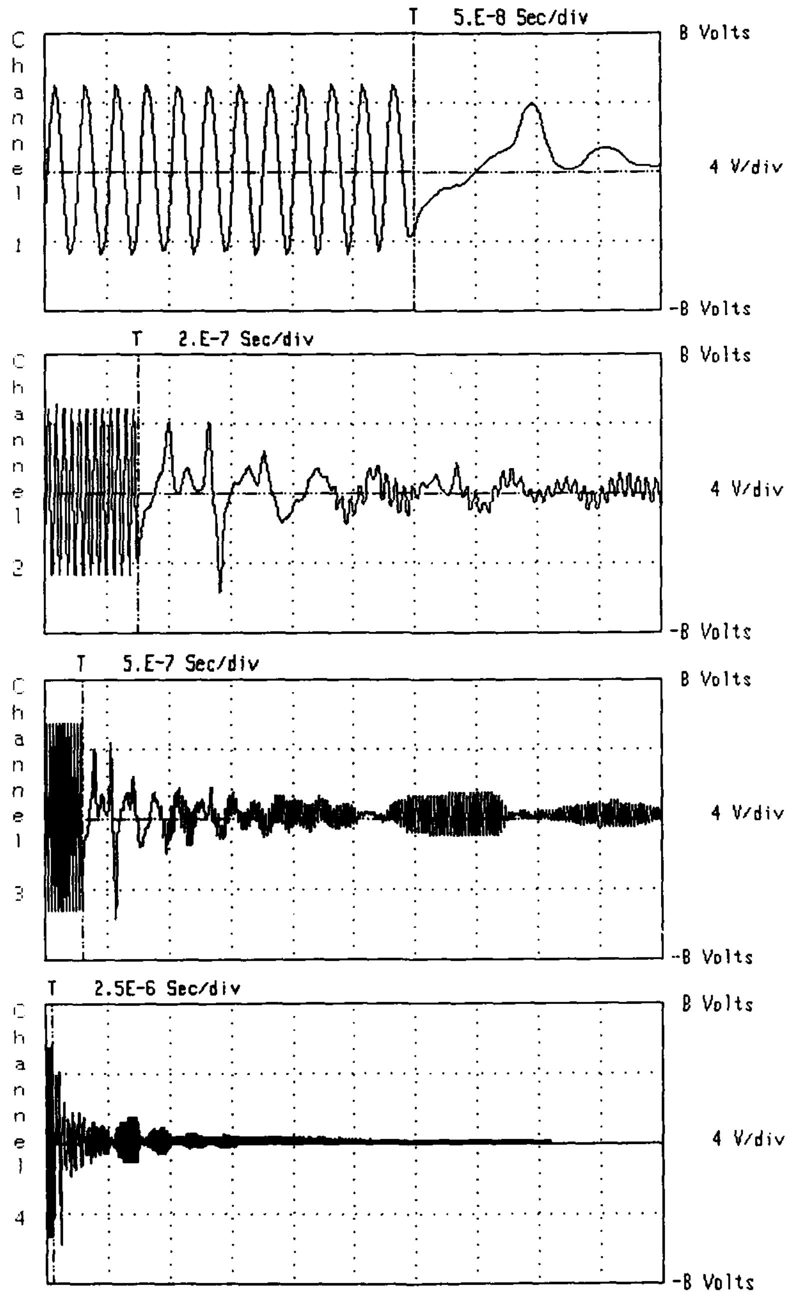

Figure (7) Response of PRC77 at 20 cm (f = 40 MHz). Note, from the third and fourth plots, that the radio is shut down for much longer times.

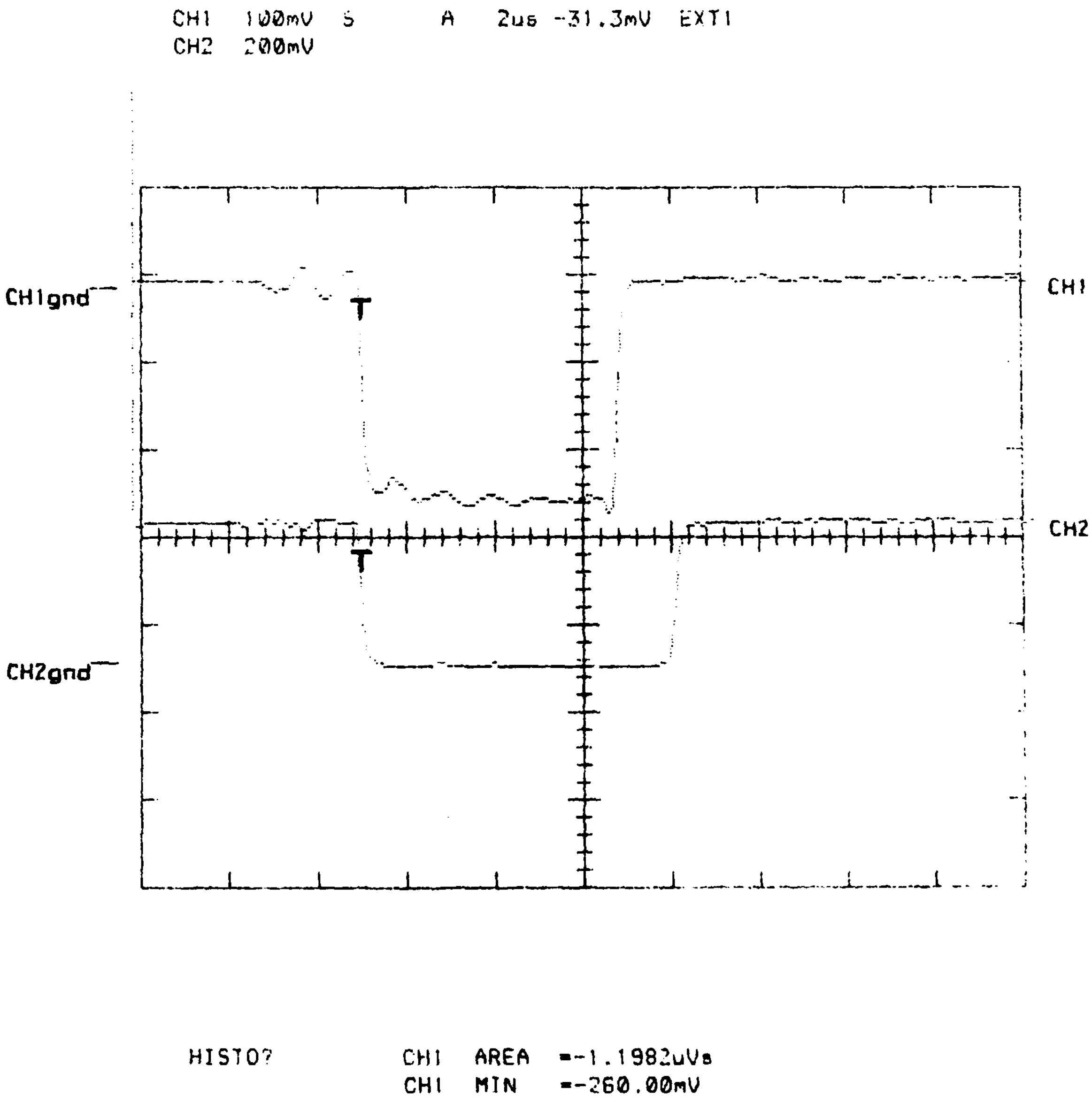

Figure (8) Results of DREO experiment at CRNL showing npn transistor response (lower trace) continuing after the LINAC pulse (upper trace). This would appear to be the basis for the PRC77 response.

