663353

DP-1315

AEC RESEARCH AND DEVELOPMENT REPORT

TERMINATION OF NUCLEAR TRANSIENTS IN THE NUCLEAR TEST GAGE

J. P. CHURCH
W. S. DURANT

DU PONT
REG. U.S. PAT. OFF.

Savannah River Laboratory

Aiken, South Carolina

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.95

663353

DP-1315

Physics
(TID-4500, UC-34)

TERMINATION OF NUCLEAR TRANSIENTS IN THE NUCLEAR TEST GAGE

by

J. P. Church
W. S. Durant

Approved by

P. L. Roggenkamp, Research Manager
Theoretical Physics Division

and

J. M. Boswell, Research Manager
Reactor Engineering Division

January 1973

E. I. DU PONT DE NEMOURS & COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, S. C. 29801

CONTRACT AT(07-2)-1 WITH THE UNITED STATES ATOMIC ENERGY COMMISSION

ABSTRACT

The Nuclear Test Gage at the Savannah River Plant is analyzed for hypothetical transients resulting from supercriticality. Inherent shutdown mechanisms that are independent of the scram systems are postulated for the calculational model. When the scram systems are assumed to be inoperable, these shutdown mechanisms are shown to limit the maximum number of fissions during the transient. For a reactivity addition of unlimited positive linear ramp, the model is used to calculate that a maximum of $\sim 5.3 \times 10^{18}$ fissions have occurred at the time the facility is shut down by inherent self-limiting mechanisms. This is well below the 4.1×10^{19} fissions corresponding to total vaporization of the core. Both the calculated maximum and the core vaporization cases lead to off-site effects below 10-CFR-100 exposure guidelines. The maximum reactivity addition that could be incurred due to charging a test assembly having very high ^{235}U content would not cause a sensible temperature rise if the charging speed is less than 1.5 ft/sec and if the scram system is operable.

CONTENTS

LIST OF FIGURES

INTRODUCTION

The Nuclear Test Gage (NTG) has been used at the Savannah River Plant for many years[1] to measure the reactivity worth of fuel and target assemblies. The NTG is fueled with enriched uranium-aluminum alloy, is moderated with H_2O, and has zero coolant flow. The NTG operates in a subcritical mode; however, a special assembly with sufficient reactivity to cause supercriticality could theoretically be inserted in the NTG.

There are probable shutdown mechanisms that operate independently of the scram systems. The investigation described here determines, based on these shutdown mechanisms, the maximum number of fissions at shutdown even if the safety systems fail to operate. The maximum number of fissions before shutdown establishes the upper limit of possible off-site exposures in the unlikely event of such an incident.

In routine operation of the NTG, the assemblies to be tested are charged to the NTG by an automatic charging system at a rate of 0.51 ft/sec. However, manual charging of the assemblies at significantly higher speeds is possible. This study determines a set of parameter pairs (assembly Δk, charging speed) for which the present reactivity scram system would prevent a sensible temperature rise.

THE NUCLEAR TEST GAGE

DESCRIPTION

The Nuclear Test Gage (NTG) is a subcritical, light-water moderated device fueled with enriched uranium. The NTG is used to determine the reactivity worths of components to be irradiated in research or production reactors by comparison with standard pieces of known content (See Appendix). The operation of the NTG is based on the sensitivity of neutron multiplication to small changes in neutron absorption or production. Operation in the subcritical mode offers advantages both in safety and in speed over critical operation. The NTG and associated equipment are shown in Figure 1. The cutaway drawing in Figure 2 shows the major components of the assembly.

The lattice tank shown in Figure 3 is 38-7/8 inches long, 38-1/4 inches wide, and 44-1/4 inches high. The tank exterior is 1/4-inch-thick 1100-H14 aluminum. A 4.579-inch-

