

U.S. Department of Energy
Washington, D.C.

ORDER

DOE 5480.24

8-12-92

SUBJECT: NUCLEAR CRITICALITY SAFETY

1. **PURPOSE.** To establish nuclear criticality safety program requirements ensuring that:
 - a. Criticality safety is comprehensively addressed and receives **an objective** review, with all identifiable risks reduced to acceptably low levels and management authorization of the operation is documented.
 - b. The public, workers, Government property and essential operations are protected from the effects of a criticality incident.

2. **SCOPE.** The **provisions** of this **Order apply to all** Departmental Elements and to covered contractors to the extent implemented under a contract or other agreement. A covered contractor is a seller of supplies or services performing work on-site at a Department of Energy **(DOE)-owned** or -leased facility and involving significant quantities of fissionable material (excluding that inside the reactor core) on nuclear sites. A covered contract includes procurement contracts and subcontracts. The term "contract" does not include small purchases.

This Order does not apply to activities that are regulated through license by the Nuclear Regulatory Commission (NRC) or a NRC agreement State.

This Order does not apply to those facilities and activities under Executive Order 12344 and Public Law 98-525 that comprise the Naval Nuclear Propulsion Program.

This Order does not apply to activities involving nuclear explosives.

3. **POLICY.** Fissionable materials shall be produced, processed, stored, transferred, disposed or handled in such a manner that the probability of a criticality incident is acceptably low, and to the extent practical, Government and private personnel and public and private property are protected from damaging effects and undue hazards that may arise from a criticality incident.

DISTRIBUTION:
All Departmental Elements

INITIATED BY:
Office of Nuclear Energy

4. REFERENCES.

- a. DOE **1324.2A**, RECORDS DISPOSITION, of 9-13-88, which contains procedures for retention of records and documents.
- b. DOE **5000.3A**, OCCURRENCE REPORTING AND PROCESSING OF OPERATIONS INFORMATION, of 5-30-90, which establishes a system for reporting unusual occurrences having programmatic significance.
- c. DOE 5480.18, ENVIRONMENT, SAFETY, AND HEALTH PROGRAM FOR DEPARTMENT OF ENERGY OPERATIONS, of 9-23-86, which sets forth the responsibilities and requirements for an environment, safety, and health (**ES&H**) program.
- d. DOE 5480.3, SAFETY REQUIREMENTS FOR THE PACKAGING AND TRANSPORTATION OF HAZARDOUS MATERIALS, HAZARDOUS SUBSTANCES, AND HAZARDOUS WASTES, of 7-9-85, which describes the requirements for packaging and transportation of hazardous materials, hazardous substances, and hazardous wastes.
- e. DOE 5480.4, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION STANDARDS, of 5-15-84, which specifies the application to mandatory ES&H standards of DOE operations.
- f. DOE 5480.11, RADIATION PROTECTION FOR OCCUPATIONAL WORKERS, of 12-21-88, which establishes DOE's on-site radiation protection program.
- g. DOE 5480.20, PERSONNEL SELECTION, QUALIFICATION, TRAINING AND STAFFING REQUIREMENTS AT DOE REACTOR AND NON-REACTOR NUCLEAR FACILITIES, of 2-20-91, which establishes requirements for selection of personnel, qualification, and training at DOE reactor and non-reactor nuclear facilities.
- h. DOE 5480.23, NUCLEAR SAFETY ANALYSIS REPORT, of 4-10-92, which establishes uniform requirements for the preparation and review of safety analyses.
- i. DOE **5482.1B**, ENVIRONMENT, SAFETY, AND HEALTH APPRAISAL PROGRAM, of 9-23-86, which presents DOE's policy and requirements for appraisals of programs.
- j. DOE 5484.1, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION INFORMATION REPORTING REQUIREMENTS, of 2-24-81, which establishes the requirements and procedures for reporting and investigating matters of significance for the protection of environment, safety, and health at DOE operations.