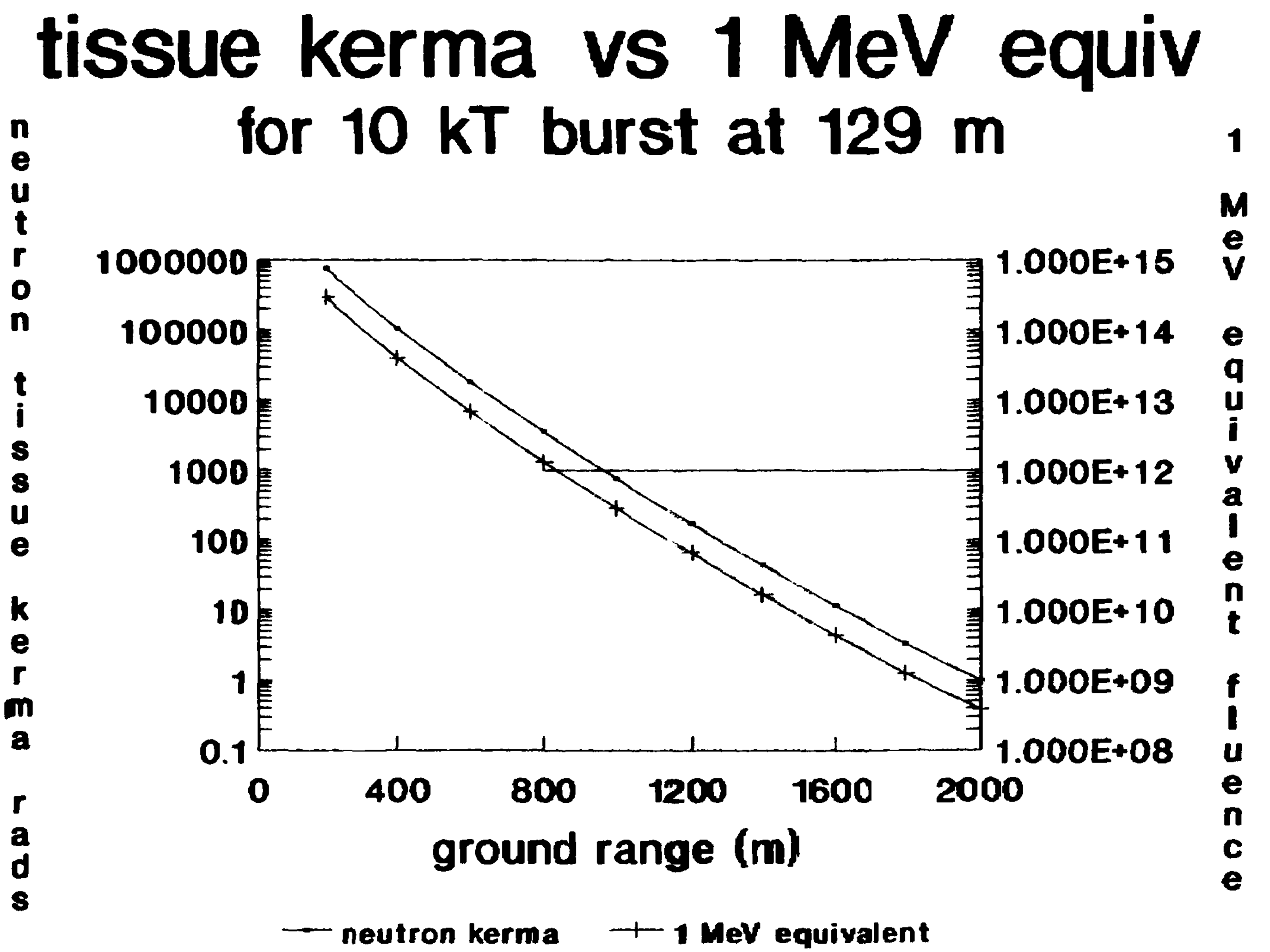

Figure (9) Comparison of neutron 1 MeV equivalent fluence and tissue kerma. Note the 10^{12} n/cm criteria intersecting at about 800 m.

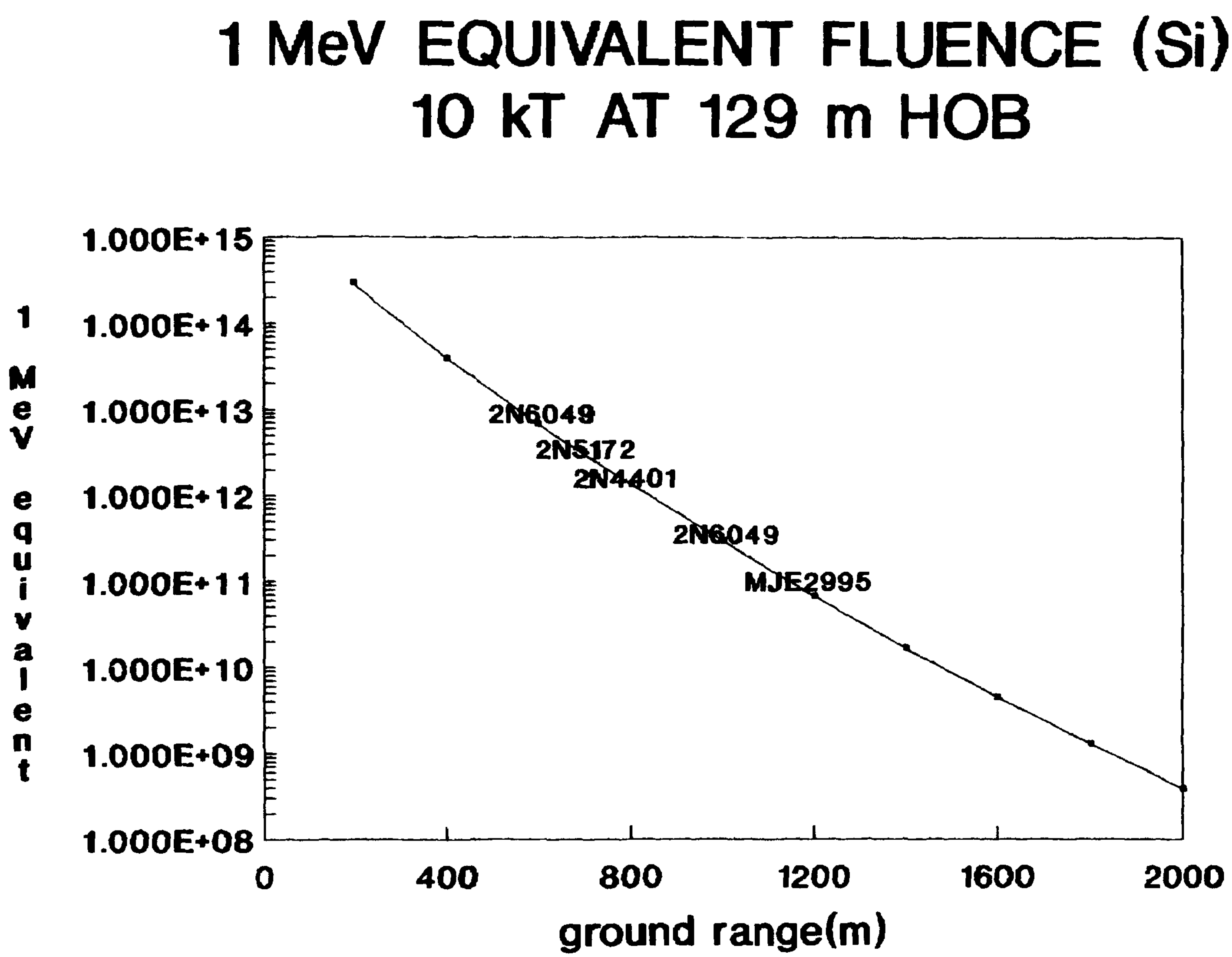

Figure (10) Results of DREO experiments at RMC superimposed on 1 MeV equivalent fluence. By reading down to the range axis, the distance at which 50% gain degradation for the particular transistor occurs may be found.