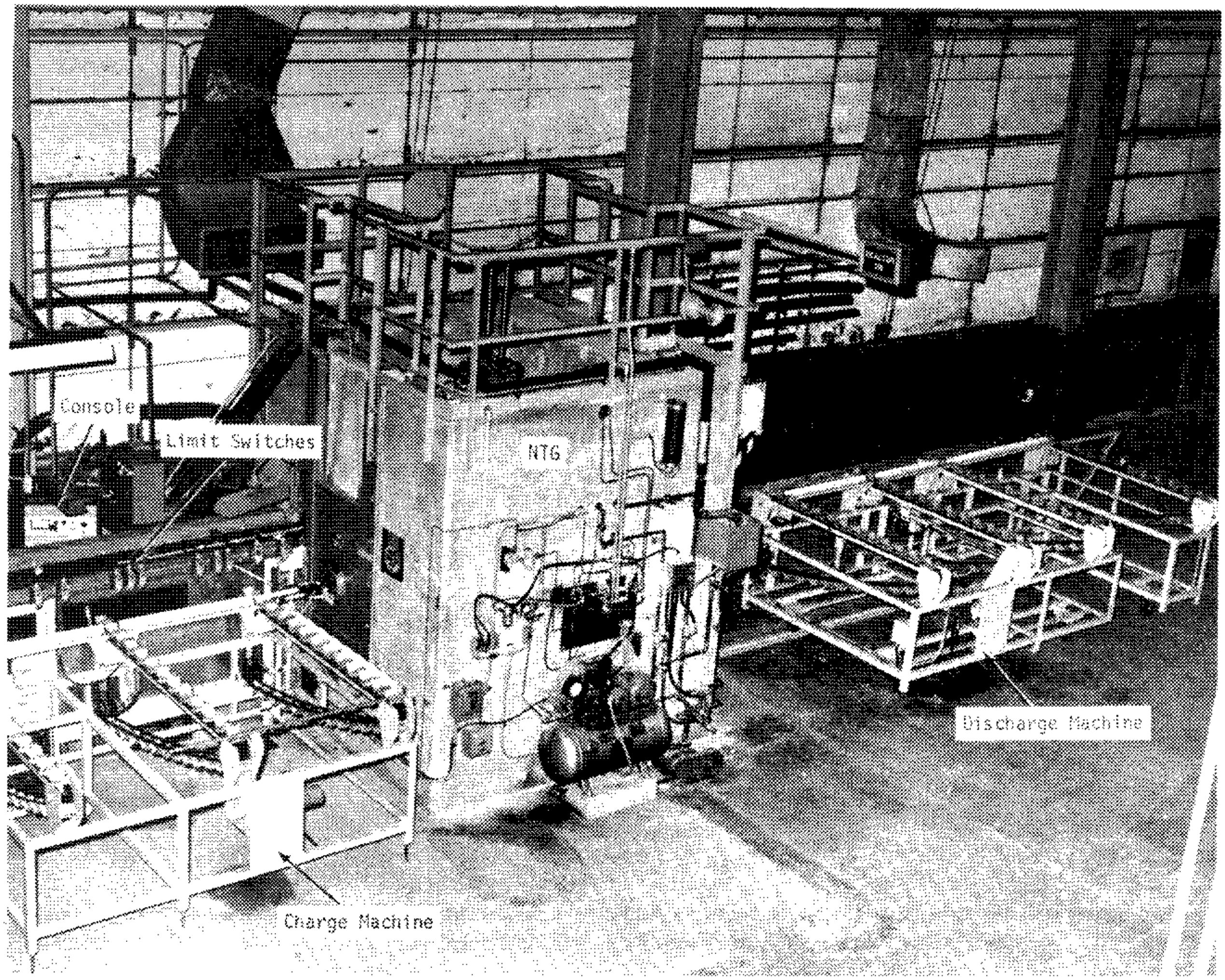

FIGURE 1. Nuclear Test Gage and Associated Equipment

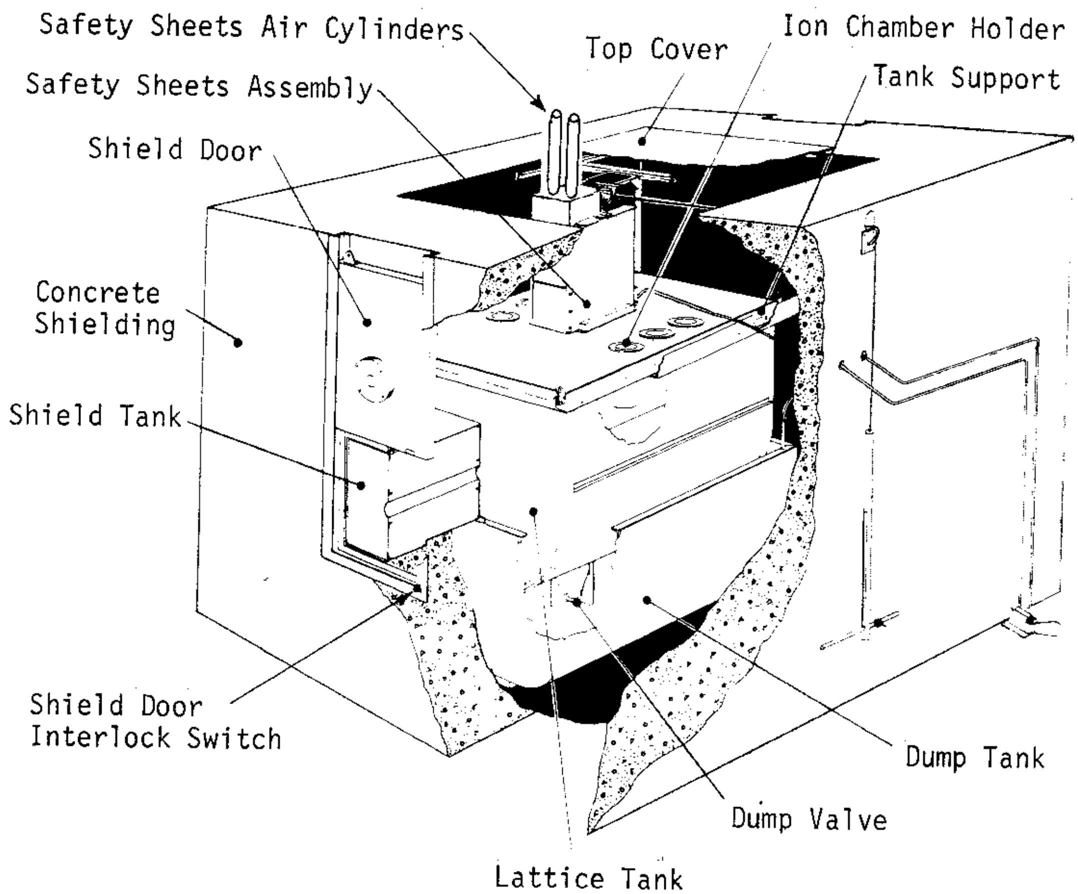

FIGURE 2. Cutaway View of the Nuclear Test Gage

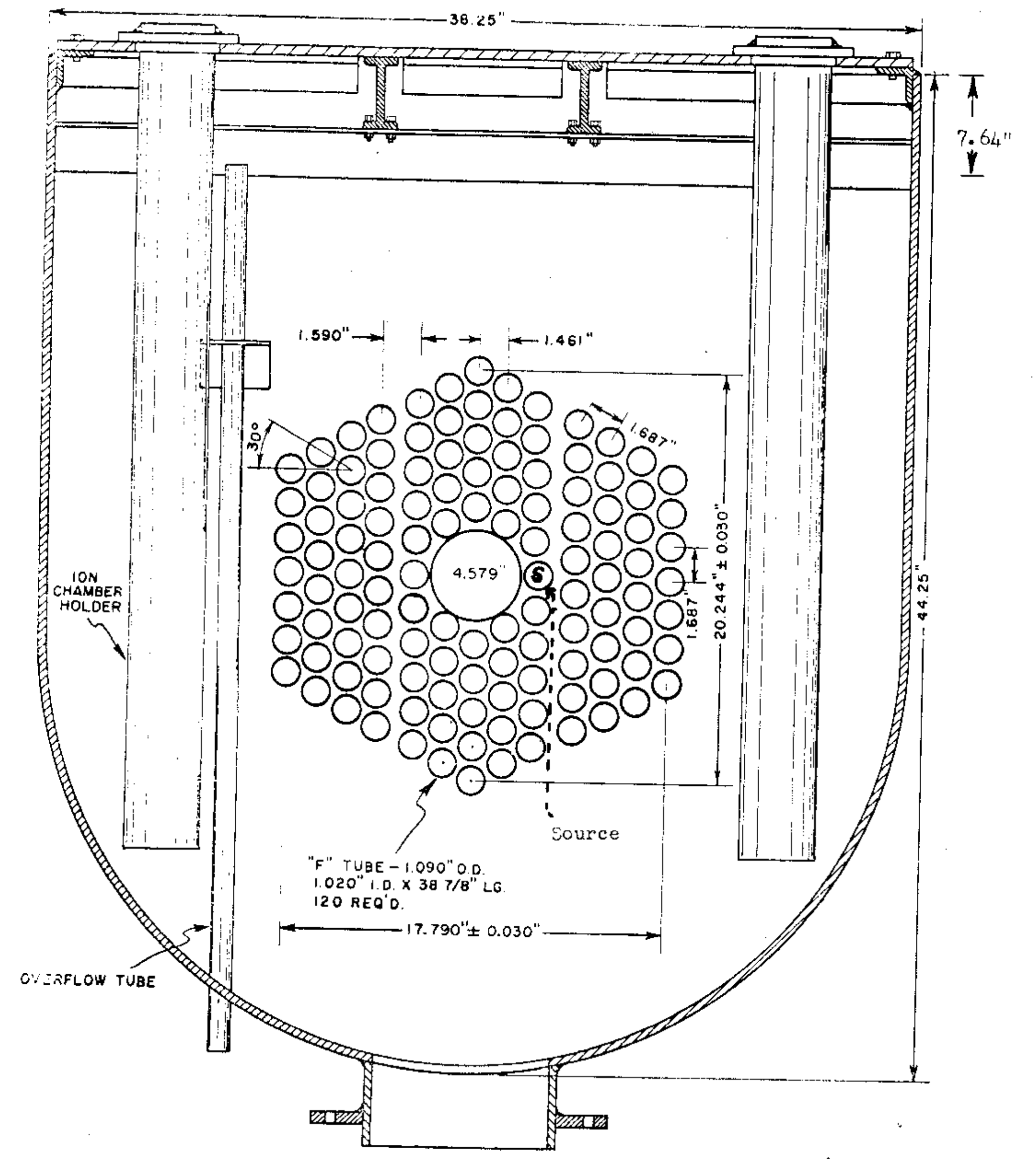

FIGURE 3. Nuclear Test Gage Tank and Lattice Arrangement

diameter sleeve extends through the tank to accommodate test material. This central test hole is surrounded by 120 tubes of Type 1100 aluminum, each 38-7/8 inches long. Each tube has an OD of 1.090 inches and an ID of 1.020 inches. The tubes are hexagonally arranged, with a center-to-center spacing of 1.687 inches.

The fuel is unclad enriched uranium-aluminum alloy in the form of cylinders, 1 inch in diameter and 12 inches long. The mass of fuel in the NTG with the standard lattice (166 slugs) is 3.64 kg ^{235}U (3.90 kg total uranium). In critical experiments with the NTG fuel at Oak Ridge National Laboratory, the optimum spacing for minimum critical mass was determined to be 1.687 inches.[2] With this spacing, any accidental deformation of the core produces a decrease in the reactivity of the device. A change of 0.1 inch in the lattice spacing reduces k by 1%.

The H_2O moderator is stored in the stainless steel dump tank (Figure 2) when the NTG is shut down. About 200 gallons of moderator are pumped into the lattice tank by a 10-gpm pump. Addition of water at this rate increases reactivity at a maximum rate of 0.0031 k/sec. The moderator level in the lattice tank is limited by a 1.02-inch-ID overflow tube, which empties into the dump tank.

Six ion chambers are located in the NTG lattice tank. The neutron-sensitive coating material is enriched ^{10}B. These chambers are not gamma compensated; thus, they measure the sum of the neutron and gamma fluxes.

Four of the six ion chambers are connected in parallel and feed the differential electrometer. The output of the differential electrometer determines the acceptability of the material being tested. The remaining two ion chambers actuate the safety system.

A 5.14-Ci RaBe source supplies neutrons to the assembly. The neutron yield is $\sim 1 \times 10^8$ neutrons/sec, based on a specific neutron yield of 19 neutrons/(μCi-sec). The active portion of the source is centered axially in the lattice, but is offset radially from the center line by 2.92 inches (center to center).

Test assembly fuel is charged into one end of the NTG, is passed through the test hole, and is discharged from the opposite end. A constant speed motor operating through a fixed gear train drives a pusher, which moves the test material into the test hole at 0.51 ft/sec. The automatic charging machine stops insertion of components when a scram signal is received. The coasting time of the machine is equivalent to 0.19 second at the normal drive speed.

NTG SAFETY SYSTEM

Although the NTG is intended to be subcritical, many safety features are included that are common to critical assemblies. The NTG is shut down (scrammed) by the simultaneous dropping of the two safety sheets and the dumping of the moderator. These two systems can be actuated either manually or automatically. Automatic scram circuits have separate ion chambers, battery power supplies, monitors, and scram relays. The ion chambers are at opposite sides of the NTG core. Scram set points correspond to an equilibrium reactivity of 0.990 k.

The two safety sheets are 34-3/8 inches long by 13 inches wide and contain 1/8-inch boral clad with 0.020-inch aluminum (1100-H14). The sheets are suspended by electromagnets attached to cables. Interruption of the electrical current to the electromagnets releases the safety sheets. When the sheets are inserted, the core is divided into three sections. The reactivity worth of the safety sheets is approximately 30% k. Approximately 0.4 second is required for the sheets to fall from the full-out position to the midplane.

The H_2O moderator can be removed quickly from the tank by means of an air-operated dump valve. The water will drain to the midplane of the core in less than 6 seconds. The NTG will scram (safety sheets fall and moderator dump valve opens) when:

- The key-operated master power switch is turned off.
- The master scram button is depressed.
- Either of the shield doors is raised.
- The electrical power fails to any instrument in the safety system.
- The test button on the response time measurement equipment is depressed.
- Both picoammeters are bypassed.
- The current reading on either picoammeter exceeds the trip point.
- The source rod retaining pin is removed.
- The source rod is removed.
- Charger speed exceeds 0.55 ft/sec.

ABNORMAL OPERATION OF THE NUCLEAR TEST GAGE

Although many rigid safety features and written procedures control the operation of the NTG, abnormal operation is possible. Individual operating errors or equipment failures that would have the greatest effect on NTG reactivity are test pieces with very high ^{235}U content, source rod removal, and manual charging at a fast rate; however, no single error or malfunction of equipment can cause a damaging transient.

HIGH ^{235}U CONTENT

If the ^{235}U content of the test piece were sufficiently high, the NTG could be made critical. During routine testing of a fuel tube, the ^{235}U content is procedurally limited to 125 g/ft, for which pulsed neutron experiments have indicated a k of 0.980 when the test assembly is centered in the test hole. The effect of ^{235}U content on k_{eff} is illustrated in Figure 4, with PDQ-5[3] calculations being normalized to experiments at 0 g/ft.

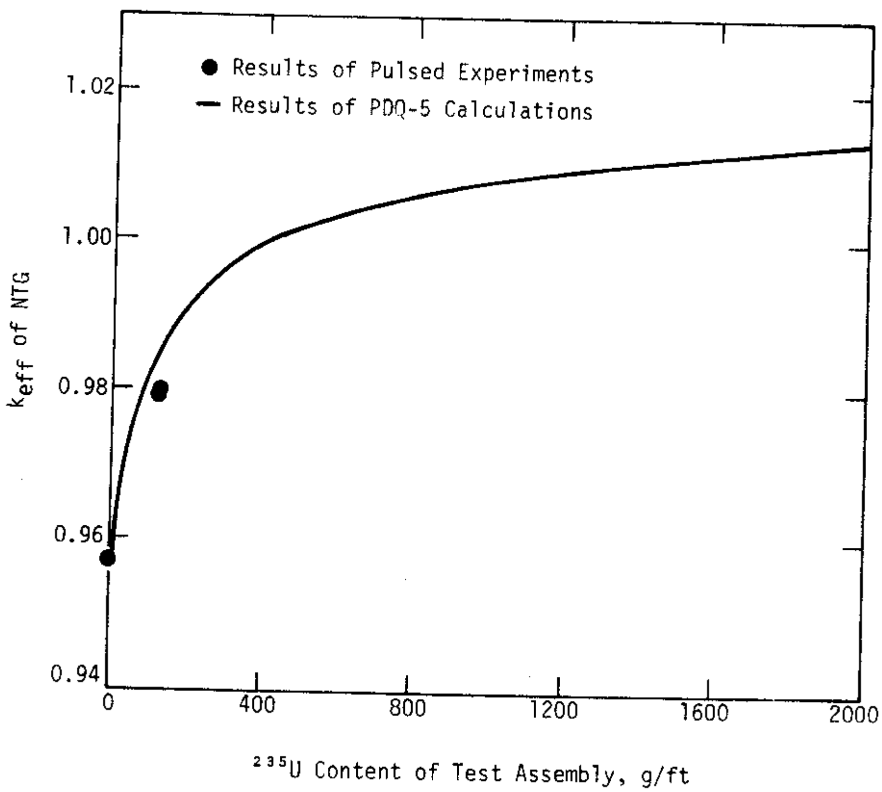

FIGURE 4. Reactivity of NTG as a Function of ^{235}U Loading of Test Assembly

SOURCE ROD REMOVAL

Complete removal of the source from the lattice will increase k by 0.0052. The NTG would not be critical, but approved limits would be exceeded.

Before the source rod can be removed, a padlock must be unlocked and removed; a scram is initiated when the source rod retaining pin or the source rod is removed. Safety sheet action will occur under these conditions before the rod can be moved. If removal of the source rod retaining pin or the rod itself did not cause a scram, k could increase from the maximum permissible value of slightly less than 0.990 to about 0.994.

MANUAL CHARGING AT A FAST RATE

Manual charging of the test assemblies to the NTG at much faster rates than normal machine charger speed (0.51 ft/sec) combined with a test tube of excessively high ^{235}U content could result in a relatively high rate of reactivity increase. High charging rates are unlikely because of procedural and equipment deterrents.

CONSEQUENCES OF ABNORMAL OPERATION

The consequences of abnormal operation were calculated by first determining the thermal and mechanical response of the NTG to nuclear excursions, and then incorporating this response into a point kinetics computer code (See p 21).

THERMAL AND MECHANICAL RESPONSE TO NUCLEAR EXCURSIONS

The physical response of the NTG core to a postulated rapid nuclear excursion is based largely on application of experimental data from the National Reactor Testing Station[4] and on kinetic studies of heterogeneous water reactors by TRW Systems.[5] The uncertainties associated with the estimates of destructive power ramps are large and difficult to define. Thus some of the numerical values quoted may be tenuous. In general, however, the responses discussed have been reported in the literature as having been experienced either deliberately or accidentally in nuclear transients.

The NTG core is assumed to have no radial or axial gradients in operating conditions. Neither are tolerances in dimensional characteristics nor variations in mechanical properties considered because of limitations in calculational capabilities.

Mechanisms For Heat Transfer

The lattice arrangement of the NTG would not provide effective heat removal from the fuel slugs during a rapid power excursion. As shown in Figure 5, the fuel slugs are smaller in diameter than the horizontal housings by 0.014 inch. Theoretically, there is only line contact between the slugs and housings. At all points except the line contact, air gaps of thicknesses up to 0.014 inch separate the slugs from the housings. For this geometry, an overall heat transfer coefficient of one pcu*/(hr-ft^2-°C) has been estimated from generalized convection equations.[6] Precise determination of the value was not made because the coefficient would have to be at least ~1000 pcu/(hr-ft^2-°C) to be comparable to gamma heating of the moderator during a rapid transient.

Heat removal by thermal radiation also would be of no significance. At the vaporization temperature of the fuel, less than one pcu/msec can be transferred from the fuel to the moderator by radiation. As discussed later, time intervals involved are so short that the effect is not important.

