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# Operating Procedures for the Pajarito Site Critical Assembly Facility

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# OPERATING PROCEDURES FOR THE PAJARITO SITE CRITICAL ASSEMBLY FACILITY

by

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ABSTRACT

Operating procedures consistent with DOE Order 5480.2, Chapter VI, and the American National Standard Safety Guide for the Performance of Critical Experiments are defined for the Pajarito Site Critical Assembly Facility of the Los Alamos National Laboratory. These operating procedures supersede and update those previously published in 1973 and apply to any criticality experiment performed at the facility.

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## I. BACKGROUND FOR PROCEDURES

### A. HISTORY

These operating procedures supercede those in "Operating Procedures for the Pajarito Site Critical Assembly Facility,"[1] published in January 1973. The only changes incorporated are those that have proven necessary or that remove temporal references. Because the organization responsible for operating this facility has carried many designations since its formation in 1945 (M-2, W-2, N-2, P-5, A-5, R-5, Q-14, and Q-2), all references to administrative structure will refer to the Operating Group and Operating Division with the expectation that the terms will be obvious from context.

### B. THE LOS ALAMOS FACILITY

These operating procedures apply to any criticality experiment performed at Pajarito Site in the facility described by several safety analyses, in particular "Safety Analysis for the Los Alamos Critical Experiments Facility."[2] The experiments are conducted in remote-control laboratories, known as kivas, that are located at some distance from the main laboratory building that houses an individual control room for each kiva. All remote controls and indicators, including closed-circuit television receivers, are mounted in the control rooms.

Each kiva is surrounded by a security fence beyond which is an additional posted area to keep personnel at a safe distance during remote operation. At other times, access within the fence is through a key-actuated gate. The same key actuates a three-position selector switch in the control room that establishes safety interlocks appropriate to activities in the kiva and controls power to assemblies.

## C. SCOPE OF PROCEDURES

Pajarito Site operations are conducted in accordance with the "American National Standard Safety Guide for the Performance of Critical Experiments."[3] The rather general requirements of this standard are supplemented by the report "Technical Specifications for the Pajarito Site Critical Experiments Facility"[4] and are implemented by these operating procedures. The procedures, as formulated, are not intended to cover all conceivable aspects of an inherently flexible program; the portion of this report that covers experimental plans (Sec. II-C) extends their scope for special operations. Further, the limitations of safety documentation are recognized. There is no intent of substituting for the principle that safety depends upon people, and that rules, at best, provide guidance for "one skilled in the art."

## D. COGNIZANT SAFETY COMMITTEES

The Los Alamos Reactor Safety Committee is responsible for the general surveillance of Pajarito Site activities. This committee, which represents the Laboratory Director, is concerned with policy as well as technical execution. It reviews modifications of these operating procedures and approves policy changes and proposed changes of operating limits.

The Operating Group Nuclear Safety Committee, appointed by the Operating Group Leader, serves in a local advisory capacity with regard to any matter that concerns the nuclear safety of an operation. It functions independently of any formal requirement external to the Laboratory. In addition to conducting a technical review of each experimental plan, this committee, on its own initiative, scrutinizes safety practices and investigates safety suggestions and concerns from any source.

## II. SPECIFIC PROCEDURES

### A. SAFETY PLANS FOR OPERATIONS IN KIVAS

The selector switch that governs the three safety plans for kiva activities is actuated by a control key. Only one such key shall be in use for each kiva and shall not be capable of actuating the selector switch for another kiva. Any duplicate control key shall be in the Operating Group Leader's custody. The safety plans are defined as follows.

#### 1. Plan 1

Plan 1 is intended for periods when the kiva is not in use or when there is no safety restriction on access to the kiva. Four conditions are established by setting the selector switch to PLAN 1.

a. A green panel light, illuminating a 1 under PLAN, is visible in the control room.

b. The red warning blinker and rotating beacon lights (located at the gate and in the kiva area) are off.

c. The gate is open. (If the gate is closed when the switch is on PLAN 2 or 3, it will open automatically when the switch is moved to PLAN 1.)

d. There is no power on any machine. The security inspectors are free to seal the kiva doors according to their regular schedule if it is obvious that no personnel are working in the kiva.

