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Safety Assessment Document
For The
Dynamic Test Complex B854

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December 11, 1981

MASTER

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Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under Contract W-7405-Eng-48.

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PREFACE

This document was originally drafted to meet the requirements of ERDA Manual Chapter 0531 about the time SAN MD 5481.1 was issued. It was agreed by DOE SAN that, with a few minor modifications, the document would meet the intent of SAN MD 5481.1. These modifications have been included.

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Abstract

A safety assessment was performed to determine if potential accidents at the 854 Complex at Site 300 could present undue hazards to the general public, personnel at Site 300, or have an adverse effect on the environment. The credible accidents that might have an effect on these facilities or have off-site consequences were considered. These were earthquake, extreme wind (including missiles), lightning, flood, criticality, high explosive (HE) detonation that disperses uranium and beryllium, spontaneous oxidation of plutonium, explosions due to finely divided particles, and a fire.

Seismic and extreme wind (including missiles) analyses indicate that the buildings are basically sound. The lightning protection system is in the process of being upgraded to meet AMCR 385-100. These buildings are located high above the dry creek bed so that a flood is improbable.

The probability of high explosive detonation involving plutonium is very remote since the radioactive materials are encased and plutonium and HE are not permitted concurrently in the same area at Site 300. (The exception to this policy is that explosive actuating devices are sometimes located in assemblies containing fissile materials. However, an accidental actuation will not affect the safe containment of the plutonium within the assembly.) There is a remote possibility of an HE explosion involving uranium and beryllium since these are permitted in the same area. However, the calculated off-site lung doses were found to be well below the accepted standards. The possibility of a criticality accident is very remote since the fissile materials are doubly encased in stout metal containers. All operations involving these materials

are independently reviewed and inspected by the Criticality Safety Office. It was determined that a fire was unlikely due to the low fire loading and the absence of ignition sources. It was also determined that the consequences of any accidents were reduced by the remote location of these facilities, their design, and by administrative controls.

All recommendations to improve facility safety are summarized in Section 9 of this report.

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SECTION 1 -- INTRODUCTION

This Safety Assessment Document (SAD) for the Dynamic Test Complex (Building 854) provides a comprehensive review of individual buildings and the operations conducted in them, discusses potential accidents, makes an assessment of risks, and recommends corrective action. Detailed procedures for handling on-site accidents are contained in the LLNL Health and Safety Manual, Disaster Control Plans, Operational Safety Procedures, and the Fire Department Operations Manual.

The Weapons Test Group of the Weapons Engineering Division in the Mechanical Engineering Department administers and operates this Test Complex, which is used for vibration and shock testing of specimens that contain hazardous materials (explosives, radioactive materials, or toxic materials). The present cost to replace the facility and equipment is over \$7,500,000.

This SAD provides the LLNL Program Leader and the Manager of Plant Services with a written objective analysis of the facility and its operations, furnishes them with recommendations for corrective action in any area that appears deficient, and permits their review of whether these operations can be performed without undue risk to the health and safety of the employees as well as the public.

There are nine sections in this report. Section 2 summarizes the information contained in Section 3 through 9. Those appendices referred to by section numbers (such as Appendix 6A) are included at the rear of this document.

This assessment determined that insufficient quantities of radioactive materials could be released during the maximum credible accident to qualify these buildings as nuclear facilities as defined in ERDA Manual Chapter 0531.

Routine releases do not occur and the largest doses under accident conditions are calculated to be 0.42 mrem from plutonium and 43 mrem from uranium. The safeguards, which have been developed to minimize the occurrences and consequences of accidental releases of radioactive materials, meet the as low as reasonably achievable (ALARA) criteria established in DOE Order 5480.1 and by LLNL. Even in the event of a maximum credible release, the calculated off-site doses of 0.42 and 43 mrem are well below the 500 mrem effluent dose limit specified in ERDAM 0524 and now prescribed in DOE Order 5480.1.

Explosives handling is the only moderate hazard at this complex, the other hazards are low as defined in DOE Order 5481.1. Since these facilities were especially designed to handle explosives, surrounded by earthen berms, located in a remote area, and considering that special operating procedures are followed, this is deemed an acceptable risk.

It is also determined from this safety assessment that the operations in the 854 Complex can be conducted according to existing codes, standards, and regulations and there will be no undue risks to the health and safety of LLNL employees or the public.

SECTION 2 -- SUMMARY OF SECTIONS 3 THROUGH 9

This section summarizes the major topics discussed in Sections 3 through 9.

Section 3 provides a description of Site 300's location, surrounding population distribution, adjacent land use, geology and seismicity, meteorology, tornado and extreme straight wind, hydrology, and archaeology.

Section 4 provides a description of the 854 Dynamic Test Complex including a brief description of each building, the supplied utilities, lighting, and communication systems, as well as the environmental maintenance features and their controls. Special emphasis is given to the description of the safety control feature..

Section 5 describes the operations conducted at the 854 Dynamic Test Complex.

Section 6 discusses the potential accidents deemed credible for the 854 Complex. Accidents due to acts of nature and human error are discussed. Consequences of these accidents are compared to existing standards.