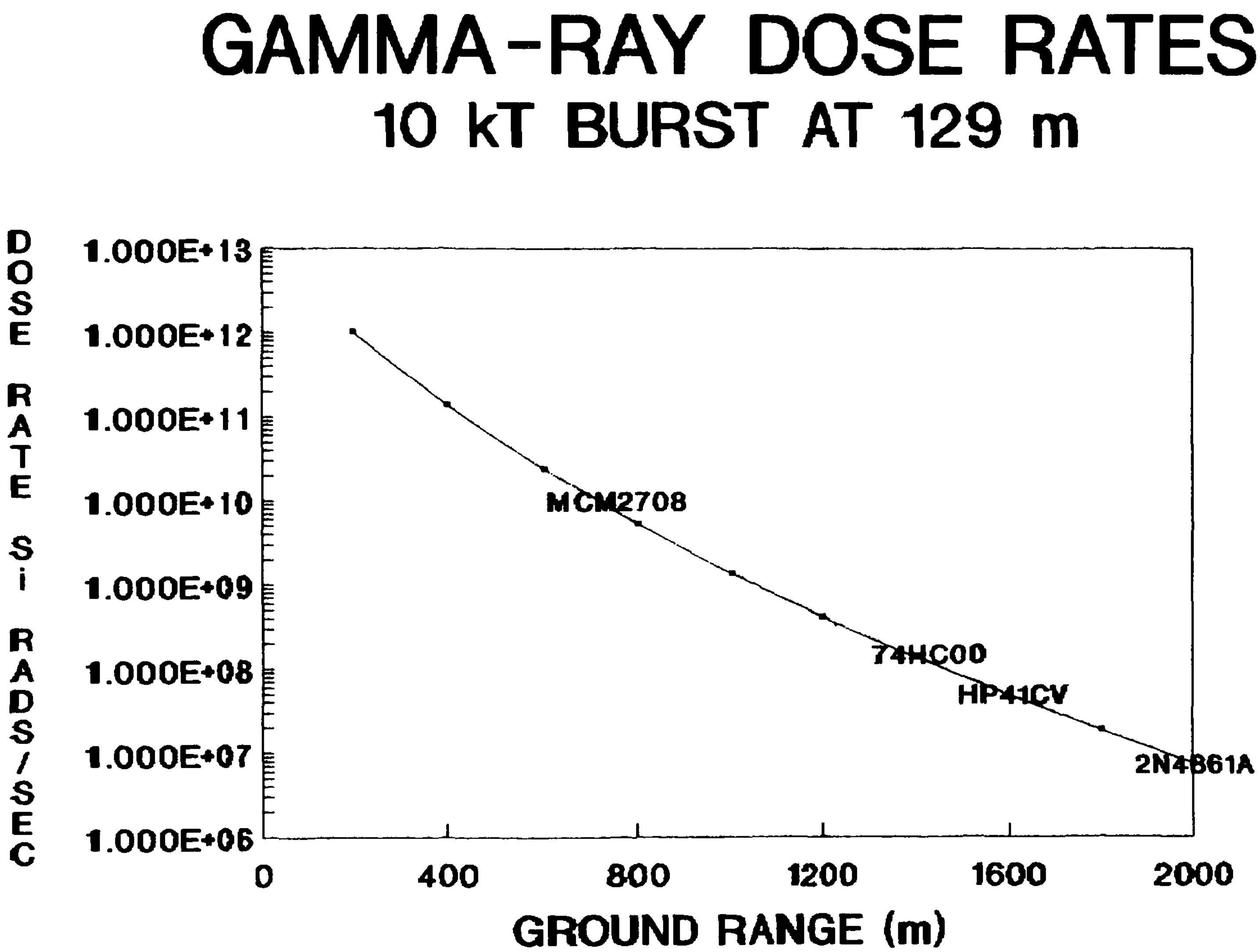

Figure (11) Results of DREO dose rate experiments superimposed on the predicted dose rates from ATR. Again reading down gives the ranges for the effects on the devices described in the text.

APPENDIX

ATR Output Used For This Report

```
*ATR VERSION 5 - - - SAIC (1 JAN 1989 REVISION )

*N-SOURCE(1)
*G-SOURCE(1)
*N-NORM 2E23
*G-NORM 5E22
*N-YIELD 1
*G-YIELD 1
*HS,M,60
*HT,M,1
*RH,M,200(200)2000
*TITLE 1 KT SFW AT 60 M HEIGHT
*DOSE/N/
*DOSE/G/
*DOSE/NG/
*EXC
```

ATR PROBLEM NUMBER 1 1 KT SFW AT 60 M HEIGHT

* *

NEUTRON SOURCE INTERNAL FISSION
NORMALIZATION=2.000E+23 NEUTRON /KT, YIELD=1.000E+00 KT
TOTAL OUTPUT=2.000E+23 NEUTRON

SOURCE SPECTRUM

ENERGY(MEV)	N	N/MEV	ENERGY(MEV)	N	N/MEV
1.07E-05-2.90E-05	0.00E+00	0.00E+00	1.83E+00-2.31E+00	2.03E+22	4.24E+22
2.90E-05-1.01E-04	0.00E+00	0.00E+00	2.31E+00-3.01E+00	7.74E+21	1.11E+22
1.01E-04-1.23E-03	0.00E+00	0.00E+00	3.01E+00-4.07E+00	1.10E+22	1.03E+22
1.23E-03-2.19E-02	3.30E+21	1.60E+23	4.07E+00-4.97E+00	2.35E+21	2.62E+21
2.19E-02-1.11E-01	4.12E+22	4.63E+23	4.97E+00-6.38E+00	3.66E+21	2.60E+21
1.11E-01-1.58E-01	3.60E+21	7.66E+22	6.38E+00-8.19E+00	2.55E+21	1.41E+21
1.58E-01-5.50E-01	3.03E+22	7.72E+22	8.19E+00-1.00E+01	1.47E+21	8.11E+20
5.50E-01-1.11E+00	4.32E+22	7.71E+22	1.00E+01-1.22E+01	0.00E+00	0.00E+00
1.11E+00-1.83E+00	2.94E+22	4.08E+22	1.22E+01-1.49E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 1 1 KT SFW AT 60 M HEIGHT

* *

GAMMA SOURCE INTERNAL FISSION
NORMALIZATION=5.000E+22 GAMMA /KT, YIELD=1.000E+00 KT
TOTAL OUTPUT=5.000E+22 GAMMA

SOURCE SPECTRUM

ENERGY(MEV)	G	G/MEV	ENERGY(MEV)	G	G/MEV
1.00E-02-4.50E-02	1.63E+21	4.66E+22	2.00E+00-2.50E+00	1.87E+21	3.74E+21
4.50E-02-1.00E-01	8.22E+20	1.49E+22	2.50E+00-3.00E+00	1.11E+21	2.23E+21
1.00E-01-1.50E-01	2.44E+21	4.88E+22	3.00E+00-4.00E+00	1.05E+21	1.05E+21
1.50E-01-3.00E-01	5.16E+21	3.44E+22	4.00E+00-5.00E+00	3.73E+20	3.73E+20
3.00E-01-4.50E-01	6.79E+21	4.52E+22	5.00E+00-6.00E+00	1.32E+20	1.32E+20
4.50E-01-7.00E-01	1.01E+22	4.05E+22	6.00E+00-7.00E+00	4.62E+19	4.62E+19
7.00E-01-1.00E+00	8.17E+21	2.72E+22	7.00E+00-8.00E+00	1.89E+19	1.89E+19
1.00E+00-1.50E+00	7.04E+21	1.41E+22	8.00E+00-1.00E+01	7.87E+18	3.94E+18
1.50E+00-2.00E+00	3.21E+21	6.43E+21	1.00E+01-1.20E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 1 1 KT SFW AT 60 M HEIGHT