- k. DOE 5500.2 B.) EMERGENCY CATEGORIES, CLASSES, AND NOTIFICATION AND REPORTING REQUIREMENTS, of 4-30-91, which establishes requirements for the coordination and direction of planning, preparedness, and response to operational emergencies.
- l. DOE **5500.3A**, PLANNING AND PREPAREDNESS FOR OPERATIONAL EMERGENCIES, of 4-30-91, which establishes requirements for the development of **site-specific** emergency plans and procedures at nuclear facilities.
- m. DOE **5500.4A**, PUBLIC AFFAIRS POLICY AND PLANNING REQUIREMENTS FOR EMERGENCIES, of 6-8-92, which establishes requirements for public affairs actions for emergency situations.
- n. DOE **5700.6C**, QUALITY ASSURANCE, of 8-21-91, which describes DOE's quality assurance program requirements for nuclear facilities and activities.
- o. DOE **6430.1A**, GENERAL DESIGN CRITERIA, of 4-6-89, which contains the criteria for the design and construction of **DOE facilities**.
- p. Code of Federal **Regulations**, Title 10, Part 40, "Domestic **Licensing** of Source Material," which establishes procedures and **criteria** for the issuance of licenses to handle source material.
- q. Code of Federal **Regulations**, Title 10, Part 50, "Domestic **Licensing** of Production and **Utilization** Facilities," which prescribes **criteria** governing **the** licensing of production and utilization **facilities**.
- r. Code of Federal Regulations, Title 10, Part 60, "Disposal of **High-Level** Radioactive **Wastes in** Geological Repositories," which regulates the disposal of high-level radioactive wastes in geological repositories.
- s. Code of Federal Regulations, Title 10, Part 70, "Domestic Licensing of Special Nuclear Material," which establishes requirements for transportation and for preparation of licensed material for shipment.
- t. Code of Federal Regulations, Title 10, Part 71, "Packaging and Transportation of Radioactive Material."
- u. DOE **1540.1A**, MATERIALS TRANSPORTATION AND TRAFFIC MANAGEMENT, of 7-8-92, which covers the management of materials transportation activities, including traffic management for other than **intrabuilding** and intrasite transfers.
- v. DOE 1540.2, HAZARDOUS MATERIAL PACKAGING FOR TRANSPORT-ADMINISTRATIVE PROCEDURES, of 9-30-86, which establishes the administrative procedures for certification and use of radioactive and other hazardous materials packaging by DOE.

5. DEFINITIONS.

- a. Criticality Incident. The release of energy as a result of accidentally producing a **self-sustaining** or divergent neutron chain reaction.
- b. Fissionable Materials. **Nuclides** capable of sustaining a neutron-induced **fission chain reaction** (e.g., **uranium-233, uranium-235, plutonium-239, plutonium-238, plutonium-241, neptunium-237, americium-241,** and curium-244).
- c. Hazard. A source of danger (i. e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to a facility or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation).
- d. Nonreactor Nuclear Facility. Those activities or operations that involve radioactive and/or fissionable materials in such form and quantity that a nuclear hazard potentially exists to the employees or the general public. Included are activities or operations that:
 - (1) produce, process, or store radioactive liquid or solid waste, fissionable materials, or **tritium**;
 - (2) conduct separations operations;
 - (3) conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations;
 - (4) conduct fuel enrichment operations; or
 - (5) perform environmental **remediation** or waste management activities involving radioactive materials.

Incidental use and generation of radioactive materials in a facility operation (e.g., check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes, and X-ray machines) would not ordinarily require the facility to be included **in this definition**. Accelerators and reactors and their operations are not included.
- e. Nuclear Criticality Safety. The prevention **or** termination of inadvertent nuclear criticality and protection against injury or damage due to an accidental nuclear criticality.
- f. Nuclear Facility. Reactor and **nonreactor** nuclear facilities.