#### 2. Plan 2

Plan 2 controls access to a kiva during preparation for remote operation, after such an operation, or during local operation of a machine. Four conditions are established by setting the selector switch to PLAN 2.

a. An amber panel light, illuminating a 2 under PLAN, is visible in the control room.

b. The red warning blinker lights at the gate are on. The rotating beacon lights (located at the gate and in the kiva area) are off.

c. The gate may be closed by a manual switch near the gate entrance. It may be opened at the entrance by the control key.

d. No power can be applied to a machine from the control room. Power can be applied to those machines equipped with local controls by use of the control key in the lock switch on the local controls panel located in the kiva; only the local controls are operative. The scram chain must be functional to operate in local control.

### 3. Plan 3

Plan 3 prevents access into a kiva area during remote operation. Six conditions are established by setting the selector switch to PLAN 3.

a. The control key is retained in the selector switch.

b. A red panel light, illuminating a 3 under PLAN, is visible in the control room.

c. The warning horns at the kiva are turned on for 1 to 2 seconds.

d. The red blinker lights at the gate and the rotating beacon lights at the gate and in the kiva area are on.

e. The gate is closed; it cannot be opened at the gate entrance because the control key cannot be removed from the plan selector switch while Plan 3 is in effect and the secure position of the gate is in the scram chain.

f. Power can be applied to the desired machine through a machine selector switch. This permits the machine to be operated remotely from the control room, but it cannot be operated from a local control board in the kiva.

## B. STORAGE OF ACTIVE MATERIALS

Usually each kiva contains some active material that is not involved in the experiment at hand and is not being used in another machine. A vault is provided in each kiva exclusively for storage of such material. Extraneous moderating materials, in particular, are excluded from the vault unless special provisions have been made for storage, for example, classified components of often-used assemblies. Shelf spacings with allowed limits of active material per cubicle are chosen to be consistent with the revised ANSI standard "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors."[5] For example, special metal clips conveniently limit the quantity of thin enriched uranium foil per storage cubicle. The main Pajarito Site vault is available for long-term storage of fissionable material.

## C. ORGANIZATION REQUIREMENTS

1. Each new experiment involving active material shall be reviewed by the Operating Group Leader. Unless this review establishes that the quantity of active material cannot be greater than three-fourths of a critical mass under foreseeable conditions, the experiment shall be covered by an experimental plan that shall be approved by the Chairman of the Operating Group Nuclear Safety Committee, the Operating Group Leader, and the Operating

Division Leader. An experimental plan that presents a unique, significant, safety question must also be approved by the chairman of the Los Alamos Reactor Safety Committee. A draft of the experimental plan will be provided to the Chairman of the Reactor Safety Committee concurrent with consideration by the Group Safety Committee for determination of unique or significant safety questions.

2. Copies of the appropriate experimental plan shall be available to the people performing the experiment, both in the control room and the assembly area, if necessary.

3. An experimental plan shall be valid for no more than 2 years after the date of issue unless reinstated. Experimental plans shall be reinstated by memo endorsed by the Chairman of the Operating Group Nuclear Safety Committee and the Operating Group Leader and filed with the experimental plan.

4. Each operating crew that performs an experiment shall be appointed by the Operating Group Leader. The crew shall consist of a crew chief, who is experienced in Pajarito Site methods of operation, and at least one other crew member or crew chief. The chief shall be responsible for all aspects of the crew's functions and shall regard personnel safety to be of paramount importance. If any crew member is dissatisfied with the safety of procedures, the operations shall be halted until all are convinced that the operations can be continued safely.

5. Entrance to a kiva for any operation on an assembly of active material shall be made by at least two persons, one of whom is the crew chief or his designated alternate. If a person is required in the control room at the same time, there shall be a third crew member.

6. A departure from an experimental plan or these operating procedures that presents no unique or significant safety question requires approval of the Operating Group Leader. Other departures require approval of the Chairman of the Los Alamos Reactor Safety Committee.