The only mode of energy transfer from the fuel to the moderator sufficiently large to consider during the initial phase of a power transient is gamma radiation. This amounts to <5% of the fission energy.[7]

Thus, the fuel slugs may be assumed to be initially heated adiabatically by the fission energy, adjusted for escape of gamma radiation and neutrinos. The effect of volumetric expansion of the slugs must be considered, however, in the physical response of the system to a rapid transient. The slugs would expand to fill the volume of the housings when the average slug temperature reached 520°C. Because of the reduction in air gap resistance and the large driving force afforded by the ~500°C temperature difference between the fuel and the moderator, the heat flux on the housing surface would rapidly rise above the 300,000 pcu/(hr-ft^2) burnout heat flux. Because the high vapor film resistance would prevent effective heat transfer to the moderator, the slug temperature would continue to increase adiabatically until the transient is terminated by core destruction. Because the total energy transferred by convection during surface boiling is very small as discussed later, the assumption of adiabatic heating throughout a rapid transient is reasonable.

* 1 pcu = quantity of heat required to increase the temperature of one pound of water 1°C.

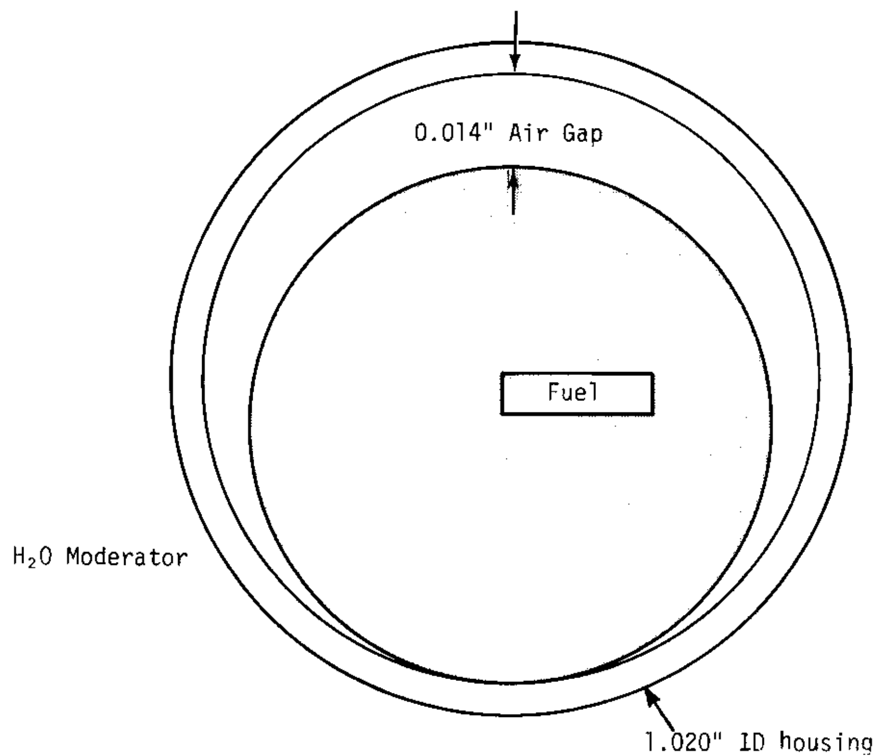

FIGURE 5. Schematic of NTG Fuel and Housing

Moderator Density Change

The density of the moderator has a significant effect on a transient because of its negative reactivity feedback. The calculated moderator density as a function of energy accumulated in the fuel slugs is shown in Figure 6. During the interval in which the slug average temperature increases to 520°C (35 MW-sec) the density change is effected only by the 5% gamma energy absorbed by the water. When the slugs expand to fill the housings, the moderator in contact with the housings undergoes a rapid transition from single phase liquid, through the nucleate boiling regime, and then into film boiling. Based on Reference 5, about 0.1% of the heat generated during the excursion is converted into steam through surface boiling which reduces the average density of the moderator. The volume of steam formed by 0.1% of the thermal energy is based on the specific volume at 100 psi, the approximate pressure estimated within the vapor film before fragmentation.[5]

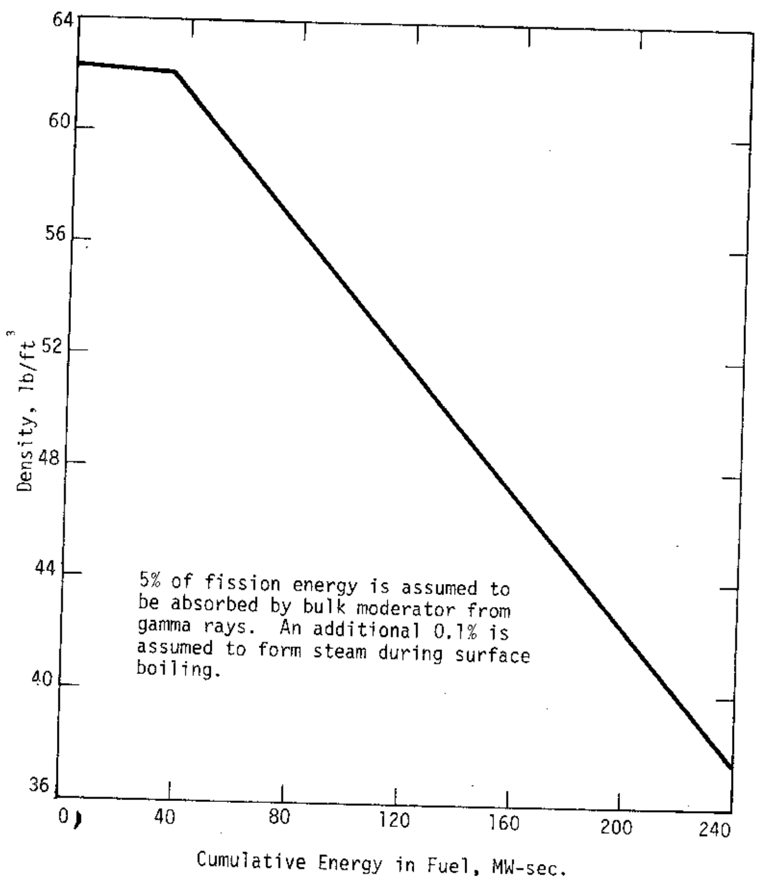

FIGURE 6. Density of Moderator During Rapid Power Transient in the NTG

Mechanisms For Shutdown

The mechanism for termination of a reactivity transient in the NTG depends on the total heat generation and on the duration of the transient. The least destructive shutdown mechanism would be boiling of the moderator. However, the rate of heat generation in the fuel must be extremely slow in order to transfer the heat without melting the fuel. About 270 MW-sec is required to raise the moderator temperature from 25°C to 100°C, but the duration must be about 2 hours because of air gap resistance between the slugs and the housings.

A relatively calm meltdown can be achieved if the total energy absorbed by the fuel lies in the range of 49 to 136 MW-sec. Forty nine MW-sec is sufficient to begin melting of the fuel. The debris will then drop toward the bottom of the vessel as approximated by the following equation:

$$X = 1/2g \left(\frac{\rho_s - \rho_1}{\rho_s}\right) t^2$$

where:

X = distance traveled, ft

g = acceleration due to gravity, 32.2 ft/sec^2

ρ_s = density of the fuel, lb/ft^3

ρ_1 = density of the moderator, lb/ft^3

t = time after start of movement, sec

Based on this equation, 350 milliseconds is assumed to allow sufficient core displacement to make the NTG deeply subcritical and to terminate the incident.

The effects of steam surrounding the fuel and of the viscosity of the fuel are assumed to be compensating. Based on data in Reference 4, the temperature of the fuel can reach about 1400°C without fragmenting during a rapid power transient. A temperature of 1400°C corresponds to about 136 MW-sec for the NTG under adiabatic conditions.

In the range of 136 to 220 MW-sec, the fuel can be fragmented by a water hammer effect from the collapse of the vapor film surrounding the molten fuel. An impact pressure pulse of about 100 psi results in a rapid increase in contact surface area for boiling. An estimated 10% of the total thermal energy in the fuel will be converted into high pressure steam when fragmentation occurs.[5]

If more than 220 MW-sec is absorbed by the fuel, the core will disintegrate from the sudden increase in specific volume caused by vaporization of the metal. Again, a steam explosion will occur.

Rate of energy addition determines whether the vaporization stage can be reached. The lifetime of the vapor film (steam) surrounding the housings is about 10 msec after the film begins to form.[5] If the energy in the fuel is between 136 and 220 MW-sec at a time 10 msec after surface boiling starts (35 MW-sec), the transient may be assumed to be terminated in an additional 0.5 msec based on impact experiments cited in Reference 5. About 0.3 msec is typical of the time required to fragment the metal, 0.1 msec for the pressure pulse rise time, and 0.1 msec to displace the core one slug diameter from its original position. The shock expansion was calculated to be in the acoustic regime. If more than 220 MW-sec is absorbed by the fuel, the core will disintegrate from the sudden increase in specific volume caused by vaporization of the metal. Again, a steam explosion will occur. If less than 10 msec has elapsed when 220 MW-sec has been reached, the transient may be assumed to be terminated 0.5 msec after the 220 MW-sec point.

Steam Explosions

The evaluation of shock wave pressure during postulated steam explosions is based on experiments of Stoner and Bleakney[8] who exploded small charges of TNT in the open air and measured the pressure registered at various distances from the charge. These data were expanded by Lipsett[9] for generalized use. Based on 136 MW-sec energy in the fuel at the minimum conditions for fragmentation and a 10% energy conversion, the equivalent mass of TNT is 7 lb.[9] At conditions for start of fuel vaporization, the TNT equivalent is 11 lb and that for total vaporization is 55 lb. It is unlikely, however, that more than a few percent of the core could be vaporized. The associated overpressures as a function of distance for explosions are plotted in Figure 7 for an unimpeded shock wave in air. At a distance of about 2 ft to the vessel wall or top, the shock pressure would be in the range of 600 to 1000 psi should a steam explosion occur.

Other energy sources that could contribute to the destruction of the NTG and surrounding facilities include the release of an additional ∿15% from chemical reaction.[10] If the temperature of the aluminum exceeds about 1700°C, ignition is likely, thus adding the hazard of fire from burning metal.