* *

GROUND LEVEL		.000KM,	.000GM/CM**2,	.000KFT,	.000MILES
HORIZ. RANGE	RH=	.200KM,	24.358GM/CM**2,	.656KFT,	.124MILES
*SLANT RANGE	RS=	.209KM,	25.468GM/CM**2,	.684KFT,	.130MILES
TARGET ALT.	HT=	.001KM,	.122GM/CM**2,	.003KFT,	.001MILES
SOURCE ALT.	HS=	.060KM,	7.329GM/CM**2,	.197KFT,	.037MILES

*SLANT ANGLE AN= -16.436DEGREES (COS= .95914)

*CALCULATED FROM OTHER COORDINATES

* *

NEUTRON DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= NON-IONIZING SI.
DOSE 7= IONIZING SILICON
DOSE 8= MID-HEAD
DOSE 9= 1MEV EQ. FLUENCE
DOSE10= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8	DOSE 9	DOSE10
2.000E+02 M	1.23E+06	9.40E+04	2.90E+04	9.67E+03	1.23E+04	1.19E+03	1.11E+03	3.99E+04	3.61E+13	0.00E+00
4.000E+02 M	1.32E+05	9.84E+03	3.42E+03	1.00E+03	1.55E+03	1.24E+02	1.11E+02	4.61E+03	3.75E+12	0.00E+00
6.000E+02 M	2.10E+04	1.55E+03	5.71E+02	1.58E+02	2.67E+02	1.94E+01	1.74E+01	7.61E+02	5.88E+11	0.00E+00
8.000E+02 M	3.99E+03	2.95E+02	1.12E+02	3.00E+01	5.28E+01	3.68E+00	3.37E+00	1.49E+02	1.11E+11	0.00E+00
1.000E+03 M	8.41E+02	6.25E+01	2.41E+01	6.39E+00	1.15E+01	7.80E-01	7.36E-01	3.20E+01	2.36E+10	0.00E+00
1.200E+03 M	1.92E+02	1.44E+01	5.54E+00	1.49E+00	2.66E+00	1.80E-01	1.76E-01	7.39E+00	5.46E+09	0.00E+00
1.400E+03 M	4.70E+01	3.56E+00	1.35E+00	3.71E-01	6.54E-01	4.49E-02	4.52E-02	1.81E+00	1.36E+09	0.00E+00
1.600E+03 M	1.23E+01	9.44E-01	3.52E-01	9.92E-02	1.71E-01	1.19E-02	1.24E-02	4.74E-01	3.62E+08	0.00E+00
1.800E+03 M	3.44E+00	2.67E-01	9.77E-02	2.83E-02	4.76E-02	3.40E-03	3.61E-03	1.32E-01	1.03E+08	0.00E+00
2.000E+03 M	1.02E+00	8.00E-02	2.88E-02	8.55E-03	1.41E-02	1.02E-03	1.11E-03	3.92E-02	3.10E+07	0.00E+00

* *

GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	2.67E+03	2.01E+03	1.23E+03	2.58E+03	1.83E+03	2.74E+03	1.44E+03	0.00E+00
4.000E+02 M	2.68E+02	2.00E+02	1.22E+02	2.68E+02	1.82E+02	2.86E+02	1.43E+02	0.00E+00
6.000E+02 M	4.41E+01	3.37E+01	2.09E+01	4.36E+01	3.07E+01	4.64E+01	2.42E+01	0.00E+00
8.000E+02 M	9.63E+00	7.57E+00	4.76E+00	9.32E+00	6.88E+00	9.86E+00	5.46E+00	0.00E+00
1.000E+03 M	2.54E+00	2.04E+00	1.30E+00	2.42E+00	1.85E+00	2.54E+00	1.48E+00	0.00E+00
1.200E+03 M	7.66E-01	6.27E-01	4.05E-01	7.19E-01	5.69E-01	7.53E-01	4.58E-01	0.00E+00
1.400E+03 M	2.55E-01	2.11E-01	1.38E-01	2.37E-01	1.92E-01	2.47E-01	1.55E-01	0.00E+00
1.600E+03 M	9.14E-02	7.66E-02	5.03E-02	8.46E-02	6.94E-02	8.80E-02	5.65E-02	0.00E+00
1.800E+03 M	3.48E-02	2.94E-02	1.94E-02	3.21E-02	2.66E-02	3.33E-02	2.17E-02	0.00E+00
2.000E+03 M	1.40E-02	1.19E-02	7.92E-03	1.29E-02	1.08E-02	1.34E-02	8.83E-03	0.00E+00

* *

NEUTRON GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	1.08E+04	9.91E+03	6.95E+03	9.90E+03	8.94E+03	1.02E+04	7.76E+03	0.00E+00
4.000E+02 M	1.80E+03	1.64E+03	1.15E+03	1.66E+03	1.48E+03	1.73E+03	1.28E+03	0.00E+00
6.000E+02 M	4.07E+02	3.68E+02	2.56E+02	3.77E+02	3.32E+02	3.92E+02	2.86E+02	0.00E+00
8.000E+02 M	1.12E+02	1.01E+02	6.99E+01	1.04E+02	9.09E+01	1.08E+02	7.80E+01	0.00E+00
1.000E+03 M	3.53E+01	3.16E+01	2.19E+01	3.29E+01	2.85E+01	3.42E+01	2.44E+01	0.00E+00
1.200E+03 M	1.24E+01	1.10E+01	7.64E+00	1.15E+01	9.96E+00	1.20E+01	8.50E+00	0.00E+00
1.400E+03 M	4.71E+00	4.20E+00	2.91E+00	4.39E+00	3.79E+00	4.57E+00	3.23E+00	0.00E+00
1.600E+03 M	1.92E+00	1.71E+00	1.19E+00	1.79E+00	1.55E+00	1.87E+00	1.32E+00	0.00E+00
1.800E+03 M	8.25E-01	7.35E-01	5.10E-01	7.69E-01	6.64E-01	8.01E-01	5.64E-01	0.00E+00
2.000E+03 M	3.70E-01	3.29E-01	2.29E-01	3.44E-01	2.98E-01	3.59E-01	2.53E-01	0.00E+00

* *

```
**EXECUTION COMPLETED
*HS,M,102
*N-YIELD 5
*G-YIELD 5
*TITLE 5 KT 102 M
*DOSE/N/
*DOSE/G/
*DOSE/NG/
*EXC
```

ATR PROBLEM NUMBER 2 5 KT 102 M

* *

NEUTRON SOURCE INTERNAL FISSION
NORMALIZATION=2.000E+23 NEUTRON /KT, YIELD=5.000E+00 KT
TOTAL OUTPUT=1.000E+24 NEUTRON

SOURCE SPECTRUM

ENERGY(MEV)	N	N/MEV	ENERGY(MEV)	N	N/MEV
1.07E-05-2.90E-05	0.00E+00	0.00E+00	1.83E+00-2.31E+00	1.02E+23	2.12E+23
2.90E-05-1.01E-04	0.00E+00	0.00E+00	2.31E+00-3.01E+00	3.87E+22	5.53E+22
1.01E-04-1.23E-03	0.00E+00	0.00E+00	3.01E+00-4.07E+00	5.48E+22	5.17E+22
1.23E-03-2.19E-02	1.65E+22	7.98E+23	4.07E+00-4.97E+00	1.18E+22	1.31E+22
2.19E-02-1.11E-01	2.06E+23	2.31E+24	4.97E+00-6.38E+00	1.83E+22	1.30E+22
1.11E-01-1.58E-01	1.80E+22	3.83E+23	6.38E+00-8.19E+00	1.27E+22	7.04E+21
1.58E-01-5.50E-01	1.51E+23	3.86E+23	8.19E+00-1.00E+01	7.34E+21	4.06E+21
5.50E-01-1.11E+00	2.16E+23	3.85E+23	1.00E+01-1.22E+01	0.00E+00	0.00E+00
1.11E+00-1.83E+00	1.47E+23	2.04E+23	1.22E+01-1.49E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 2 5 KT 102 M