## D. EQUIPMENT REQUIREMENTS

### 1. Radiation and Counting Equipment

The radiation and counting equipment to be used with each kiva assembly shall include the following items.

a. At least two neutron pulse-counting systems, one with a signal audible in the kiva. Scalers shall be available and operable in both the kiva and the control room.

b. An ionization chamber with a linear amplifier (or an equivalent system) for automatically recording in the control room the neutron flux level in the kiva.

c. At least two scram monitors for automatic disassembly of any remotely controlled machine at a preset neutron flux level.

d. Portable multirange $\gamma$ and $\alpha$ radiation survey meters shall be located in each kiva, and in any accessory building housing an assembly outside a kiva.

e. Portable multirange $\gamma$, n, and $\alpha$ radiation survey meters shall be located in the control room area.

## 2. General Design of Assembly

Each assembly shall be designed so that power failure results in a scram. Switches for assembly mechanisms and manual control shall be of the dead-man type. Because design specifications should depend upon the reactivity involved, it is convenient to classify assemblies into three types according to the intended scope of operation.

a. Class I: For Limited Subcritical Operation. A Class I assembly shall have the following safety features.

(1) At least one major disassembly mechanism that can be triggered (scrammed) both manually and automatically by the radiation monitors. The disassembly process shall produce a monotonically decreasing reactivity at a rate exceeding that of assembly, and shall result in an assembly with a multiplication less than 10 (see Appendix) or a demonstrated safe shutdown configuration.

(2) An indicator in the control room to give the position of the major movable part that closes the assembly.

(3) An adjustable positive stop on the major assembly mechanism so that the multiplication may be measured as a function of closure distance.

b. Class II: For Normal Critical Operation. A Class II assembly shall have the following safety features.

(1) At least two major disassembly devices (of which one may be a set of safety rods), both of which can be triggered automatically by the radiation monitors and manually. The disassembly process shall produce a monotonically decreasing reactivity at a rate exceeding that of assembly, and shall result in a configuration with a multiplication less than 10. At least one of the devices shall reduce the reactivity 100 cents or more in 1 second.

(2) A limited rate of assembly of the major parts such that reactivity cannot be added more rapidly than 5 cents/second when the multiplication is greater than 100. In some cases, the assembly rate at lower multiplication values should be limited.

(3) An indicator in the control room to give the position of the major movable part that completes the assembly process.

(4) At least one vernier control that changes the reactivity in a continuous manner. The overall value should be 50 cents or more. The rate

shall be limited so that the reactivity cannot increase more than 5 cents/second. The position of control rods shall be displayed in the control room at all times during operation.

c. Class III: For Unusual Operation. Class III will include assemblies intended for special purposes, such as prompt-burst devices or neutronically coupled assemblies.

## 3. System of Interlocks for Reset on Plan 3

There shall be interlocks in the scram circuit such that the following conditions must be met before the machine can be reset for operation.

### a. Conditions Established at the Kiva Area

(1) Air pressure at the machine must be adequate if air cylinders are used for operation of the safety rods or disassembly mechanism. Adjustment in the kiva is required if the air pressure should be insufficient.

(2) A scram circuit common to all machines, with a manual actuating button located near the door of each kiva, must be reset at the kiva if it is tripped.

(3) The gate must be closed.

### b. Conditions Established at the Control Room

(1) The plan selector switch must point to PLAN 3 before the machine selector switch is effective.

(2) Control power is supplied to the desired control panel by means of the machine selector switch.

(3) The linear amplifier and recorder are on (an administrative requirement).

(4) Scram monitors are on and reset.

(5) The machine is disassembled or otherwise placed in the position of minimum reactivity.

(6) Vernier control, where provided, is in the position of minimum reactivity.

## 4. Sequence of Plan 3 Operations

Upon reset, additional interlocks or automatic features shall dictate the following sequence of operations.

a. Safety rods, where provided, are moved to the position of maximum reactivity, as indicated by appropriate lights. A control signal for assembling the machine is then available.

b. The major parts must be assembled completely, as indicated by a red panel light actuated by a limit switch. Vernier control, where provided, is then operable.

c. If the major disassembly mechanism or the safety rods move so as to open a limit switch, reactivity cannot be added by means of vernier control.

d. The major parts disassemble automatically when one of the following actions occurs: whenever a scram button is pushed, as the result of a signal from the scram monitors, or upon power failure.

e. All controls will be logical, for example, clockwise rotation produces an increase in reactivity regardless of the motion of the affected components.

f. All routine operations will be conducted with an approved checklist filed in the machine logbook.