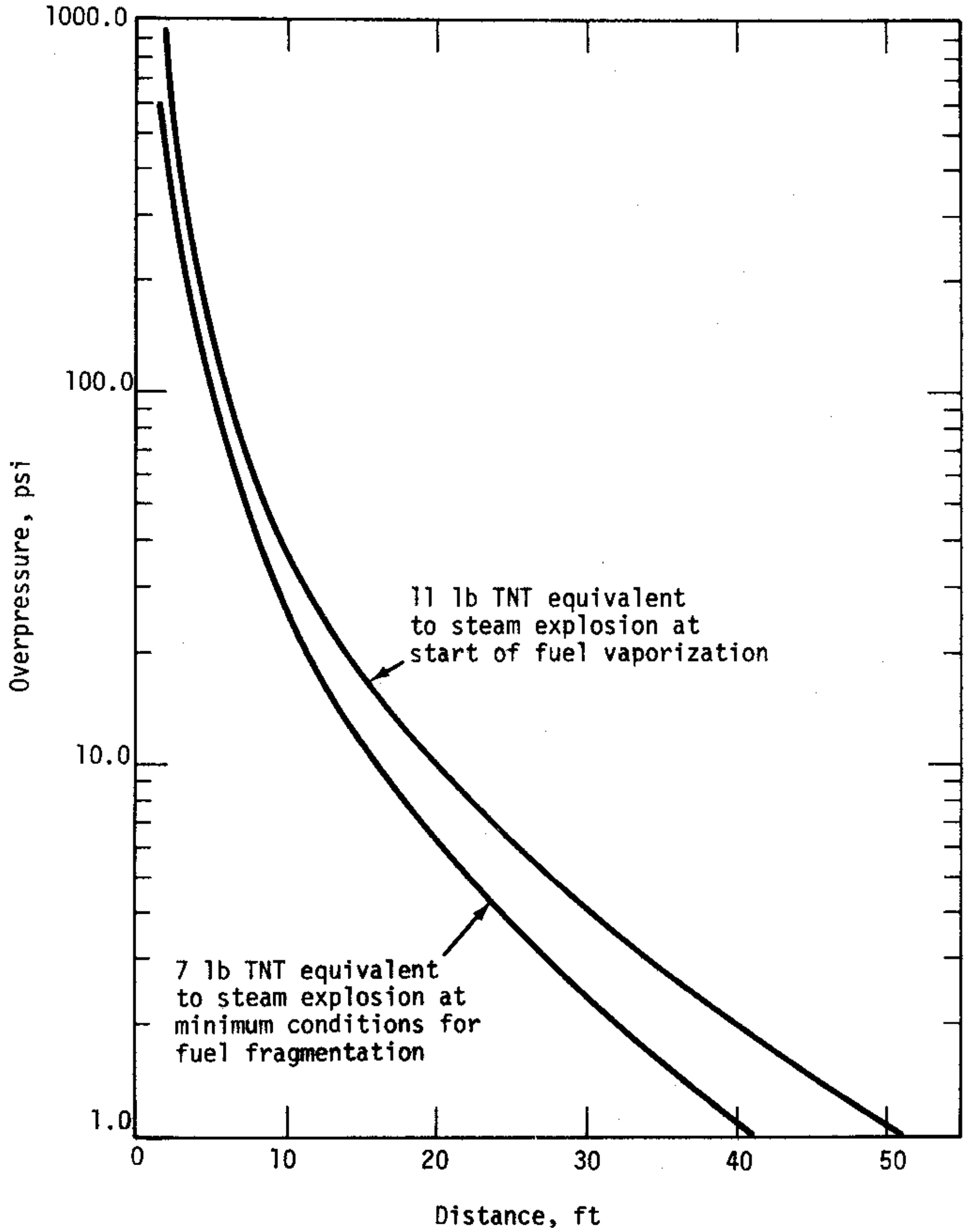

FIGURE 7. Overpressures Calculated for Steam Explosions in the NTG

Hydrogen Formation, Burning, or Explosion

Hydrogen formation, burning, or explosion would not be a significant consideration in the analysis of a rapid excursion in the NTG. The threshold temperature for reaction between steam and enriched uranium fuel in an aluminum matrix is about 1200°C. Above ∿1400°C fuel temperature, a steam explosion would probably occur with an energy release at least ten times that of a hydrogen explosion. The time interval in which a transient could be sustained for this narrow range of conditions where hydrogen generation could be a dominant factor is too small to permit significant hydrogen formation. Less than 1 ml of hydrogen would be generated during 100 msec interval before core destruction.

If, however, core disruption occurs without fragmentation, post-meltdown conditions could be aggravated by a small accumulation of hydrogen within the NTG vessel and a possible explosion. Although detailed calculations have not been made, shock pressures up to ∿80 psi are possible; however, they are more likely to be in the range 20 to 30 psi.[11]

SIMULATION OF KINETIC RESPONSE TO NUCLEAR EXCURSIONS

The physical phenomena described above were incorporated into a point kinetics model of the Nuclear Test Gage. This computer code was used to estimate the total fissions at shutdown for various possible excursions. The computer code, which computes transients for subcritical as well as critical systems, included provisions to account for the adiabatic heating effects and void reactivity feedback effects, and to represent the scram system particular to the NTG. The heat transfer coefficient is maintained at zero throughout the simulated transients.

The moderator temperature coefficient incorporated in the kinetics code was

$$\int_{T_o}^{T} dk = a\left[1 - \exp \quad -b(T-T_o)\right]$$

which gives the cumulative reactivity effect (k) due to heating the moderator from its equilibrium temperature T_o to T, where temperatures are expressed in °C. The void coefficient also included in the kinetics code was

$$\int_{520}^{T} dk = c\left[1-dT^{g}\right]$$

which gives the cumulative reactivity effect due to voids in the moderator expressed as a function of fuel assembly temperature T(°C). The reactivity is based on the correlation of moderator density vs energy absorbed in fuel (Figure 6). The coefficients a, b, c, d, and g in the above equations are constants determined from lattice calculations with the HAMMER[12] code.

The simplifications and assumptions in the calculational model are intended to be conservative. For example, the assumptions that the flux shape (and hence void distribution) is flat, and that all the fuel melts before slumping occurs are model simplifications. The value of 350 msec after melting is presumed sufficient time for the bottom assembly to have slumped down to the bottom of the tank. The geometry changes that would occur are not accounted for in the calculations, but the reactivity of the core would be decreased significantly by the melting that would occur first in the regions of highest flux.

The moderator and void coefficients discussed earlier are also somewhat conservative in that the moderator coefficient is calculated for 9% voids and the void coefficient is calculated for 20°C. However, based on HAMMER calculations, these negative reactivity effects enhance each other so that their effects are more than just additive as assumed.

Scram Systems Operable

Reactivity Scram System

The primary scram system is designed to prevent incidents due to charging highly reactive test assemblies. Scram set points correspond to an equilibrium core k_{eff} of 0.990. Initiation of a scram drops safety sheets and dumps the H_2O moderator. However, only the effect of the safety sheets is considered in this analysis because their response time is ten times faster than that of the moderator. The safety sheets have a 0.21-sec delay time before they enter the core, and are fully inserted at 0.53 sec with a total worth of 0.30 k. The automatic charging system routinely used to charge test assemblies to the NTG operates at a normal speed of 0.51 ft/sec. Standard operating procedure requires that the charging speed shall not exceed 0.55 ft/sec. However, charging assemblies manually at much higher speeds is possible. Tests indicate that manual charging speeds might range up to 14 ft/sec, while a probable manual charging speed might be one ft/sec.

A set of parameter pairs (test assembly Δk, charging speed) was calculated for which the NTG would show no sensible temperature rise provided the scram system operates properly. The reactivity worth curve of the safety sheets is shown in Figure 8. The reactivity worth of an assembly was computed assuming a cosine flux shape along its length. As discussed in the Appendix, this assumption is conservative. The scram was initiated in the code when the relative power (relative flux level) had increased to four times its initial value. This would correspond to an increase in k_{eff} from 0.96 to 0.99 if the relative flux values were equilibrium values. However, because the NTG was on a positive transient, by the time $\phi/\phi_o = 4$, the value of k_{eff} was significantly higher than 0.99. The actual value depended on the particular transient imposed.

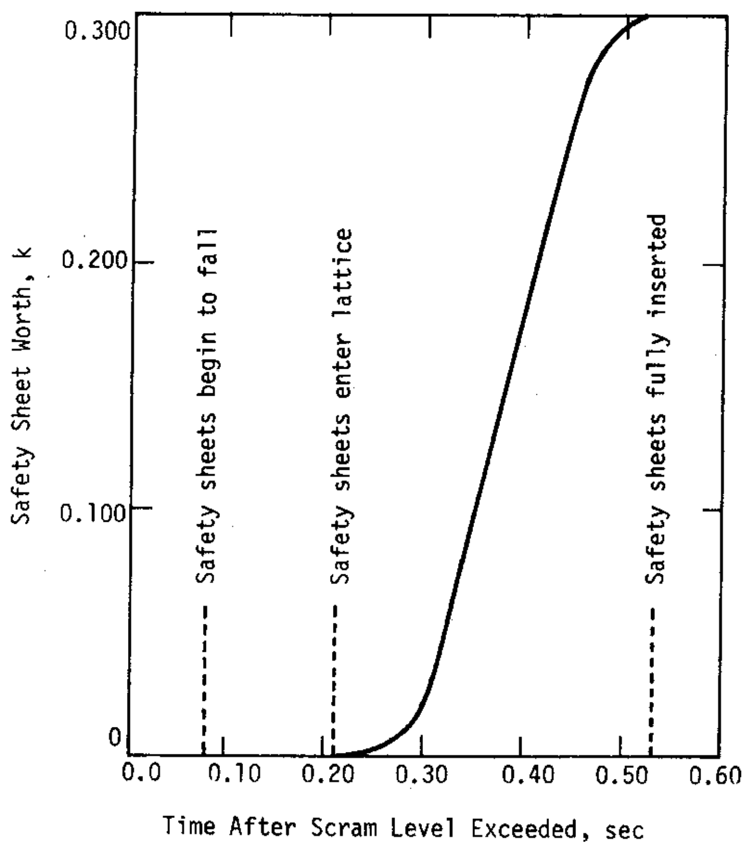

FIGURE 8. Safety Sheet Response

The results (Figure 9) indicate that, for any credible test assembly, a charging speed of 1.5 ft/sec or less would permit the scram system easily to shut down the NTG before any sensible

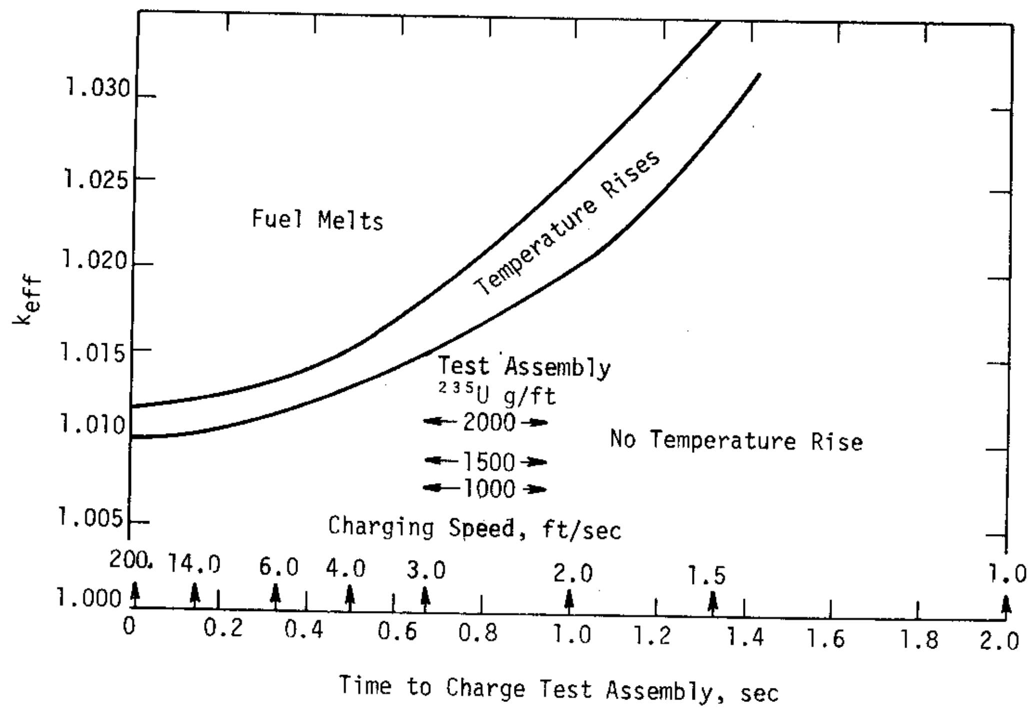

FIGURE 9. Calculated Response of NTG to Reactivity Transients Assuming Scram at $\phi/\phi_0 = 4$

temperature rise occurs in the fuel assemblies. k_{eff} values* were calculated for the NTG charged with test assemblies having ^{235}U loadings of 1000, 1500, and 2000 g/ft (Figure 9). As mentioned earlier, the HAMMER-PDQ results were normalized to neutron pulse experiments for lower g/ft values. Although these computer codes are considered to be quite suitable for such calculations, there is considerable uncertainty in the actual reactivity of the NTG when loaded with these very heavy test assemblies because there is no experimental verification in this range. However, even assuming an error in k_{eff} as large as 1%, a charging speed of less than 1.5 ft/sec would permit the scram system to shut down the NTG before any sensible temperature rise. Although not shown in Figure 9, calculations for a charging speed of 0.55 ft/sec indicate no sensible temperature rise for a test assembly having a Δk as high as 0.22.

The normal delay time after scram initiation until the safety sheets enter the core is 0.21 second with the safety sheets being fully inserted by 0.53 second. If either the delay

*Note that k_{eff} values indicated in Figure 9 are really $k_{eff} = 0.96 + \Delta k_{assy}$, where k = 0.96 is the reactivity of the NTG before charging with a test assembly.

time or the "full-in" time were lengthened, the effect would be to allow the transients to continue longer and hence to allow greater temperature rise before the reactor is shut down. Thus, there would be a reduction in the amount of reactivity that could be charged and still have the scram system prevent sensible temperature rise. Increased delay time was calculated maintaining a constant time of 0.32 second for the safety sheets to move from the top of the core to fully inserted. Thus, increases in the delay time were also added to the full-insertion time, so that the effect simulates a delay in release of the safety sheets. An initial reactivity of 0.96 and an assembly charging speed of 0.55 ft/sec were assumed.