* *

GAMMA SOURCE INTERNAL FISSION
NORMALIZATION=5.000E+22 GAMMA /KT, YIELD=5.000E+00 KT
TOTAL OUTPUT=2.500E+23 GAMMA

SOURCE SPECTRUM

ENERGY(MEV)	G	G/MEV	ENERGY(MEV)	G	G/MEV
1.00E-02-4.50E-02	8.15E+21	2.33E+23	2.00E+00-2.50E+00	9.36E+21	1.87E+22
4.50E-02-1.00E-01	4.11E+21	7.47E+22	2.50E+00-3.00E+00	5.56E+21	1.11E+22
1.00E-01-1.50E-01	1.22E+22	2.44E+23	3.00E+00-4.00E+00	5.27E+21	5.27E+21
1.50E-01-3.00E-01	2.58E+22	1.72E+23	4.00E+00-5.00E+00	1.86E+21	1.86E+21
3.00E-01-4.50E-01	3.39E+22	2.26E+23	5.00E+00-6.00E+00	6.62E+20	6.62E+20
4.50E-01-7.00E-01	5.06E+22	2.03E+23	6.00E+00-7.00E+00	2.31E+20	2.31E+20
7.00E-01-1.00E+00	4.08E+22	1.36E+23	7.00E+00-8.00E+00	9.44E+19	9.44E+19
1.00E+00-1.50E+00	3.52E+22	7.04E+22	8.00E+00-1.00E+01	3.94E+19	1.97E+19
1.50E+00-2.00E+00	1.61E+22	3.21E+22	1.00E+01-1.20E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 2 5 KT 102 M

* *

GROUND LEVEL		.000KM,	.000GM/CM**2,	.000KFT,	.000MILES
HORIZ. RANGE	RH=	.200KM,	24.259GM/CM**2,	.656KFT,	.124MILES
*SLANT RANGE	RS=	.224KM,	27.310GM/CM**2,	.735KFT,	.139MILES
TARGET ALT.	HT=	.001KM,	.122GM/CM**2,	.003KFT,	.001MILES
SOURCE ALT.	HS=	.102KM,	12.433GM/CM**2,	.335KFT,	.063MILES

*SLANT ANGLE AN= -26.794DEGREES (COS= .89263)
*CALCULATED FROM OTHER COORDINATES

NEUTRON DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= NON-IONIZING SI.
DOSE 7= IONIZING SILICON
DOSE 8= MID-HEAD
DOSE 9= 1MEV EQ. FLUENCE
DOSE10= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8	DOSE 9	DOSE10
2.000E+02 M	5.65E+06	4.30E+05	1.36E+05	4.41E+04	5.77E+04	5.45E+03	4.99E+03	1.86E+05	1.65E+14	0.00E+
4.000E+02 M	7.07E+05	5.24E+04	1.85E+04	5.32E+03	8.44E+03	6.58E+02	5.84E+02	2.48E+04	1.99E+13	0.00E+
6.000E+02 M	1.17E+05	8.65E+03	3.21E+03	8.77E+02	1.50E+03	1.08E+02	9.62E+01	4.27E+03	3.27E+12	0.00E+
8.000E+02 M	2.27E+04	1.68E+03	6.40E+02	1.70E+02	3.03E+02	2.09E+01	1.90E+01	8.50E+02	6.33E+11	0.00E+
1.000E+03 M	4.85E+03	3.60E+02	1.39E+02	3.68E+01	6.63E+01	4.49E+00	4.21E+00	1.85E+02	1.36E+11	0.00E+
1.200E+03 M	1.12E+03	8.34E+01	3.22E+01	8.60E+00	1.55E+01	1.04E+00	1.01E+00	4.29E+01	3.16E+10	0.00E+
1.400E+03 M	2.74E+02	2.07E+01	7.89E+00	2.15E+00	3.81E+00	2.61E-01	2.62E-01	1.06E+01	7.89E+09	0.00E+
1.600E+03 M	7.16E+01	5.48E+00	2.05E+00	5.76E-01	9.95E-01	6.94E-02	7.17E-02	2.76E+00	2.10E+09	0.00E+
1.800E+03 M	1.99E+01	1.54E+00	5.66E-01	1.64E-01	2.76E-01	1.96E-02	2.08E-02	7.67E-01	5.95E+08	0.00E+
2.000E+03 M	5.87E+00	4.60E-01	1.66E-01	4.91E-02	8.11E-02	5.88E-03	6.36E-03	2.26E-01	1.78E+08	0.00E+

* *

GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	1.15E+04	8.60E+03	5.23E+03	1.12E+04	7.84E+03	1.20E+04	6.14E+03	0.00E+00
4.000E+02 M	1.34E+03	1.00E+03	6.09E+02	1.35E+03	9.12E+02	1.44E+03	7.12E+02	0.00E+00
6.000E+02 M	2.30E+02	1.76E+02	1.09E+02	2.28E+02	1.60E+02	2.43E+02	1.26E+02	0.00E+00
8.000E+02 M	5.11E+01	4.01E+01	2.52E+01	4.95E+01	3.64E+01	5.24E+01	2.89E+01	0.00E+00
1.000E+03 M	1.36E+01	1.09E+01	6.94E+00	1.29E+01	9.89E+00	1.36E+01	7.91E+00	0.00E+00
1.200E+03 M	4.11E+00	3.36E+00	2.17E+00	3.86E+00	3.04E+00	4.04E+00	2.45E+00	0.00E+00
1.400E+03 M	1.37E+00	1.13E+00	7.39E-01	1.27E+00	1.03E+00	1.33E+00	8.33E-01	0.00E+00
1.600E+03 M	4.91E-01	4.12E-01	2.70E-01	4.55E-01	3.73E-01	4.74E-01	3.03E-01	0.00E+00
1.800E+03 M	1.87E-01	1.58E-01	1.04E-01	1.73E-01	1.43E-01	1.79E-01	1.17E-01	0.00E+00
2.000E+03 M	7.53E-02	6.40E-02	4.25E-02	6.93E-02	5.79E-02	7.20E-02	4.74E-02	0.00E+00

* *

NEUTRON GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	5.44E+04	5.00E+04	3.50E+04	5.00E+04	4.51E+04	5.17E+04	3.92E+04	0.00E+00
4.000E+02 M	9.72E+03	8.86E+03	6.19E+03	8.97E+03	7.99E+03	9.30E+03	6.92E+03	0.00E+00
6.000E+02 M	2.23E+03	2.02E+03	1.40E+03	2.07E+03	1.82E+03	2.15E+03	1.57E+03	0.00E+00
8.000E+02 M	6.19E+02	5.56E+02	3.86E+02	5.75E+02	5.02E+02	5.98E+02	4.31E+02	0.00E+00
1.000E+03 M	1.96E+02	1.75E+02	1.21E+02	1.82E+02	1.58E+02	1.90E+02	1.35E+02	0.00E+00
1.200E+03 M	6.88E+01	6.14E+01	4.25E+01	6.41E+01	5.54E+01	6.67E+01	4.73E+01	0.00E+00
1.400E+03 M	2.63E+01	2.34E+01	1.62E+01	2.45E+01	2.12E+01	2.55E+01	1.80E+01	0.00E+00
1.600E+03 M	1.08E+01	9.58E+00	6.64E+00	1.00E+01	8.65E+00	1.04E+01	7.36E+00	0.00E+00
1.800E+03 M	4.63E+00	4.12E+00	2.86E+00	4.31E+00	3.72E+00	4.49E+00	3.17E+00	0.00E+00
2.000E+03 M	2.07E+00	1.85E+00	1.28E+00	1.93E+00	1.67E+00	2.01E+00	1.42E+00	0.00E+00