Section 7 discusses the environmental program conducted at Site 300. It summarizes the various sampling methods used to detect any changes in environmental levels on and around the Site.

Section 8 provides an assessment of the risks involved in conducting the operations at the 854 Complex. A matrix lists the potential hazards and exposure, the mitigating features and their possibility of failure, identifies the consequences of such failures, and determines the level of risk.

Section 9 summarizes the findings and recommendations of this safety assessment.

SECTION 3 — DESCRIPTION AND SAFETY ASSESSMENT OF SITE 300

Location, Population Distribution, and Land Use

The Explosives Test Site (Site 300) is located about 16 km southeast of the Lawrence Livermore National Laboratory in the sparsely populated hills of the Diablo Range. This range separates the Livermore and San Joaquin Valleys. The Site occupies an area of 28 km^2 , or a little less than 7000 acres. About one-sixth of the Site, along the western edge, lies in Alameda County. The remainder of the Site is located in San Joaquin County. Figure 3-1 shows Site 300 and the surrounding communities.

The nearest communities to Site 300 are Tracy to the northeast and the city of Livermore to the west. The Tracy city limits are 9 km northeast of the eastern Site boundary. Tracy has a population of about 20,000. Livermore is a community of about 50 000 people with the city limits about 13 km west of the western boundary of Site 300. Figure 3-2 shows the estimated populations by 22.5 degree sectors within 9.6 km of Site 300.

Land use adjacent to Site 300 consists of four major users to the south; i.e., 1) Carnegie Cycle Park, an outdoor recreational facility for off-the-road motorcycle riding, testing, and racing, 2) the Connolly Ranch, which is used primarily for the grazing of cattle, 3) Stanford Research Institute, which operates an explosives test site adjacent to the Carnegie Cycle Park, and 4) Physics International, which operates an explosive test site adjacent to Site 300's north-east side. Surrounding Site 300 on the west, north, and east are small farms and ranches used primarily for cattle grazing.

Geology and Seismicity

Site 300 is located on the eastern side of the Diablo Range. The southern boundary of the Site lies adjacent to the west-east Corral Hollow Valley. The relief of the Site increases rapidly from the valley floor in a north and northwest direction. The lowest elevation is a little less than 150 m at the southeastern edge of the Site, and the highest point is over 510 m in the northwestern sector. The hills are smooth and rounded, and the drainage patterns are well developed by gullies and steep ravines.

Faults have been identified in the vicinity of the Site area -- the Corral Hollow Fault, the Tesla Fault, and the Carnegie-Patterson Pass Fault system. Although some of the faults may be considered active, none of them have had any violent action in historic times.³⁻¹

Meteorology

LLNL has operated a climatological observation station at Site 300 for many years. Station instruments measure and record surface temperatures, pressure, humidity, and precipitation, as well as surface and limited upper air winds. Much of the following data are taken from these records.³⁻²

The mean annual precipitation is about 267 mm, although wide variation occurs from year to year. Most of the precipitation falls between the months of October and April in the form of rain, although a light dusting of snow can occur on the coldest days. Localized thunderstorms with the threat of lightning are infrequent.

Maximum temperatures in the winter months, November to February, average around 13°C. During these months the minimum temperatures are never much below the freezing level. Relative humidity is about 85 to 90% at night, decreasing to 60 or 70% during the afternoon. Winds are predominantly from the west and average about 5 to 7 m/s in the winter months.³⁻³

The dry season extends from May through September. Daytime temperatures in the mid 30's and low 40's (°C) are common in the middle of the summer. The relative humidity ranges from about 30 to 50% in the driest part of the year (fall). Persistent westerly winds are characteristic of this area from spring to fall. Marine air flows through the canyons into the San Joaquin Valley and results in moderately strong winds in the afternoon and evening.

Tornado and Extreme Wind

The tornado (extreme wind) assessment for Site 300 is based on the report, "Development of a Design Basis Tornado and Structural Design Criteria for Lawrence Livermore National Laboratory's Site 300" by McDonald, Mehta and Minor.³⁻⁴ Two probabilities were considered for evaluating damage potential to facilities at Site 300; i.e. tornado criteria based on an occurrence of 10^{-6} /year, and extreme wind criteria based on an occurrence of 10^{-4} /year³⁻⁵. The maximum wind speeds associated with these frequencies are 46 m/s and 54 m/s. Winds approaching these speeds have not been observed at Site 300; the maximum wind speed recorded at the Site is about 40 m/s.

Hydrology and Flooding

Surface

The drainage divide for the coastal ranges in the area between Livermore and Stockton is the Diablo Range. Since Site 300 lies on the eastern flank of this range, all of the runoff from the Site flows to the San Joaquin Valley. Most of the Site runoff flows into Corral Hollow Creek, which is close to the southern boundary of the Site. Corral Hollow Creek is an intermittent stream carrying water only in the rainy season, and it flows toward the San Joaquin River, which is located approximately 28 km east of Site 300.