The results of these calculations are shown in Figure 10. Even though the curve indicates the delay time has a pronounced effect, an additional delay of at least 0.2 sec could be tolerated at the charging speed of 0.55 ft/sec and still have the reactivity scram system prevent any sensible temperature rise.

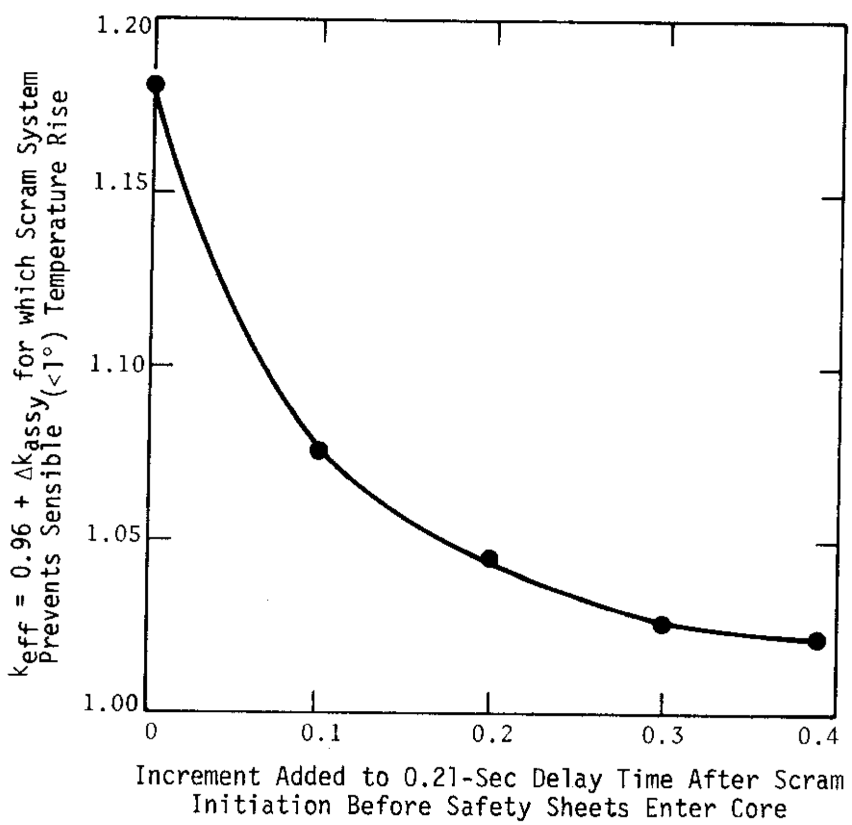

FIGURE 10. Effect of Increasing Delay Time Before Safety Sheets Enter Core

Charging Speed = 0.55 ft/sec

Tachometer Scram System

Another scram system on the NTG is intended to scram the reactor if the charging speed exceeds 0.55 ft/sec. If the reactivity of the NTG is less than 0.99 before inserting the test assembly, and if the test assembly is charged at speeds >0.55 ft/sec, then the tachometer scram can be considered additional protection over and above the reactivity scram system because the tachometer device will then be the initiator of the scram. However, for charging speeds <0.55 ft/sec the reactivity scram must be relied on for automatic protection against supercritical incidents.

Scram Systems Inoperable

This portion of the study is designed to determine if the proposed shutdown mechanisms will limit the total fissions at shutdown to some maximum value. Continuous linear reactivity insertions were imposed, and the total fissions at shutdown were calculated for both shutdown mechanisms. Transients for a large rate of reactivity input, $\dot{k} = 0.2\ sec^{-1}$, are illustrated in Figures 11 and 12. Reactivity increases rapidly due to the imposed $\dot{k}$, reaching prompt critical at 82 msec. The power then rises rapidly with minimal feedback from the moderator (gamma heating only) until 198 msec, at which time the assemblies have filled the housing tubes and boiling begins. A very fast negative reactivity transient ensues due to the voids; the power drops so that the assembly temperature stays fairly constant for a while. The imposed $\dot{k}$ continues; the power increases to a level at which further heating of the assembly occurs with consequent greater feedback due to additional voids.

The fissions produced from this type of transient as a function of ramp rate are shown in Figure 13. For the model described above, the shutdown mechanisms are such as to limit the total integrated fissions to $\sim 5.3 \times 10^{18}$. The mechanism for the occurrence of the maximum at about 0.4 k/sec is that, at high $\dot{k}$ values, the 10.5 msec limit (after 136 MW-sec integrated energy has been absorbed in the fuel assemblies) occurs while the reactor is still subcritical due to the negative void coefficient. Even with the continuing linear $\dot{k}$ input transient, the reactor does not get back to critical before it has shut down due to the steam explosion. If it were not for the second shutdown mechanism caused by the collapsing vapor film fragmenting the fuel, there is no indication that the first mechanism would produce a maximum in the integrated fissions at shutdown.

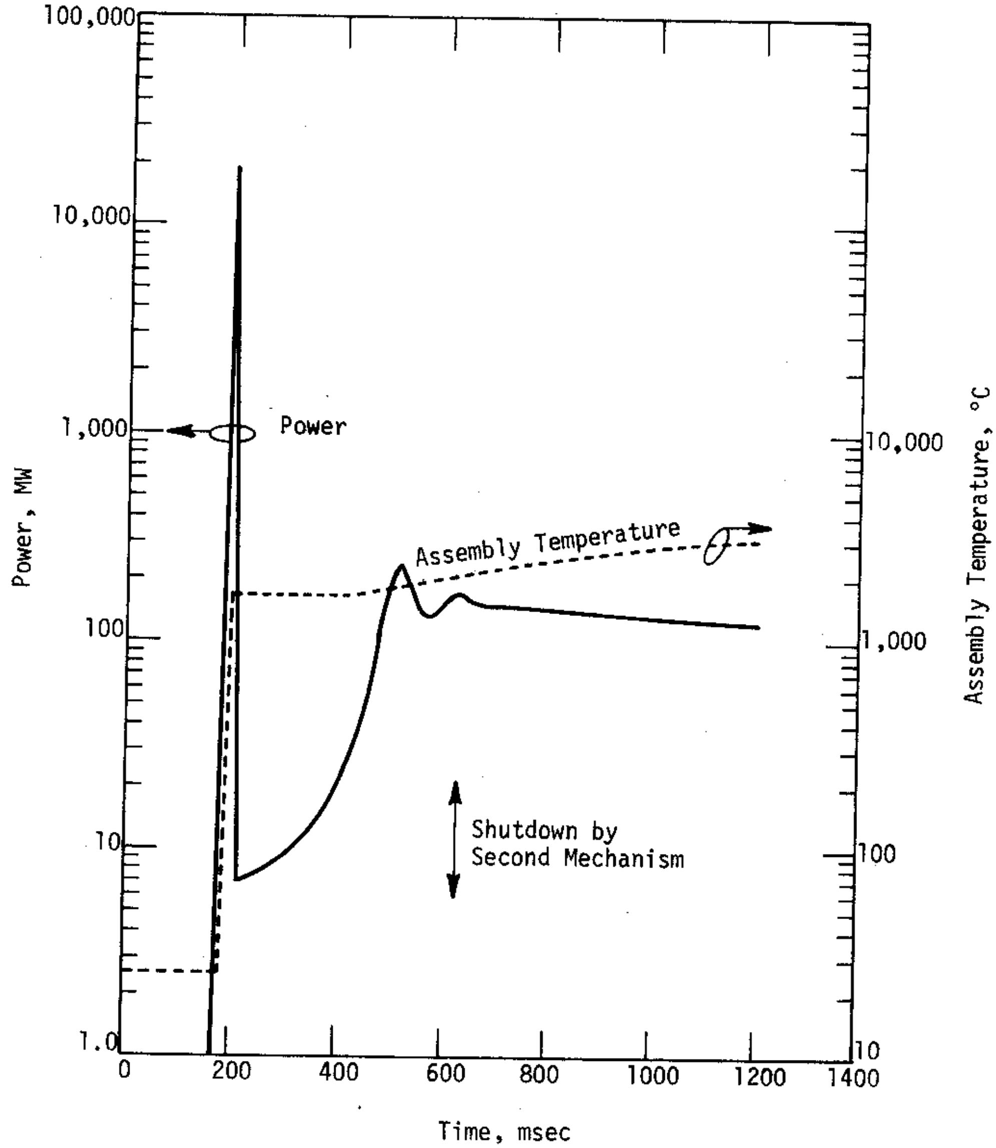

FIGURE 11. Power Response and Temperature Response for a Calculated NTG Transient for Continuous Ramp $\dot{k}$ = 0.20 k/sec

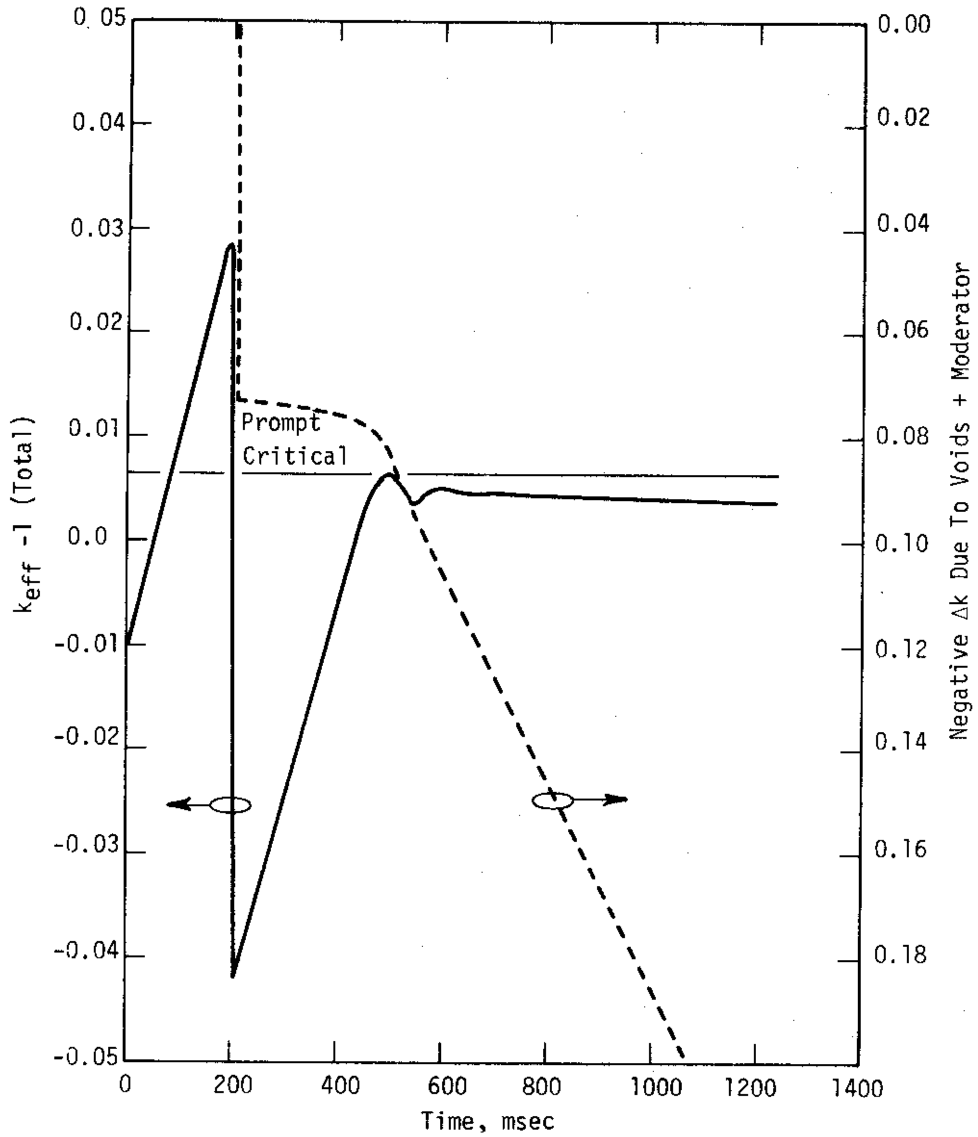

FIGURE 12. Total Reactivity Transient and Moderator Reactivity Feedback for Calculated NTG Transient for Continuous Ramp $\dot{k}$ = 0.20 k/sec