* *

**EXECUTION COMPLETED
*HS,M,129
*N-YIELD 10
*G-YIELD 10
*TITLE 10 KT AT 129 M
*EXC

ATR PROBLEM NUMBER 3 10 KT AT 129 M

* *

NEUTRON SOURCE INTERNAL FISSION
NORMALIZATION=2.000E+23 NEUTRON /KT, YIELD=1.000E+01 KT
TOTAL OUTPUT=2.000E+24 NEUTRON

SOURCE SPECTRUM

ENERGY(MEV)	N	N/MEV	ENERGY(MEV)	N	N/MEV
1.07E-05-2.90E-05	0.00E+00	0.00E+00	1.83E+00-2.31E+00	2.03E+23	4.24E+23
2.90E-05-1.01E-04	0.00E+00	0.00E+00	2.31E+00-3.01E+00	7.74E+22	1.11E+23
1.01E-04-1.23E-03	0.00E+00	0.00E+00	3.01E+00-4.07E+00	1.10E+23	1.03E+23
1.23E-03-2.19E-02	3.30E+22	1.60E+24	4.07E+00-4.97E+00	2.35E+22	2.62E+22
2.19E-02-1.11E-01	4.12E+23	4.63E+24	4.97E+00-6.38E+00	3.66E+22	2.60E+22
1.11E-01-1.58E-01	3.60E+22	7.66E+23	6.38E+00-8.19E+00	2.55E+22	1.41E+22
1.58E-01-5.50E-01	3.03E+23	7.72E+23	8.19E+00-1.00E+01	1.47E+22	8.11E+21
5.50E-01-1.11E+00	4.32E+23	7.71E+23	1.00E+01-1.22E+01	0.00E+00	0.00E+00
1.11E+00-1.83E+00	2.94E+23	4.08E+23	1.22E+01-1.49E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 3 10 KT AT 129 M

* *

GAMMA SOURCE INTERNAL FISSION
NORMALIZATION=5.000E+22 GAMMA /KT, YIELD=1.000E+01 KT
TOTAL OUTPUT=5.000E+23 GAMMA

SOURCE SPECTRUM

ENERGY(MEV)	G	G/MEV	ENERGY(MEV)	G	G/MEV
1.00E-02-4.50E-02	1.63E+22	4.66E+23	2.00E+00-2.50E+00	1.87E+22	3.74E+22
4.50E-02-1.00E-01	8.22E+21	1.49E+23	2.50E+00-3.00E+00	1.11E+22	2.23E+22
1.00E-01-1.50E-01	2.44E+22	4.88E+23	3.00E+00-4.00E+00	1.05E+22	1.05E+22
1.50E-01-3.00E-01	5.16E+22	3.44E+23	4.00E+00-5.00E+00	3.73E+21	3.73E+21
3.00E-01-4.50E-01	6.79E+22	4.52E+23	5.00E+00-6.00E+00	1.32E+21	1.32E+21
4.50E-01-7.00E-01	1.01E+23	4.05E+23	6.00E+00-7.00E+00	4.62E+20	4.62E+20
7.00E-01-1.00E+00	8.17E+22	2.72E+23	7.00E+00-8.00E+00	1.89E+20	1.89E+20
1.00E+00-1.50E+00	7.04E+22	1.41E+23	8.00E+00-1.00E+01	7.87E+19	3.94E+19
1.50E+00-2.00E+00	3.21E+22	6.43E+22	1.00E+01-1.20E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 3 10 KT AT 129 M

* *

GROUND LEVEL		.000KM,	.000GM/CM**2,	.000KFT,	.000MILES
HORIZ. RANGE	RH=	.200KM,	24.195GM/CM**2,	.656KFT,	.124MILES
*SLANT RANGE	RS=	.237KM,	28.905GM/CM**2,	.779KFT,	.148MILES
TARGET ALT.	HT=	.001KM,	.122GM/CM**2,	.003KFT,	.001MILES
SOURCE ALT.	HS=	.129KM,	15.704GM/CM**2,	.423KFT,	.080MILES

*SLANT ANGLE AN= -32.619DEGREES (COS= .84227)
*CALCULATED FROM OTHER COORDINATES

* *

NEUTRON DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= NON-IONIZING SI.
DOSE 7= IONIZING SILICON
DOSE 8= MID-HEAD
DOSE 9= 1MEV EQ. FLUENCE
DOSE10= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8	DOSE 9	DOSE10
2.000E+02 M	1.01E+07	7.68E+05	2.47E+05	7.86E+04	1.05E+05	9.71E+03	8.82E+03	3.37E+05	2.94E+14	0.00E+0
4.000E+02 M	1.42E+06	1.05E+05	3.72E+04	1.06E+04	1.71E+04	1.32E+03	1.16E+03	4.99E+04	3.98E+13	0.00E+0
6.000E+02 M	2.44E+05	1.80E+04	6.68E+03	1.82E+03	3.14E+03	2.24E+02	1.99E+02	8.89E+03	6.78E+12	0.00E+0
8.000E+02 M	4.81E+04	3.54E+03	1.36E+03	3.59E+02	6.41E+02	4.41E+01	4.00E+01	1.80E+03	1.33E+12	0.00E+0
1.000E+03 M	1.04E+04	7.68E+02	2.98E+02	7.84E+01	1.42E+02	9.57E+00	8.94E+00	3.95E+02	2.90E+11	0.00E+0
1.200E+03 M	2.40E+03	1.79E+02	6.93E+01	1.84E+01	3.33E+01	2.24E+00	2.17E+00	9.23E+01	6.78E+10	0.00E+0
1.400E+03 M	5.90E+02	4.46E+01	1.70E+01	4.64E+00	8.23E+00	5.61E-01	5.62E-01	2.28E+01	1.70E+10	0.00E+0
1.600E+03 M	1.54E+02	1.18E+01	4.42E+00	1.24E+00	2.15E+00	1.50E-01	1.54E-01	5.96E+00	4.53E+09	0.00E+0
1.800E+03 M	4.30E+01	3.33E+00	1.22E+00	3.52E-01	5.96E-01	4.23E-02	4.48E-02	1.65E+00	1.28E+09	0.00E+0
2.000E+03 M	1.26E+01	9.90E-01	3.57E-01	1.06E-01	1.75E-01	1.27E-02	1.37E-02	4.86E-01	3.83E+08	0.00E+0