## 5. Plan 2 Conditions

On Plan 2, all control switches in the control room shall be inactive.

## 6. New Machines

a. Plans for the design of new machines shall be discussed with the Operating Group Nuclear Safety Committee before construction of the machine. More general discussions within the group are also encouraged.

b. Reliability of operation of each new system, including proper behavior of interlocks and scrams, shall be established by a series of tests under conditions such that the multiplication will not exceed 10.

## 7. Secure

When the machines are closed down and the kiva area is secured, the manual scram in the kiva shall be tripped.

## E. OPERATING PROCEDURES

### 1. Preparation for Operation

a. Unless specified otherwise in the experimental plan, there shall be a neutron source within the assembly during both local and remote operations. In certain assemblies, the normal spontaneous-fission or ($\alpha$,n) source may be adequate. Source strength and neutron counting equipment and techniques normally should be interrelated to give multiplication values within a statistical precision of 5%. The neutron source and counters shall be located such that the counters will see the neutrons born in the assembly in preference to the neutrons coming directly from the source.

b. During operation periods (Plan 2 or 3), entrance to the kiva area shall be controlled by the crew chief. A member of the operating crew shall be in *the control room at all times during Plan 3 operation. If the control room area* is to be unattended while on Plan 2, the control key shall remain in possession of a crew member or locked in the control room safe. During nonoperating periods, the control key shall be locked in the safe.

c. The kiva area shall be cleared of personnel prior to operation on Plan 2 or Plan 3. Tests shall verify proper performance of the safety monitor systems (at least two independent monitors shall function properly, although three are normally used) and of the manually actuated scrams. Because each monitor may be set on one of several trip levels, the crew chief is responsible for setting it to respond to the lowest level consistent with the intended operation.

### 2. Local Operation (see Appendix)

a. No assembly step shall be performed in the presence of personnel unless there is clear evidence that the resulting multiplication will not exceed 10 or that the resulting assembly will be in a demonstrated safe configuration.

b. Any hand assembly of an unmeasured configuration shall be monitored by means of an audible counter system responding to neutrons from the assembly. Each increase of reactivity shall be limited such that the reciprocal multiplication is not reduced by more than a factor of two.

c. Occasionally it may be necessary for personnel to be in the kiva while on Plan 3 to observe or to adjust the motion of a part such as a control rod. Such an operation shall be performed only by personnel thoroughly familiar with the particular assembly. There shall be definite precautions to ensure that the multiplication cannot exceed 10, for example, the removal of active material or the insertion of a mechanical stop between major components.

d. Some machines may have normal shutdown margins that allow multiplications in excess of 10. Adjustment or modifications may be made to such machines provided that the change does not increase reactivity (decrease the shutdown margin). These operations shall be specifically addressed in the experimental plan with the specification of appropriate machine-specific precautions.

3. Remote Operation (see Appendix)

a. General

(1) All assembly procedures shall be monitored by two or more counters that are responsive to the reactivity of the system.

(2) A plot of reciprocal multiplication (or reciprocal counting rate) versus the parameter controlling reactivity (such as the amount of active material) shall serve as a guide to the incremental increases of reactivity. Each increment of reactivity increase shall be limited such that reciprocal multiplication is reduced by no more than a factor of two, until vernier control (if any) can be used to attain delayed criticality.