- g. **Nuclear Operation.** Processing, storage, transferring, or handling of significant **quantities** of fissionable material.
- h. **Safety Analysis.** A documented process: (1) to provide systematic identification of hazards within a given DOE operation; (2) to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards; and (3) to analyze and evaluate potential accidents and their associated risks.
- i. **Safety Analysis Report (SAR).** That report which documents the adequacy of safety analysis for a nuclear facility to ensure that the facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations.
- j. **Significant Quantity of Fissionable Material.** The minimum mass of fissionable material for which control of at least one parameter is required to ensure **subcriticality** under all normal and credible abnormal conditions.
- k. **Technical Safety Requirements (TSR).** Those requirements that define the conditions, **safe** boundaries, and the management or administrative controls necessary to ensure the safe operation of a nuclear facility and to reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposures due to inadvertent criticality. A TSR consists of operating limits, surveillance requirements, administrative controls, use and application instructions, and the bases thereof. (Formerly known as operational **safety** requirements for nonreactor nuclear facilities and technical specifications for nuclear reactor facilities.)
1. **Temporary Exemption.** A short-term release from a criticality safety requirement.

6. **RESPONSIBILITIES AND AUTHORITIES.**

- a. **The Secretary (S-1)** has overall responsibility and authority for the Department's nuclear facilities and shall take the necessary management actions, through the Deputy Secretary (**S-2**) or the Under Secretary (**S-3**), to:
 - (1) Ensure safety of operations, including directing the curtailment and suspension of operations when such operations would result in an undue risk; and
 - (2) Grant permanent exemptions from criticality safety requirements.

- b. The Assistant Secretary for Nuclear Energy (NE-1), in addition to the responsibilities prescribed in paragraph 6e below, has overall responsibility for nuclear facility safety policy including nuclear criticality safety policy and specifically shall:
- (1) Develop, promulgate, and maintain Departmental nuclear safety policy for criticality safety;
 - (2) Develop, promulgate, and maintain guidance materials and provide advice and assistance concerning implementation of nuclear criticality safety policy requirements at nuclear facilities;
 - (3) Provide a central point for coordination within DOE and liaison with other agencies and groups in the development of nuclear facility criticality policy, standards, guidance, and requirements for DOE operations;
 - (4) Review proposed criticality statutes, regulations, standards, and requirements for their application to, and potential impact on, the requirements of this Order; and
 - (5) Concur with requests for permanent exemptions from criticality safety requirements.
- c. The Director of the Office of Nuclear Safety (NS-1), acting as the Department's independent element responsible for nuclear safety oversight, has the following responsibilities:
- (1) Assess and report to the Secretary of Energy on all aspects of nuclear safety related to the **implementation of** this Order including the performance of the program offices, DOE Field Offices, and contractors;
 - (2) Review and concur in proposed policy, regulations, standards, and requirements to assess their potential effects on the nuclear safety of DOE facilities;
 - (3) Concur **with** requests for permanent exemptions from criticality safety requirements; and
 - (4) Develop an enforcement policy and establish an enforcement program consistent with the civil and criminal penalty authority of the Price-Anderson Amendments Act.

- d. The Assistant Secretary for Environment, Safety and Health (EH-1), acting as the Department element responsible for radiological protection policy development shall:
- (1) Develop radiological protection **pol**icy related to all aspects of this Order.
- e. Program Secretarial Officers (PSOs), shall:
- (1) Assume primary responsibility for implementation of the DOE nuclear criticality safety program;
 - (2) Provide clear and explicit delegations of responsibility and authority for implementing this Order;
 - (3) Confirm that nuclear criticality safety requirements are identified and provided to the contracting officers for inclusion in contracts;
 - (4) **Perform** reviews, appraisals, and audits at nuclear facilities and **field** organizations to confirm effective implementation of DOE requirements by program and field organizations. Assure that recommendations made by external and internal oversight groups **are** addressed in a responsive and timely manner;
 - (5) Transmit the results of the actions taken under subparagraph (4) above to the responsible Head of the Field Organization including **any** necessary or appropriate instructions as to subsequent action to **be** taken. Copies of these documents should also be forwarded to **NE-1** and **NS-1**;
 - (6) Confirm, for facilities under their cognizance, that Heads of Field Organizations comply with subparagraph **6f** below. The execution of this responsibility should include assurance that recommendations made by other offices are addressed in a responsive and timely manner;
 - (7) Ensure that appropriate nuclear criticality safety requirements are included in long-range program plans, construction, operation, modification, and decommissioning of DOE operations;
 - (8) Obtain special technical assistance, as needed, in the performance of assigned functions when the expertise required is not available in a given office;
 - (9) Take such action as may be appropriate to ensure nuclear criticality safety, including directing the DOE Field Office Manager to curtail

and suspend operations when, in the **PSO's** opinion, such operation would result in undue **risk**;