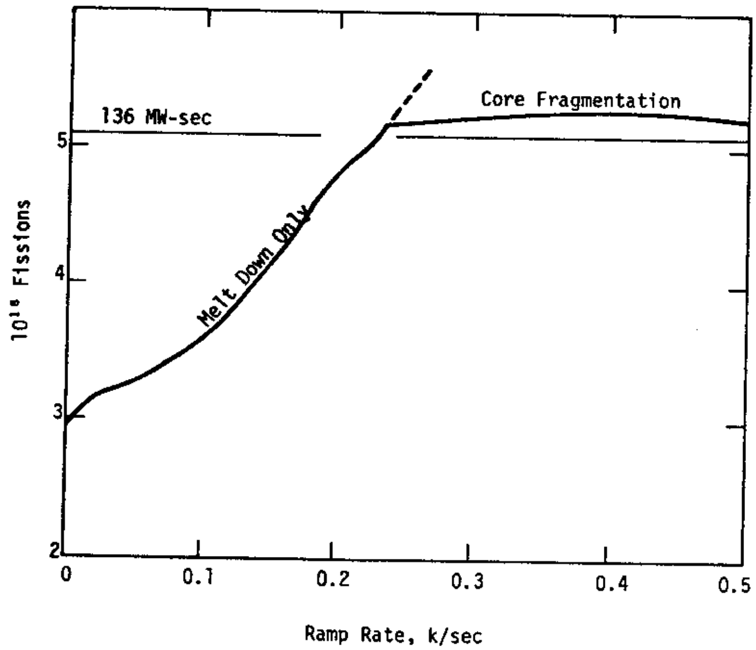

FIGURE 13. Fissions at Shutdown with No Scram

An integrated energy of 1100 MW-sec would vaporize the entire core and would represent total fissions of 4.1×10^{19}.* The shutdown mechanisms described above yield total fissions that are about one eighth of that produced by vaporizing the entire core.

The general study described above for constant $\dot{k}$ is applicable for particular Δk insertions in a given time. For example, the charging of a 2-ft length of test assembly at 4 ft/sec (Δk = 0.07) would provide a $\dot{k}$ of 0.14 k/sec for ~0.5 sec. This would give about the same total fissions at shutdown as a persisting $\dot{k}$ of that value. This is because the mechanism of the model is such that after initial boiling the reactor is deeply subcritical, the power is nil, and the assembly temperature remains fairly constant. As the imposed $\dot{k}$ persists, the power eventually rises sufficiently to cause an increase in assembly temperature, which in turn increases the rate of boiling and the void fraction. The net effect is that by the time the reactor is shut down by either mechanism described above, the assembly temperature has not risen much over the value obtained before the power decrease. These effects are illustrated in Figure 11.

---

* In these calculations, only ~170 Mev/fission is assumed to be absorbed in the core. Most of the prompt gamma energy is absorbed in the moderator, and the delayed β,γ energy is ignored for the rapid transients considered here.

OFF-SITE CONSIDERATIONS

Location of NTG

The NTG is located on the Savannah River Plant site, about 17 miles south of Aiken, South Carolina. The building that houses the NTG is 0.96 mile from the nearest plant boundary and three miles from the nearest town, as shown in Figure 14. A complete site description of the area, including geology, hydrology, meteorology and seismology data, may be found in Reference 13.

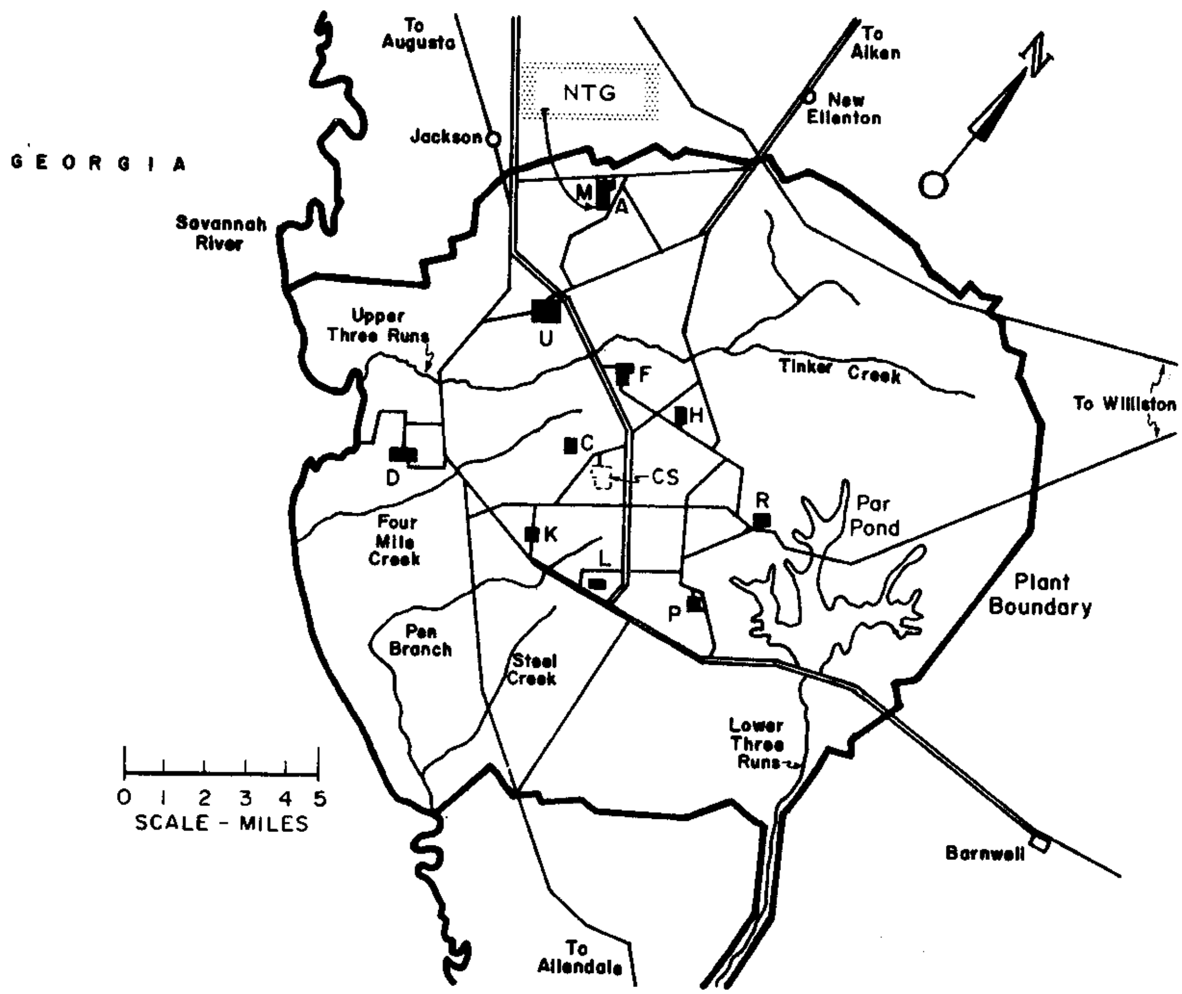

FIGURE 14. Location of NTG on Savannah River Plant

Thyroid Exposure At Plant Boundary

The Code of Federal Regulations pertaining to atomic energy and designated 10-CFR-100[14] specifies a guideline value of 300 rem as a limiting accidental thyroid dose at the nearest boundary of the site exclusion area.* This dose is assumed to be associated with a 95th percentile, i.e., the probability is 0.95 that the dose would be less than 300 rem. Calculations of 24-hour exposures (95th percentile) were based on the following assumptions:

- A criticality incident in which 10^{20} fissions occur.
- No fission product buildup before the incident.
- A release to the atmosphere of 50% of the iodines as they are formed.
- Release to the atmosphere at ground level.
- Savannah River measured meteorological data.[15]

Dose estimates reflect the integrated effect of the total iodine released over a 24-hour period following the postulated incident. During this period, the variation in azimuthal direction is accounted for according to meteorological measurements. Other dose rates for hypothetical incidents may be scaled directly on the basis of relative energy release, i.e., relative number of fissions at shutdown. These results are summarized in Table I. As indicated in that table, no conceivable incident in the NTG could even approach the 10-CFR-100 guide.[14]

---

* Although the corresponding 10-CFR-100 guide[14] for whole body exposure is 25 rem, the thyroid dose guide is the more stringent of the two guides for accidents of this type in which filtration of iodine is not assumed.

TABLE I. 24-HOUR EXPOSURE AT PLANT BOUNDARY, rem

	Relative Energy Release	Thyroid Dose (0.95)
10-CFR-100 Guide		300.
10^{20} Fission Excursion	1.0	1.5
Vaporize NTG Core	0.45	0.68
Continuous $\dot{k}$, No Scram	0.058	0.09
1000 g/ft ^{235}U, 0.55 ft/sec		
- No Scram	0.034	0.05
- Scram (Delay time = 0.21 sec; sheets fully inserted in 0.53 sec)	No Temperature Rise	0

APPENDIX

REACTIVITY WORTH OF A TEST ASSEMBLY

The effects on reactivity worth with a cosine flux shape (axial) used to compute the assembly worth was compared to the effects with the PDQ-5[3] calculated worth curves. Only the 24-inch central portion of the NTG was considered. This comparison is considered in Figure A-1 for a very light assembly (25 g/ft ^{235}U, and not reactive enough to initiate a scram) and for two very heavy assemblies (2000 g/ft ^{235}U, but with $\nu\Sigma_f$ increased to give fictitiously high k_{eff} values).

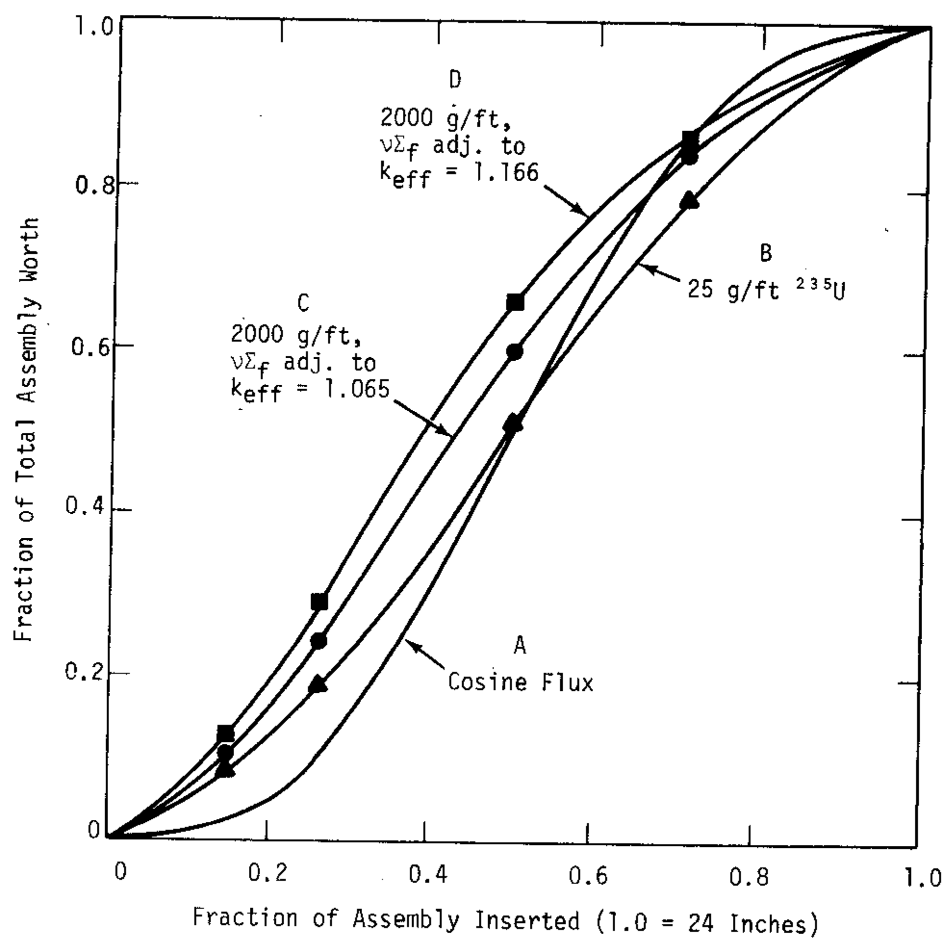

FIGURE A-1. Comparison of Reactivity Worths Calculated with PDQ-5 and with an Assumed Cosine Flux Shape

The critical parameter to consider is the rate of reactivity insertion after scram initiation, which at slow charging speeds will occur at about the same k_{eff} value (∿0.995) for assemblies having different total Δk values. (At very high charging speeds the assembly would be inserted so quickly that the shape of its reactivity worth curve would be unimportant to the consequences of the incident.)