(3) During the initial closure of an assembly, a stepwise procedure shall be used. The same procedure shall be used after any change in stacking that cannot be clearly demonstrated to be less than +50 cents net. At each step of closure there shall be a wait of at least 30 seconds to permit observation of the buildup of delayed neutrons as indicated by the counters. The size of each step shall not exceed one-half the increment to delayed criticality. In any questionable case, the reciprocal counting rate shall be plotted against position.

b. Class I Assemblies. The multiplication shall not exceed 200, but the nominal multiplication limit should be about 100.

c. Class II Assemblies. The reactivity limit should correspond normally to a positive period of about 10 seconds. If reliability has been demonstrated at longer periods, the positive period limit may be decreased to no less than 5 seconds by consent of the Operating Group Leader. For a system progressing above delayed criticality, the Keepin-Wimett relationship between measured positive period and reactivity in cents is our best guide toward approaching shorter periods; see, for example, "Delayed Neutrons from Fissionable Isotopes of Uranium, Plutonium and Thorium."[6]

d. Class III Assemblies. Special operations (such as the production of prompt bursts) and their limits shall be detailed in the experimental plan.

## F. RADIOLOGICAL HEALTH PROCEDURES

Persons working with radioactive material shall follow the radiation safety policies in Chapter 1 of the "Los Alamos Handbook of Radiation Monitoring."[7] These policies are implemented for Pajarito Site by the "Pajarito Plan for Radiation Emergency."[8]

The following are rules of particular significance to site operations.

1. Health physics surveyors are available to give advice regarding radiation levels and tolerance doses. Their presence with an operating crew should be requested whenever there is significant risk of exposure. They should be

notified of any change in crew schedule or of any unscheduled kiva entry when fissile material may be handled.

2. All personnel entering the kiva areas or handling sources or any sizable amounts of active material shall wear standard dosimeters. With approval of a health physics surveyor, a tour badge may be issued for a group. If only a short visit is anticipated and no significant exposure is possible, the health physics surveyor may approve a single entry without a badge.

3. Neutron sources shall be swipe-tested for leakage immediately before removal from or return to the source storage room. A health physics surveyor shall be asked to investigate any evidence of leakage.

4. Before each day's operation with alpha-active material such as plutonium or $^{233}U$, enclosing surfaces shall be swipe-tested, and any evidence of leakage shall immediately be brought to the attention of a health physics surveyor.

5. In the event of a radiation accident, the "Pajarito Plan for Radiation Emergency"[8] shall be followed.

6. The Operating Group shall establish a regular schedule consistent with operations for the health physics surveyors to monitor the kivas for contamination.

7. When personnel first enter the kiva for a day's operations or when conditions require, radiation survey instruments should be used to establish the radiation levels in the working area or to identify regions of contamination.

# APPENDIX
# SAFETY INDICES

## NEUTRON MULTIPLICATION LIMITS

The multiplication limits that appear in these procedures are to be interpreted with discretion. The values refer to leakage neutron multiplication with a central source and imply a meaningful unmultiplied count that cannot always be obtained.

For near-equilateral fast-neutron systems, a central-source multiplication (M) of 10 corresponds to about 75% of the critical mass, and a multiplication of 100 to about 97.5%. Where there is doubt about the significance of measured multiplication values (as for many moderated systems), a multiplication limit should be interpreted in terms of the equivalent fraction of critical mass for a compact fast-neutron system. Thus, the hand-stacking limit of M = 10 would be interpreted as a mass limit that is 75% of the critical mass, or as the equivalent reactivity limit when the system does not have a compact shape. Conservatively extrapolated plots of reciprocal counting rate versus the parameter controlling reactivity will show whether the reinterpreted limit is satisfied.

Further guidance for interpreting multiplication appears in "Practical Aspects of Pajarito Neutron Multiplication Measurements,"[9] and Chapter 5, Volume 1 of "The Technology of Nuclear Reactor Safety."[10]

Note that the hand-stacking limit of M = 10 does not guarantee criticality safety. For example, a bare or lightly reflected system within this limit can be made supercritical by adding an effective reflector (as by dropping it in a tub of water). Adherence to this limit, however, does mean that criticality can be avoided by straightforward precautions, that is, by separation from massive reflectors and other fissile material and by precluding flooding.

## DEPENDENCE OF NEUTRON MULTIPLICATION UPON SPACING BETWEEN MAJOR COMPONENTS

An initial approach to criticality when large components are brought together is an operation requiring good judgment. Some guidance for the appropriate stepwise approach appears in "Practical Aspects of Pajarito Neutron Multiplication Measurements."[9] Further information about the dependence of 1/M upon spacing between components of various assemblies appears in the Figure.