- (10) Ensure that documents generated under this Order and other related **DOE** Orders are reviewed for classification where appropriate;
- (11) Grant **temporary** exemptions for criticality safety requirements after providing the **Secretary** notice. Prior to approval, **NS-1** shall also be notified in a timely manner in order to discharge its assigned responsibilities.
- (12) Request the Secretary grant permanent exemptions from critical **ity** safety requirements and responsibilities after concurrence from the Assistant Secretary for Nuclear Energy and the Director of the Office of Nuclear Safety;
- (13) Transmit adequate criticality safety program information in a timely manner to **NS-1**;
- (14) Recommend to the Secretary facility restart after shutdown for criticality safety reasons;
- (15) Approve the determination that the potential for criticality does not exist for activities specified in paragraph **7b** below; and
- (16) Approve in situ subcritical measurements.

f. **DOE Field Office Managers** shall:

- (1) Assume line management responsibility for the criticality safety of assigned nuclear facilities as directed by the **PSO**;
- (2) Assure adequate consideration for, and take action on, critical **ity** safety issues related to protection of environment, safety, and health during siting, design, construction, operation, maintenance, modification, and decommissioning;
- (3) Review safety analyses including nuclear critical **ity** safety evaluations and changes thereto consistent with this Order, DOE 5480.23, and other Orders in the DOE 5480 **series**;
- (4) Take such action as may be appropriate, including curtailment and suspension of operations, when, in their opinion, such operations may result in an undue risk to health, safety, or the environment;

- (5) **Assist** in the review and development of ES&H codes, standards, and guides;
 - (6) Provide the PS0 (copy to **NS-1**) with independent criticality safety evaluations;
 - (7) Assure **that** DOE contractors to whom this Order is made applicable implement the requirements in paragraph 7 of this Order and provide advisory services to DOE contractors and subcontractors on matters involving policies, standards, codes, guides, and procedures for environmental, safety, and health protection including the requirements of this Order;
 - (8) Provide For an overview of criticality safety; and
 - (9) Assure **the** integration of both criticality safety and materials control and accountability in developing a cost effective criticality safety program.
- g. **Director of the Naval Nuclear Propulsion Program:** Executive Order 12344, statutorily prescribed by P.L. 98-525 (42 U.S.C. 7158, Note) establishes the responsibilities and authority of the Director of the Naval Nuclear Propulsion Program (who is also the Deputy Assistant Secretary for Naval Reactors within the Department) for all facilities and activities that comprise the Program, a joint Navy-DOE organization. These executive and legislative actions establish that the Director is responsible for all matters pertaining to naval nuclear propulsion, including direction and oversight of environment, safety, and health matters for all program facilities **and** activities. Accordingly, the provisions of this Order do not apply to the Naval Nuclear Propulsion Program.

7. **REQUIREMENTS.** The contractor criticality safety program for nuclear facilities shall include the following requirements:
- a. The basic elements and control parameters of programs for nuclear criticality safety shall satisfy the requirements of the following mandatory American Nuclear Society's **ANSI/ANS** nuclear criticality safety standards:

ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," except paragraphs 4.2.2 and 4.2.3.

ANS-8.3, "Criticality Accident Alarm System," except paragraphs 4.2 and 4.2.2.

ANS-8.5, "Use of **Borosilicate-Glass** Raschig Rings as a Neutron Absorber in Solutions of **Fissile** Material."

ANS-8.15, "Nuclear Criticality Control of Special Actinide Elements."

ANS-8.19, "Administrative Practices for Nuclear Criticality Safety."

ANS-8.7, "Guide for Nuclear Criticality Safety in the Storage of **Fissile** Materials."