* *

GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	1.98E+04	1.48E+04	8.95E+03	1.95E+04	1.35E+04	2.08E+04	1.05E+04	0.00E+00
4.000E+02 M	2.60E+03	1.93E+03	1.18E+03	2.61E+03	1.76E+03	2.79E+03	1.38E+03	0.00E+00
6.000E+02 M	4.62E+02	3.52E+02	2.17E+02	4.57E+02	3.21E+02	4.87E+02	2.52E+02	0.00E+00
8.000E+02 M	1.04E+02	8.15E+01	5.11E+01	1.01E-02	7.41E+01	1.07E+02	5.88E+01	0.00E+00
1.000E+03 M	2.78E+01	2.23E+01	1.42E+01	2.65E+01	2.03E+01	2.79E+01	1.62E+01	0.00E+00
1.200E+03 M	8.46E+00	6.91E+00	4.45E+00	7.95E+00	6.27E+00	8.32E+00	5.05E+00	0.00E+00
1.400E+03 M	2.83E+00	2.34E+00	1.52E+00	2.63E+00	2.12E+00	2.75E+00	1.72E+00	0.00E+00
1.600E+03 M	1.02E+00	8.51E-01	5.58E-01	9.41E-01	7.71E-01	9.79E-01	6.27E-01	0.00E+00
1.800E+03 M	3.87E-01	3.27E-01	2.16E-01	3.57E-01	2.96E-01	3.72E-01	2.42E-01	0.00E+00
2.000E+03 M	1.56E-01	1.33E-01	8.81E-02	1.44E-01	1.20E-01	1.49E-01	9.82E-02	0.00E+00

* *

NEUTRON GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	1.03E+05	9.49E+04	6.65E+04	9.50E+04	8.56E+04	9.83E+04	7.43E+04	0.00E+00
4.000E+02 M	1.97E+04	1.80E+04	1.26E+04	1.82E+04	1.62E+04	1.89E+04	1.40E+04	0.00E+00
6.000E+02 M	4.62E+03	4.18E+03	2.91E+03	4.28E+03	3.77E+03	4.45E+03	3.25E+03	0.00E+00
8.000E+02 M	1.29E+03	1.16E+03	8.06E+02	1.20E+03	1.05E+03	1.25E+03	8.99E+02	0.00E+00
1.000E+03 M	4.11E+02	3.68E+02	2.55E+02	3.82E+02	3.32E+02	3.98E+02	2.84E+02	0.00E+00
1.200E+03 M	1.45E+02	1.29E+02	8.95E+01	1.35E+02	1.17E+02	1.40E+02	9.96E+01	0.00E+00
1.400E+03 M	5.55E+01	4.94E+01	3.43E+01	5.17E+01	4.47E+01	5.38E+01	3.80E+01	0.00E+00
1.600E+03 M	2.27E+01	2.02E+01	1.40E+01	2.12E+01	1.83E+01	2.21E+01	1.56E+01	0.00E+00
1.800E+03 M	9.80E+00	8.73E+00	6.06E+00	9.13E+00	7.88E+00	9.51E+00	6.70E+00	0.00E+00
2.000E+03 M	4.39E+00	3.91E+00	2.72E+00	4.09E+00	3.53E+00	4.26E+00	3.00E+00	0.00E+00

* *

```
**EXECUTION COMPLETED
*HS,M,278
*N-YIELD 100
*G-YIELD 100
*TITLE 100 KT AT 278 M
*EXC
```

ATR PROBLEM NUMBER 4 100 KT AT 278 M

* *

NEUTRON SOURCE INTERNAL FISSION
NORMALIZATION=2.000E+23 NEUTRON /KT, YIELD=1.000E+02 KT
TOTAL OUTPUT=2.000E+25 NEUTRON

SOURCE SPECTRUM

ENERGY(MEV)	N	N/MEV	ENERGY(MEV)	N	N/MEV
1.07E-05-2.90E-05	0.00E+00	0.00E+00	1.83E+00-2.31E+00	2.03E+24	4.24E+24
2.90E-05-1.01E-04	0.00E+00	0.00E+00	2.31E+00-3.01E+00	7.74E+23	1.11E+24
1.01E-04-1.23E-03	0.00E+00	0.00E+00	3.01E+00-4.07E+00	1.10E+24	1.03E+24
1.23E-03-2.19E-02	3.30E+23	1.60E+25	4.07E+00-4.97E+00	2.35E+23	2.62E+23
2.19E-02-1.11E-01	4.12E+24	4.63E+25	4.97E+00-6.38E+00	3.66E+23	2.60E+23
1.11E-01-1.58E-01	3.60E+23	7.66E+24	6.38E+00-8.19E+00	2.55E+23	1.41E+23
1.58E-01-5.50E-01	3.03E+24	7.72E+24	8.19E+00-1.00E+01	1.47E+23	8.11E+22
5.50E-01-1.11E+00	4.32E+24	7.71E+24	1.00E+01-1.22E+01	0.00E+00	0.00E+00
1.11E+00-1.83E+00	2.94E+24	4.08E+24	1.22E+01-1.49E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 4 100 KT AT 278 M

* *

GAMMA SOURCE INTERNAL FISSION
NORMALIZATION=5.000E+22 GAMMA /KT, YIELD=1.000E+02 KT
TOTAL OUTPUT=5.000E+24 GAMMA

SOURCE SPECTRUM

ENERGY(MEV)	G	G/MEV	ENERGY(MEV)	G	G/MEV
1.00E-02-4.50E-02	1.63E+23	4.66E+24	2.00E+00-2.50E+00	1.87E+23	3.74E+23
4.50E-02-1.00E-01	8.22E+22	1.49E+24	2.50E+00-3.00E+00	1.11E+23	2.23E+23
1.00E-01-1.50E-01	2.44E+23	4.88E+24	3.00E+00-4.00E+00	1.05E+23	1.05E+23
1.50E-01-3.00E-01	5.16E+23	3.44E+24	4.00E+00-5.00E+00	3.73E+22	3.73E+22
3.00E-01-4.50E-01	6.79E+23	4.52E+24	5.00E+00-6.00E+00	1.32E+22	1.32E+22
4.50E-01-7.00E-01	1.01E+24	4.05E+24	6.00E+00-7.00E+00	4.62E+21	4.62E+21
7.00E-01-1.00E+00	8.17E+23	2.72E+24	7.00E+00-8.00E+00	1.89E+21	1.89E+21
1.00E+00-1.50E+00	7.04E+23	1.41E+24	8.00E+00-1.00E+01	7.87E+20	3.94E+20
1.50E+00-2.00E+00	3.21E+23	6.43E+23	1.00E+01-1.20E+01	0.00E+00	0.00E+00

* *

ATR PROBLEM NUMBER 4 100 KT AT 278 M

* *

GROUND LEVEL		.000KM,	.000GM/CM**2,	.000KFT,	.000MILES
HORIZ. RANGE	RH=	.200KM,	23.848GM/CM**2,	.656KFT,	.124MILES
*SLANT RANGE	RS=	.342KM,	41.291GM/CM**2,	1.121KFT,	.212MILES
TARGET ALT.	HT=	.001KM,	.122GM/CM**2,	.003KFT,	.001MILES
SOURCE ALT.	HS=	.278KM,	33.600GM/CM**2,	.912KFT,	.173MILES

*SLANT ANGLE AN= -54.170DEGREES (COS= .58538)