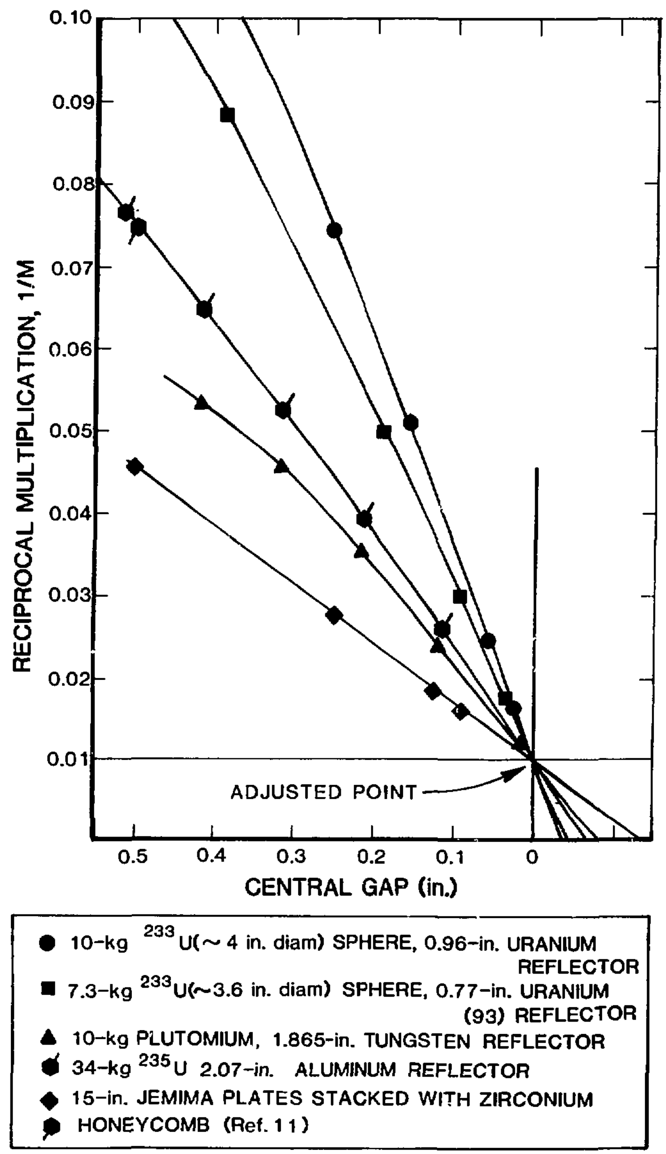


Fig. 1.
Typical relations between reciprocal multiplication and gap on median plane; adjusted to M = 100 at zero gap.

RELATIONSHIP BETWEEN INCREMENTS OF RECIPROCAL MULTIPLICATION AND OF REACTIVITY

Limits on the rate of reactivity addition in cents/second require an estimate of rate before criticality is attained. Such an estimate can be obtained from a plot of 1/M versus position of the moving component and the speed of the component, provided that a relationship between Δ(1/M) and the change of reactivity in cents is known. Guidance for selecting an approximate relationship appears in the Table. In cases where the multiplication scale may be distorted, the surface mass increments per 100 cents that appear in the last column may be used for cents calibration of reactivity changes.

TABLE

MULTIPLICATION SENSITIVITIES FOR SEVERAL CONFIGURATIONS

| Configuration | Machine | Δ(1/M)/100¢ | $\left(\frac{\Delta m_{surface}}{m_c}\right)\Big/100¢$ |
|---|---|---|---|
| bare $^{235}U$ | Godiva | 0.007 | 0.0243 |
| bare $^{239}Pu$ | Jezebel | 0.0025 | 0.0069 |
| bare $^{233}U$ | Jezebel | — | 0.0106 |
| $^{235}U$ in thick uranium | Flattop | 0.009 | 0.0242 |
| $^{239}Pu$ in thick uranium | Flattop | 0.003 | 0.010 |

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