- (1) Contractors shall be required to comply with the requirements ("shall" statements) and the recommendations ("should" statements) of the mandatory **ANS** nuclear criticality safety standards except as modified below. When the cognizant **PSO** approves the technical basis for nonadherence of a recommendation in the **ANS** standards, the recommendation shall not become a requirement of this Order. Conversely, when the cognizant **PSO** does not approve nonadherence of a recommendation of the **ANS** standards, that recommendation shall become a requirement under this Order.

- (2) For DOE application, the following sections of **ANS-8.1**, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," shall be read as follows:

- (a) 4.2.2 Double Contingency Principle. Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. Protection shall be provided by either (a) the control of two independent process parameters (which is the preferred

approach, if practical) or (b) a system of multiple (at least two) controls on a **single parameter**. In all cases, no single failure shall result in the potential for a criticality accident. The basis for selecting either approach shall be fully documented.

- (t) **4.2.3 Geometry Control** As a first priority, reliance **shall** be placed on equipment design in which dimensions of the contained fissionable material and spacing between equipment are limited via passive engineering controls. Where geometry control is not feasible, the preferred order of controls is other passive engineering controls, active engineering controls, and administrative controls. Feasibility is determined by weighing risk versus practicality/cost. Full advantage may be taken of any nuclear characteristics of the process materials and equipment. All dimensions, nuclear properties, and other features upon which **reliance** is placed shall be verified prior to beginning operations, and control shall be exercised to maintain them. The basis for not selecting geometry control shall be fully documented.

b. The requirements in **ANSI/ANS-8.3** relating to the needs for an alarm system are not applicable to this Order. For the purpose of this Order, Criticality Alarm Systems (**CAS**) and criticality detection systems shall be required as follows:

- (1) In those cases where the mass of fissionable material exceeds the **limits established** in paragraph 4.2.1 of **ANSI/ANS-8.3** and the probability of criticality is greater than 10^{-6} per year (as documented in a DOE approved **SAR**), a **CAS** meeting **ANSI/ANS-8.3** shall be provided to cover occupied areas in which the expected dose exceeds 12 **Rads** in free air, where a **CAS** is defined to include a criticality accident detection device and a personnel evacuation alarm.
- (2) In those cases where the mass of fissionable material exceeds the **limits** [established in paragraph 4.2.1 of **ANSI/ANS-8.3** and the probability of criticality is greater than 10^{-6} per year, (as documented in a DOE approved **SAR**), but there are no occupied areas in which the expected dose exceeds 12 **Rads** in free air, a criticality detection system shall be provided where a criticality detection system is defined to be an appropriate criticality accident detection device but without an immediate evacuation alarm. The criticality accident detection system response time should be sufficient to allow for appropriate process-related mitigation and recovery actions. While an immediate evacuation alarm is not required under these circumstances, evacuation shall be implemented

(i.e. evacuation notification or delayed alarm) if potential doses to occupational workers could be effectively limited by such actions in accordance with DOE 5480.11.

- (3) In those cases where the mass of fissionable material exceeds the limits established in paragraph 4.2.1 of **ANSI/ANS-8.3**, but a criticality accident is determined to be impossible due to the physical form of the fissionable material, **or the probability** of occurrence is determined to be less than 10⁻⁶ per year (as documented in a DOE approved **SAR**), neither a **CAS** nor a criticality detection system is required. In addition, neither a **CAS** nor a criticality detection system is required to be installed underwater when fissionable material is handled or stored beneath water shielding that is adequate to protect personnel; however a means to detect fission product gasses or other volatile fission products should be provided in occupied areas immediately adjacent to such underwater storage areas except for fuel systems where no fission products are likely to be released. Also, neither a **CAS** nor a criticality detection system are required for fissionable material during shipment of fissionable material packaged in approved shipping containers, or fissionable material packaged in approved shipping containers awaiting transport provided no other operation involving fissionable material not so packaged is permitted on the dock or in the shipment area.
- (4) The decision to install a criticality detection system rather than a **CAS**, and the decision that neither a **CAS** nor a criticality detection system is necessary, must be justified based upon a documented DOE approved Safety Analysis.
- c. Nuclear criticality safety programs shall be fully documented. In addition to the requirements of the ANS standards, contractors shall perform detailed nuclear criticality safety analyses for specific operations, storage arrangements, and the handling and transportation of fissionable materials.