*CALCULATED FROM OTHER COORDINATES

* *

NEUTRON DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= NON-IONIZING SI.
DOSE 7= IONIZING SILICON
DOSE 8= MID-HEAD
DOSE 9= 1MEV EQ. FLUENCE
DOSE10= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8	DOSE 9	DOSE10
2.000E+02 M	3.94E+07	2.92E+06	1.02E+06	2.96E+05	4.56E+05	3.66E+04	3.20E+04	1.37E+06	1.11E+15	0.00E+0
4.000E+02 M	1.00E+07	7.34E+05	2.70E+05	7.42E+04	1.26E+05	9.17E+03	7.97E+03	3.60E+05	2.78E+14	0.00E+0
6.000E+02 M	2.23E+06	1.63E+05	6.20E+04	1.65E+04	2.93E+04	2.03E+03	1.78E+03	8.22E+04	6.16E+13	0.00E+0
8.000E+02 M	5.03E+05	3.69E+04	1.43E+04	3.74E+03	6.78E+03	4.59E+02	4.11E+02	1.89E+04	1.39E+13	0.00E+0
1.000E+03 M	1.17E+05	8.67E+03	3.39E+03	8.83E+02	1.62E+03	1.08E+02	9.99E+01	4.50E+03	3.27E+12	0.00E+0
1.200E+03 M	2.86E+04	2.13E+03	8.30E+02	2.19E+02	3.99E+02	2.67E+01	2.56E+01	1.11E+03	8.07E+11	0.00E+0
1.400E+03 M	7.31E+03	5.51E+02	2.11E+02	5.72E+01	1.02E+02	6.92E+00	6.88E+00	2.83E+02	2.10E+11	0.00E+0
1.600E+03 M	1.96E+03	1.50E+02	5.62E+01	1.57E+01	2.73E+01	1.89E+00	1.94E+00	7.57E+01	5.72E+10	0.00E+0
1.800E+03 M	5.52E+02	4.27E+01	1.57E+01	4.51E+00	7.67E+00	5.43E-01	5.71E-01	2.13E+01	1.64E+10	0.00E+0
2.000E+03 M	1.63E+02	1.28E+01	4.62E+00	1.36E+00	2.26E+00	1.63E-01	1.76E-01	6.29E+00	4.94E+09	0.00E+0

* *

GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	6.47E+04	4.75E+04	2.87E+04	6.53E+04	4.33E+04	7.01E+04	3.37E+04	0.00E+00
4.000E+02 M	1.59E+04	1.18E+04	7.20E+03	1.60E+04	1.08E+04	1.72E+04	8.41E+03	0.00E+00
6.000E+02 M	3.70E+03	2.82E+03	1.74E+03	3.67E+03	2.57E+03	3.91E+03	2.02E+03	0.00E+00
8.000E+02 M	9.51E+02	7.44E+02	4.67E+02	9.22E+02	6.77E+02	9.76E+02	5.37E+02	0.00E+00
1.000E+03 M	2.74E+02	2.19E+02	1.40E+02	2.61E+02	1.99E+02	2.74E+02	1.59E+02	0.00E+00
1.200E+03 M	8.70E+01	7.10E+01	4.57E+01	8.18E+01	6.44E+01	8.57E+01	5.18E+01	0.00E+00
1.400E+03 M	3.00E+01	2.48E+01	1.61E+01	2.79E+01	2.25E+01	2.91E+01	1.82E+01	0.00E+00
1.600E+03 M	1.10E+01	9.20E+00	6.03E+00	1.02E+01	8.33E+00	1.06E+01	6.77E+00	0.00E+00
1.800E+03 M	4.26E+00	3.59E+00	2.37E+00	3.93E+00	3.25E+00	4.08E+00	2.65E+00	0.00E+00
2.000E+03 M	1.73E+00	1.47E+00	9.75E-01	1.59E+00	1.33E+00	1.65E+00	1.09E+00	0.00E+00

* *

NEUTRON GAMMA DOSE VS. HORIZ. RANGE (RADS)

DOSE 1= ANS STANDARD-REM
DOSE 2= SOFT TISSUE
DOSE 3= MID-PHANTOM
DOSE 4= CONCRETE
DOSE 5= AIR
DOSE 6= IONIZING SILICON
DOSE 7= MID-HEAD
DOSE 8= USER SUPPLIED

HORIZ. RANGE	DOSE 1	DOSE 2	DOSE 3	DOSE 4	DOSE 5	DOSE 6	DOSE 7	DOSE 8
2.000E+02 M	5.17E+05	4.72E+05	3.31E+05	4.76E+05	4.26E+05	4.93E+05	3.70E+05	0.00E+00
4.000E+02 M	1.54E+05	1.40E+05	9.79E+04	1.43E+05	1.27E+05	1.48E+05	1.09E+05	0.00E+00
6.000E+02 M	4.40E+04	3.97E+04	2.76E+04	4.08E+04	3.58E+04	4.23E+04	3.08E+04	0.00E+00
8.000E+02 M	1.35E+04	1.21E+04	8.42E+03	1.25E+04	1.09E+04	1.30E+04	9.39E+03	0.00E+00
1.000E+03 M	4.53E+03	4.05E+03	2.81E+03	4.22E+03	3.66E+03	4.39E+03	3.13E+03	0.00E+00
1.200E+03 M	1.65E+03	1.47E+03	1.02E+03	1.54E+03	1.33E+03	1.60E+03	1.14E+03	0.00E+00
1.400E+03 M	6.48E+02	5.77E+02	4.00E+02	6.03E+02	5.21E+02	6.28E+02	4.44E+02	0.00E+00
1.600E+03 M	2.70E+02	2.40E+02	1.67E+02	2.51E+02	2.17E+02	2.62E+02	1.85E+02	0.00E+00
1.800E+03 M	1.18E+02	1.05E+02	7.29E+01	1.10E+02	9.48E+01	1.14E+02	8.06E+01	0.00E+00
2.000E+03 M	5.32E+01	4.75E+01	3.30E+01	4.96E+01	4.29E+01	5.17E+01	3.64E+01	0.00E+00

* *

**EXECUTION COMPLETED
*STOP
*FIN
Stop - Program terminated.

5.0 REFERENCES

1. L. Huszar, W.A. Woolson and E.A. Straker, "Version 4 of ATR", Defence Nuclear Agency Report No. DNA 3995F, January 1976.

2. T. Cousins and B.E. Hoffarth, "The Measured Response of Selected Electronic Components to Fast Pulse Electronics (U)", DREO Technical Note 88-13 (CONFIDENTIAL), May 1988.

3. T. Cousins, DREO Trip Report, "Visit to RMC SLOWPOKE Facility", 5 July 1988, DREO 1776-1 (PSD/NES).

4. S. Glasstone and P.J. Dolan, "The Effects of Nuclear Weapons", USDOD and USDEA, 1977, pp 16-18.

5. A. Friedman, Science Applications International Corporation, personal communication to T. Cousins, July 1988.

6. T.J. Jamieson and T. Cousins, "VPF Version 2", presented at NATO AEP-14 Meeting, Munich W.Germany, October 1988.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) DEFENCE RESEARCH ESTABLISHMENT OTTAWA DEPARTMENT OF NATIONAL DEFENCE OTTAWA, ONTARIO KOA 1Z4	2. SECURITY CLASSIFICATION (overall security classification of the document. including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

THE USE OF THE COMPUTER CODE ATR TO RELATE DREO EXPERIMENTAL RESULTS TO NUCLEAR BATTLEFIELD THREATS (UNCLASSIFIED)

4. AUTHORS (Last name, first name, middle initial)

COUSINS, THOMAS

5. DATE OF PUBLICATION (month and year of publication of document) FEBRUARY 1989	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 31	6b. NO. OF REFS (total cited in document) 6

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

TECHNICAL NOTE

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)
DEFENCE RESEARCH ESTABLISHMENT OTTAWA
DEPARTMENT OF NATIONAL DEFENCE
OTTAWA, ONTARIO KOA 1Z4

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) 041LS	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availabilty (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

13. ABSTRACT (*a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).*

The computer code ATR allows quick reliable predictions of the neutron and gamma-ray radiation environments to be expected on the battlefield. This report details how ATR output may be related to recent DREO experimental results, especially in the TREE (Transient Radiation Effects on Electronics) area. It is the conclusion of this work that the prompt gamma-ray dose rate effects will be the most serious on the battlefield.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Air-Transport of Radiation
Transient Radiation Effects on Electronics
Neutron
Gamma-Ray
Nuclear Weapons
Dose
Fluence
Dose Rate