For example, Curve D in Figure A-1 is for an assembly having a total reactivity worth of 0.206 to the NTG (total k_{eff} of 1.166 minus initial k_{eff} = 0.960). A reactivity of 0.995 (approximate value of k_{eff} when scram is initiated as explained earlier in the text) would correspond to (0.995 - 0.960)/0.206 = 0.170, or 17% of the total assembly worth. Above the 17% fractional reactivity worth Curve A (cosine flux) has a steeper slope than Curve D (PDQ-5). The relative reactivity addition rates can be calculated for succeeding time intervals. These relative k values are indicated in Table A-I for several assemblies.

TABLE A-I. Reactivity Addition Rates After Scram Initiation, Expressed As PDQ-5 Calculations Relative To Cosine Flux Calculations

Assembly Calculation by PDQ-5	Fraction of Assembly Worth Inserted at Scram Initiation	Relative Reactivity (PDQ/cos ϕ) Due to Incremental Insertion of Assembly 0-10%	10-20%	20-40%
2000 g/ft ^{235}U, $\nu\Sigma_f$ adj. k_{eff} = 1.166	0.17	0.91	0.95	0.58
2000 g/ft ^{235}U $\nu\Sigma_f$ adj. k_{eff} = 1.065	0.33	0.82	0.76	0.90
1000 g/ft ^{235}U, k_{eff} = 1.029	0.51	0.86	0.92	1.00
400 g/ft ^{235}U k_{eff} = 1.020	0.58	0.87	1.00	1.02

In the table, a number less than one indicates that the PDQ-5 calculation would provide an estimate of less reactivity addition after scram initiation than the cosine flux calculation. After scram initiation, the rate of reactivity addition is higher with the reactivity worths calculated assuming a cosine flux shape than with those calculated by PDQ-5. Hence, for convenience the calculations for scram systems operable were all done with this conservative assumption of a cosine flux shape for computed assembly reactivity worths.

REFERENCES

1. T. F. Parkinson, et al. *The Nuclear Test Gauge.* USAEC Report DP-147, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S.C. (1956).

2. E. P. Blizard, ed. *Physics Division Semiannual Progress Report for Period Ending September 10, 1954.* USAEC Report ORNL-1820, Oak Ridge National Laboratory, Oak Ridge, Tenn. (1955).

3. L. A. Hageman and C. J. Pfeifer. *The Utilization of the Neutron Diffusion Program PDQ-5.* USAEC Report WAPD-TM-395, Westinghouse Electric Corporation, Bettis Atomic Power Laboratory, Pittsburgh, Pa. (1965).

4. *Chemical Engineering Division Summary Report.* USAEC Report ANL-6648, p. 201-209, Argonne National Laboratory, Argonne, Ill. (1963).

5. *Kinetic Studies of Heterogeneous Water Reactors,* STL-372-50, TRW Systems Group (1966).

6. A. I. Brown and S. M. Marco. *Introduction to Heat Transfer.* McGraw-Hill Book Co., New York (1951).

7. S. Glasstone. *Principles of Nuclear Reactor Engineering.* D. Van Nostrand Co., New York (1955).

8. R. G. Stoner and W. J. Bleakney. "The Attenuation of Spherical Shock Waves in Air." *Appl. Phys. 19,* 670 (1948).

9. S. G. Lipsett. "Explosions from Molten Materials and Water." *Fire Technology 2*(2), 118 (1966).

10. J. F. Kunze (ed), *Final Report on the SL-1 Recover Operation.* USAEC Report IDO-19311, Idaho Operations Office, Idaho Falls, Idaho (1962).

11. J. G. Moore. "The Formation of Shock Waves from the Combustion of Gaseous Mixtures with Special Consideration of the Sodium-Air Reaction." *Nucl. Eng. Des. 3,* 320 (1966).

12. J. E. Suich and H. C. Honeck. *The HAMMER System, Heterogeneous Analysis by Multigroup Methods of Exponentials and Reactors.* USAEC Report DP-1064, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S.C. (1967).

13. W. L. Marter and T. M. Langley. *The Savannah River Plant Site.* USAEC Report DP-1323, Savannah River Laboratory, E. I. du Pont de Nemours and Co, Akien, S. C. (to be published).

14. "Reactor Site Criteria." Title 10. *Code of Federal Regulations,* Part 100, 10-CFR-100 (1961).

15. R. E. Cooper and B. C. Rusche. *The SRL Meteorological Programs and Off Site Dose Calculations.* USAEC Report DP-1163, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S.C. (1968).

J22 (Rev. 7/71)

SAVANNAH RIVER LABORATORY PUBLICATION APPROVAL SHEET

SHADED AREAS FOR TIS USE ONLY

DOCUMENT NO. DP-1315

TYPE OF PUBLICATION (Check one)

DP REPORT XX PAPER ☐

DP CATEGORY UC-34 Physics

AUTHOR(S) J. P. Church and W. S. Durant

TITLE DETERMINATION OF SELF-LIMITING TRANSIENTS IN THE NUCLEAR TEST GAGE

DIVISION Theoretical Physics and Reactor Engineering

MANUSCRIPT APPROVAL

Route in turn to:

	Initials	Date
1. AUTHOR	JPC WSD	8-31-72 8-31-72
2. SUPERVISOR	[illegible]	8/31/72 9/6/72
3. DIVISION HEAD	[illegible]	9/7/72 9/11
4. TIS EDITOR	[illegible]	10/10
5. DIVISION HEAD	[illegible]	12/14 12/12
6. SECTION DIRECTOR	GDSM	12/11
7. DIRECTOR OF EAP ~~(if applicable)~~	BCR	12-15-72
8. ASS'T. LAB. DIRECTOR	[illegible]	12/19/72
9. TIS	[illegible]	1/18/73

REPRODUCTION COPY APPROVAL

Route in turn to:

	Initials	Date
1. AUTHOR		
2. SUPERVISOR		
3. DIVISION HEAD		
4. TIS EDITOR		

CLASSIFICATION

Circle one for each

				CLASSIFICATION GUIDE TOPICS
OVERALL	S	C	(U)	2.2 [illegible]
ABSTRACT	S	C	(U)	703
TITLE	S	C	(U)	[illegible]
TRANSMITTAL LETTER	S	C	(U)	

APPROVAL: ______ Division Head ______ TIS

PATENT CONSIDERATIONS

POSSIBLE NOVEL FEATURES [illegible]

CLOSEST PRIOR ART

APPROVAL: ______ Author ______ TIS

FILL IN FOR PAPERS ONLY

PAPER FOR: PRESENTATION ONLY ☐ PUBLICATION ONLY ☐ PRESENTATION AND PUBLICATION ☐

MEETING

Give complete official title and attach copy of instructions to contributors.

CITY

DATES

DEADLINE FOR SUBMISSION

CHAIRMAN

ABSTRACT NO. COPIES

ADDRESS

PAPER NO. COPIES

FOR ORAL PRESENTATION, THE AUTHOR MUST SIGN THE FOLLOWING STATEMENT AFTER THE CLASSIFICATION REVIEW IS COMPLETE:

I UNDERSTAND THE SIGNIFICANCE OF, AND THE LIMITATIONS IMPOSED BY, THE PERTINENT SROO CLASSIFICATION GUIDE TOPICS COVERING CLASSIFIED INFORMATION RELATED TO THE SUBJECT OF THIS PAPER. THE PERTINENT TOPICS INCLUDE:

Author

JOURNAL

CC: A. F. Westerdahl, SROO
L. C. Evans - J. W. Croach -
A. A. Johnson, Wilm.
S. A. McNeight
S. W. O'Rear - TIS File

January 9, 1973

TO: S. W. O'REAR

FROM: H. S. HILBORN

DOCUMENT REVIEW

Document: DP-1315

Title: **"Termination of Nuclear Transients in the Nuclear Test Gage"**

Author(s): **J. P. Church and W. S. Durant**

Contractual Origin: AT(07-2)-1

Present Classification: **Unclassified DP**

References:

No items were noted that, in my opinion, should be called to the attention of the AEC for patent consideration.

OSR 24-A117
(REV. 3-70)

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED

SAVANNAH RIVER LABORATORY
AIKEN, SOUTH CAROLINA 29801

(TWX: 810-771-2670, TEL: 803-824-6331, WU: AUGUSTA, GA.)

CC: L. C. Evans - J. W. Croach -
A. A. Johnson, Wilm.
S. A. McNeight
S. W. O'Rear - TIS File

January 9, 1973

Mr. A. F. Westerdahl, Chief
Patent Branch
Savannah River Operations Office
U. S. Atomic Energy Commission
Aiken, South Carolina 29801

Dear Mr. Westerdahl:

REQUEST FOR PATENT REVIEW

Please review for patent matter:

DP-1315, "Termination of Nuclear Transients in the Nuclear Test Gage" by J. P. Church and W. S. Durant.

If any technical clarification is needed please call H. S. Hilborn, whose Document Review is attached.

Please telephone your comments to the TIS office (ext. 3598) and notify me by signing and returning to TIS the original of this letter. A copy is provided for your file.

If you decide to pursue a patent on any development covered, I shall be happy to supply additional information required such as appropriate references and the names of persons responsible for the development.

Very truly yours,

J. W. Croach, Director
Technical Division

The above item is approved for release.

By: ____________________
H. S. Hilborn

____________________ __________
A. F. Westerdahl Date
Chief, Patent Branch
SROO, USAEC

EXTERNAL RELEASE OF TECHNICAL INFORMATION

Description of Material No. DP-1315 Date 1/9/73

Title: "Termination of Nuclear Transients in the Nuclear Test Gage"

Author(s): J. P. Church and W. S. Durant

Type of Material

[ ] Classified DP Report
[x] Unclassified DP Report
[ ] Classified Letter
[ ] Unclassified Letter
[ ] Classified Paper
[ ] Unclassified Paper
[ ] Classified Abstract or Summary
[ ] Unclassified Abstract or Summary

Technical Content Please make the changes noted in the text.

Approved by P L Roggenkamp J M Boswell Date 1/18/73 1/22/73
P.L. Roggenkamp - J. M. Boswell

Classification

Approved by P L Roggenkamp J M Boswell Date 1/18/73 1/22/73
P. L. Roggenkamp - J. M. Boswell

Approved by [signature] Date 1/9/73

Authority

Topics 2.2 and 5.2.3 Classification Guide - UF-2
Topic 703 SROO Classification Guide
SROO Classification Notice #26

Category if DP Report

Approved by [signature] Date 1/9/73
Supervisor, TIS

Final Du Pont Release

Approved by [signature] Date 2/12/73
Coordinating Organization Director

Released by:

A. F. Westerdahl 2/5/73

OSR 24-A116
(REV 1-72)

DU PONT

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
ATOMIC ENERGY DIVISION
SAVANNAH RIVER LABORATORY
AIKEN, SOUTH CAROLINA 29801
(TWX: 810-771-2670, TEL: 803-824-6331, WU: AUGUSTA, GA.)

CC: L. C. Evans - J. W. Croach -
A. A. Johnson, Wilm.
S. A. McNeight
S. W. O'Rear - TIS File

January 9, 1973

Mr. A. F. Westerdahl, Chief
Patent Branch
Savannah River Operations Office
U. S. Atomic Energy Commission
Aiken, South Carolina 29801

Dear Mr. Westerdahl:

REQUEST FOR PATENT REVIEW

Please review for patent matter:

DP-1315, "Termination of Nuclear Transients in the Nuclear Test Gage" by J. P. Church and W. S. Durant.