The basis for criticality safety shall be included in the facility SAR. Additionally, the limiting conditions of operation for criticality safety shall be included in the facility TSRS. Values presented in the standards to ensure criticality safety should be used cautiously and should include all adjustments, conditions, and ranges of applicability called for by the mandatory standards in paragraph **7a** of this Order.

The Criticality Safety section of the **SAR** shall include (or be included by referring to other sections of the **SAR**) but not be limited to the following:

- (1) A description, using appropriate sketches or drawings, of equipment and facilities in which the hazard of criticality exists showing dimensions in sufficient detail to permit evaluation of the information mentioned in subparagraphs **7c(3)** through **7c(6)** below.
- (2) A statement of the chemical and physical form of fissionable material in each step of the process, including isotopic content, the **nature** of any material, and the resulting concentrations, densities, and degrees of moderation throughout the steps of the process,
- (3) A statement of the maximum quantities of fissionable material at any one **time** in each step of the process, including a description of the technical practices which are intended to prevent exceeding these maximum quantities.
- (4) A description of the methods of collection, handling, and transportation products from each process area or individual operation and evaluation of the nuclear safety of these methods,
- (5) An analysis of criticality incident scenarios and their impact on health **and** safety of the workers and/or public. This analysis will be used to determine the conditions of operation for criticality safety, the design of the **CAS** as noted in subparagraph (7) below, and the need for audible and/or visual alarms.
- (6) A **description** of the safety control parameters which are intended to prevent criticality resulting from events such as: accumulation of fissionable material in scrap or waste, lathe turnings, crucible slag, pickling solutions, choppings, **sumps**, filters, etc. Also included shall be the description of the technical practices used to prevent exceeding the safety control parameters.
- (7) A **description** of the installed **CAS** and emergency procedures, including alarm levels, fail-safe features, response time of devices, and frequency of evacuation drills. Pertinent documents shall show the location of **all** detectors, their distance to possible sources of criticality, and intervening shielding and audio and visual alarms.
- (8) A description of the technical practices and measurement control program (including reliability and operability characteristics) used in determining the quantities of fissionable material (or other materials such as soluble poisons to prevent accidental criticality) present in any location and the uncertainties of the measured

values. The measurement control program shall be in accordance with the latest edition of DOE **5700.6C**, QUALITY ASSURANCE.

- (9) An analysis of the spacing of masses of fissionable material within each process area and separation from fissionable material in adjoining areas.
- d. Contractors shall **establish** a monitoring and surveillance program to prevent accumulations of fissionable materials in, but not limited to, process equipment and storage, pipe, and ventilation systems. If unsafe accumulations are detected, corrective measures shall be taken to prevent criticality hazards.
- e. Transportation and Storage Requirements for Fissionable Material.
- (1) The requirements of this Order shall apply to all activities where fissionable material is transferred from one operation to another within a facility and from one on-site location to another.
 - (2) For on-site transportation, contractors shall be required to follow the guidelines of an approved on-site transportation safety manual.
 - (3) The requirements of DOE 5480.3 shall be complied with regarding **off-site** shipment of fissionable material.
 - (4) DOE 5610.1 shall apply for the safe transportation of weapon components and special assemblies shipped in national defense.
 - (5) Fissionable materials shall be defined as either "in process" or "not in process" for facilities that involve both processes and storage. Fissionable material not in process shall be properly stored.
- f. Guidelines for Fire Fighting
- (1) Contractors shall establish guidelines for permitting fire fighting water or other moderating materials used to suppress fires within or adjacent to moderation controlled areas. These guidelines **shall** be based on comparisons of risk and consequences of accidental criticality with the risks and consequences of postulated fires for the respective area(s). The basis for the guidelines shall be fully documented in a DOE approved Safety Analysis.
8. **IMPLEMENTATION PLAN.** Contractors shall submit a plan to the Lead PSO for **approval to implement** the requirements of this Order. Submittal of the Implementation-plan shall occur within 180 days after the date of issuance of this Order.



James D. Watkins
JAMES D. WATKINS
 Admiral, U.S. Navy (Retired)