If any technical clarification is needed please call H. S. Hilborn, whose Document Review is attached.

Please telephone your comments to the TIS office (ext. 3598) and notify me by signing and returning to TIS the original of this letter. A copy is provided for your file.

If you decide to pursue a patent on any development covered, I shall be happy to supply additional information required such as appropriate references and the names of persons responsible for the development.

Very truly yours,

J. W. Croach, Director
Technical Division

By: [signature]
H. S. Hilborn

The above item is approved for release.

[signature] 2/5/73
A. F. Westerdahl Date
Chief, Patent Branch
SROO, USAEC

Form AEC-426
(6/70)
AECM 3201

U. S. ATOMIC ENERGY COMMISSION
MAJOR CONTRACTOR'S RECOMMENDATION FOR DISPOSITION OF SCIENTIFIC AND TECHNICAL DOCUMENT

(See Instructions on Reverse Side)

1. AEC REPORT NO.
DP-1315

2. SUBJECT CATEGORY NO.
UC-34

3. TITLE
"Termination of Nuclear Transients in the Nuclear Test Gage"

4. TYPE OF DOCUMENT (Check one):

[X] a. Scientific and technical report.
[ ] b. Conference paper not to be published in a journal:
Title of conference ______
Date of conference ______
Exact location of conference ______
Sponsoring organization ______
[ ] c. Other (Specify) ______

5. COPIES TRANSMITTED (Check one or more applicable boxes):

[X] a. Copies being transmitted for standard distribution by AEC – DTIE.
[ ] b. Copies being transmitted for special distribution by AEC – DTIE, per attached list.
[ ] c. Two reproducible copies being transmitted to AEC – DTIE.

6. RECOMMENDED DISTRIBUTION (Check one):

[X] a. Normal handling (after patent clearance): no restraint on distribution except as may be required by the security classification.
[ ] b. Normal handling in the U.S. (after patent clearance), but no foreign distribution.
[ ] c. Make available only to U.S. Government agencies and their contractors.
[ ] d. Make available only within AEC and to AEC contractors.
[ ] e. Make available only within AEC.
[ ] f. Make available only to those listed in item 11., below.
[ ] g. Other (Specify) ______

7. RECOMMENDED ANNOUNCEMENT (Check one):

[X] a. Normal procedure may be followed.
[ ] b. Recommend following announcement limitations: ______

8. REASON FOR RESTRICTIONS RECOMMENDED IN 6. OR 7. ABOVE:

9. PATENT CLEARANCE (Check one):

[X] a. AEC patent clearance has been granted by responsible AEC patent group.
[ ] b. Document has been sent to responsible AEC patent group for clearance.

10. DEFENSE INFORMATION (For classified document only. Check one):

Document a.[ ] does b.[ ] does not contain defense information other than restricted data.

11. ADDITIONAL INFORMATION OR REMARKS (Continue on separate sheet if necessary.):

12. SUBMITTED BY: NAME AND POSITION (Please print or type)

F. H. Springer

Organization
Savannah River Laboratory

Signature: F. H. Springer, Jr.

Date: 3/13/73

INSTRUCTIONS

Who uses this Form: All AEC contractors except those specifically instructed by their AEC contract administrator to use the shorter Form AEC-427.

When to Use: Submit one copy of this Form with each document which is sent to AEC's Division of Technical Information Extension (DTIE) in accordance with the requirements of AEC Manual Chapter 3201.

Where to send: Forward this Form and the document(s) to:

USAEC – DTIE
P. O. Box 62
Oak Ridge, TN 37830

Item instructions:

Item 1. The first element in the number shall be an AEC-approved code to be determined as follows: (a) The responsible field office may request DTIE approval of a unique code for a contractor, e.g., BNL, BMI, ORNL, etc.; (b) A program division may request DTIE approval of a unique code for a program or series of reports, e.g., PNE, VUF, etc.; (c) An operations office may instruct a contractor to use the code approved for the operations office, i.e., NYO, COO, ORO, IDO, SRO, SAN, ALO, RLO, NVO; and (d) Program divisions shall use the code WASH for reports which they themselves prepare unless there is reason to use some other approved code.

The code shall be followed by a sequential number, or by a contract number plus a sequential number, as follows: (a) Contractors or programs with unique codes may complete the report number by adding a sequential number to the code, e.g., ORNL-101, ORNL-102, etc.; or PNE-1, PNE-2, etc.; or they may add the identifying portion of the contract number and a sequential number, e.g., ABC-2105-1, ABC-2105-2, etc.; (b) Contractors using the operations office code shall complete the report number by adding the identifying portion of the contract number and a sequential number, e.g., NYO-2200-1, NYO-2200-2, etc.; (c) Subcontractor reports shall be identified with the code used by the prime contractor; and (d) Program divisions using the WASH code shall complete the report number by adding a sequential number which they request from the Publication and Visual Aids Branch, Division of Headquarters Services.

Item 2. Insert the appropriate subject category from TID-4500 ("Standard Distribution for Unclassified Scientific and Technical Reports") or M-3679 ("Standard Distribution for Classified Scientific and Technical Reports") for both classified and unclassified documents, whether or not printed for standard distribution.

Item 3. Give title exactly as on the document itself unless title is classified. In that case, omit title and state "classified title" in the space for item 3.

Item 4. If box c is checked, indicate type of item being sent, e.g., thesis, translation, etc.

Item 5. a. If box a is checked, the number of copies specified for the appropriate category or categories in M-3679 or TID-4500 shall be forwarded to DTIE for distribution.

b. If box b is checked, complete address list must be provided DTIE.

c. If box c is checked, at least one copy shall be original ribbon or offset and be completely legible. A clear carbon copy is acceptable as a second reproducible copy.

Item 6. If box a is checked for an unclassified document, it may be distributed (after patent clearance) to addressees listed in TID-4500 for the appropriate subject category, to libraries in the U.S. and abroad, which through purchase of microfiche maintain collections of AEC reports, and to the Clearinghouse for Federal Scientific and Technical Information for sale to the public.

If box a is checked for a classified document, it may be distributed to addressees listed in M-3679 for the appropriate subject category.

If a box other than a is checked, the recommended limitation will be followed unless DTIE receives other instructions from the responsible AEC program division.

Box g may be checked in order to specify special instructions, such as "Make available only as specifically approved by the program division," etc.

Item 7. a. Announcement procedures are normally determined by the distribution that is to be given a document. If box a or b in item 6 is checked for an unclassified document, it will normally be listed in the weekly "Accessions of Unlimited Distribution Reports by DTIE" (TID-4401) and may be abstracted in "Nuclear Science Abstracts" (NSA).

A classified document, or an unclassified document for which box c, d, e, f, or g in item 6 is checked, may be cited with appropriate subject index terms in "Indexes of Limited Distribution Reports" (ILDR).

b. Check 7b if the normal announcement procedures described in 7a are not appropriate and indicate recommended announcement limitations.

Item 8. If a box other than a is checked in item 6, or if 7b is checked, state reason for the recommended restriction, e.g., "preliminary information," "prepared primarily for internal use," etc.

Item 9. It is assumed that there is no objection to publication from the standpoint of the originating organization's patent interest. Otherwise explain in item 11.

Item 10. The purpose of this item is to determine whether a given classified document can be distributed to access permittees. If box a is checked, it cannot be made available to them (Code of Federal Regulations, 10 CFR, Part 35, subpart 25.6); if box b is checked, DTIE will determine whether or not to make it available.

Item 11. Use this space if necessary to expand on answers given above, e.g., item 6f and item 9.

Item 12. Enter name of person to whom inquiries concerning the recommendations on this Form may be addressed.

Form SR-60
Rev. 2/72

U. S. ATOMIC ENERGY COMMISSION
Savannah River Operations Office

DOCUMENT REVIEW SHEET

TO: Those Listed Below

Please review and return with your comments to
[illegible]

RE: Contract AT(07-2)-1

Document No.: DP-1315
Title : Termination of Nuclear Transients in the Nuclear Test Gage

Author(s) : J. P. Church and W. S. Durant
Present Classification: [x] Unclassified [ ] Confidential [ ] Secret
Reason for Review: [ ] Declassification [x] Publication [x] External Distribution

---

1. PATENT BRANCH

[ ] From a patent standpoint, there is no objection to publication or declassification as proposed.

- [ ] No items of patent interest noted.
- [ ] Released on basis of patent review by contractor representative
- [ ] Subject matter previously released for publication in ______________________
- [ ] AEC Case No.______________
  - [ ] Release will not adversely affect this case
  - [ ] Release subject to deletions or restrictions noted.

[ ] Contractor and AEC restrictive stamps cancelled; AEC disclaimer stamp affixed. THIS SHOULD BE DONE TO ALL COPIES TRANSMITTED.

[ ] Publication withheld pending patent action.

____
Chief, Patent Branch (date)

cc: R. A. Anderson, Washington (Patent review only)

---

2. ______________________________

____
Signature (date)

---

3. TECHNICAL AND PRODUCTION DIVISION

Classification Opinion

Categorization: ________

____
Chief, Classif. & Tech. Inf. Br. (date)

DP- 1315

DP REPORT PROCESSING FORM
(Perform last item checked)

AUTHOR(S): Church, Durant

CLASSIFICATION: ✓ DATE:

1. PRINT SHOP:

Editor L. Langley Date 1-4-72

Reproduce 13 Preliminary Copies, Pages
Transmittal Letter (copies for preliminary and final distribution)
13 Preliminary Distribution

Send to Editor:

Approval copy of report
Transmittal Letter
Preliminary Distribution

Yellow

Photocopy
Transmittal Letter Master

This Form

Date to Editor

2. EDITOR:

Review Approval Copy and prepare Document Review and Release Forms.

TO 1-8-73 FROM

Send Approval Copy, Document Reviews, Release Forms, and this Form to Print Shop

3. PRINT SHOP AND DOCUMENT SECTION:

Editor Date

Bind and issue Preliminary Copies

Date of Preliminary Issue 1-31-73

Send Preliminary Record Copy with this Form to Editor. Date to Editor

4. EDITOR:

Collect corrections and releases. SAM AEC AUTHOR SWO'R

FHS 2-14

Send corrected Preliminary Record Copy, corrected photocopy, Internal Distribution Master, Transmittal Letter Master (if letter is revised), and this Form to Print Shop.

5. PRINT SHOP:

Editor L. Langley Date 2-21-73

Make corrections and print copies 212 *report, Pages 6 Price $
— Transmittal Letter
36 Internal Distribution

Send to Editor:

Approval copy of report
Transmittal Letter
Internal Distribution

Corrected Photocopy
This Form

Date to Editor

*Calculate number of copies by filling in Item 7

EDITOR:

Review printed Record Copy. Return printed Record Copy with AEC Recommendation Form, 2 copies of External Release Form, and this Form to Print Shop.

---

7. PRINT SHOP AND DOCUMENT SECTION:

Editor T. Langley Date 3-13-73

Bind and issue report:

INTERNAL DISTRIBUTION COPIES 3 with TL
36 without TL (3 SROO* ____ Suppl ____ Spc)
25 **without TL (TIS File)

Send to Doc. Sec. together → ______ and 3 extra copies of TL
EXTERNAL DISTRIBUTION Copies 236 without TL

TOTAL COPIES 297 of report

Send Record Copy, External Distribution List, and this Form to Editor.

* Attach copy of External Release Form.
** 50 for isotope reports

Int. Issue Date 3-15-73
Ext. Issue Date 3-15-73
Date to Editor ______

---

8. EDITOR:

Send file folder to DP Record File, including:

✓ File Record Copy
✓ Report Data Sheet
✓ Document Review
✓ Request for Patent Review
– Transmittal Letter
✓ Preliminary Distribution
✓ Special Distribution

✓ External Release of Tech. Info.
✓ AEC Approval Letter
✓ AEC Recommendation Form
✓ DP Report Processing Form
____ Internal Distribution
____ Internal References

Date to File 3-16-73

Send camera copy and negatives to Document Section.