Subsurface

In a region (the coast ranges) noted for structural complexity, the geology of Site 300 is apparently simply structured. The dominant feature is the Patterson Pass Anticline that lies in the midst of the Site. The 854 Complex is situated east of the nose of the anticline. Assuming a close similarity between the ground surface topography and the water table configuration, it is inferred that shallow subsurface flow takes place in all directions from the 854 Complex and that flow is generally from north to south. Shallow groundwater flow should generally follow the steepest topographic gradients until it arrives beneath natural drainage ways. From there, subsurface flow will likely continue beneath the surface ravines towards the major drainage way of the area, Corral Hollow.³⁻⁶

Flooding

It is extremely unlikely that flooding of Corral Hollow Creek will affect the 854 Complex at Site 300. The building is located on the crest of a hill having an elevation in excess of 260 m. The creek elevation is approximately 150 m and has a wide flood plain.

Archaeology

An archaeological reconnaissance of Site 300 was performed by the Archaeological Consulting and Research Services, Mill Valley, California.³⁻⁷ This study identified seven archaeological sites, or evidences of aboriginal activity, and provided a thorough discussion of each area. None of these sites are located in the vicinity of the buildings discussed in this report.

A Class III cultural resource inventory performed by Basin Research Associates, Hayward, California³⁻⁸, disclosed 24 cultural resource properties and 25 site types. Most of these were located in and around canyon-gully areas. None of these findings were in the vicinity of the 854 Complex.

Fig. J-1. Site 300 location

Fig. 3-2. Estimated population within 9.6 km
of Site 300 (1976).

References

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- 3-4 McDonald, J. R., J. E. Minor, and K. C. Mehta, Development of a Design Basis Tornado and Structural Design Criteria for Lawrence Livermore Laboratory's Site 300, California, Lawrence Livermore National Laboratory Report UCRL-13667, November 1975.
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- 3-6 Inferred Patterns of Shallow Ground-Water Movement from the 834, 836, and 854 Building Complexes at Site 300, Lawrence Livermore Laboratory, Internal Memo HRG 76-21 from R. Stone to W. J. Silver, September 7, 1976.

SECTION 4 -- FACILITY DESCRIPTIONS

General

The 854 Dynamic Test Complex consists of Test Buildings (B-854C,E,F,H), Mechanical Equipment buildings (B-854B,D,G), and Control Building (B-854A), which is located in the center of the Complex. The test buildings (test cells) are located behind large earth barricades (berms). The mechanical equipment buildings are positioned between the Central Control Facility (B-854A) and the test cells. A system of underground conduits and pipes for carrying electrical instruments and control wiring and various utilities (compressed air, water, oil, etc.) are provided between the Control Building, the Mechanical Equipment Buildings, and the various Test Cells. Figure 4-1 shows the location of the 854 Complex at Site 300. A plan layout of the 854 Complex is given in Fig. 4-2. The gross area of these facilities is 1042 m² and net area is 633 m². Table 4-1 lists the area of each building and room in these facilities. Background data for this section was obtained from References 4-1 through 4-5.

The 854 Complex is used primarily for vibration and shock testing of test specimens that contain hazardous materials (explosives, radioactive, or toxic materials). Portable HEPA filters are connected to Buildings 854C, F, and H when testing items containing radioactive materials. Building 854E has a permanent HEPA filter system. All buildings, except 854B (Mechanical Equipment Building), are sprinklered.

All electrical equipment installed as part of Test Cells C, E, F, and H, conforms to the electrical classification of Class II, Division I, Group G.

Note: Electrical classifications are outlined in the National Electric Code, NFPA 70-1976, Article 500. When non-Class II electrical equipment is required for testing in these cells, the equipment is evaluated and modified to provide safety features to preclude being a source of ignition.

Building Descriptions

Control Building (B-854A)

The Control Building is a square shaped structure constructed of reinforced concrete, i.e., walls, roof, and floor. An extensive trench system for instrument rack cabling is located below the floor. Protective steel plates cover the trenches and form part of the floor surface.

The building is designed to withstand the overpressures generated from an accidental detonation of 90 kg of explosives or less, from any test cell in the Complex. An operating limit of 36 kg for each test cell is currently authorized for each test cell. The exterior walls are 0.2 m thick, and the roof is constructed of 0.18-m-thick concrete slabs supported by steel girders. The exterior covering over the concrete roof consists of 51 mm of insulation and a 25-mm-thick layer of tar and gravel. The main entrance and the entrance to the mechanical room have reinforced-steel doors, which are blast resistant. One emergency escape route is provided; it is located in the opposite wall from an entrance and covered by a 0.6 x 0.6 m blast-resistant steel plate that is hinged to open outward.

The Control Building has a removable, reinforced-steel panel in the middle of the east wall. This 1.98 x 2.83 m panel is blast resistant and was installed to allow electronic racks to be added, or removed, from the Control Room (see Fig. 4-3).

Table 4-1. Total Areas of Various Buildings and Rooms in the 854 Complex.

<u>Building/Room</u>	<u>Area (m²)</u>
B-854C	184
B-854E	133
Main test room	55
Basement (pit area)	31
Mechanical space	5
Other (walls, etc.)	42
B-854F	70
Main Test room	59
Mechanical space	9
Other (walls, etc.)	2
B-854H	251
Main test room	126
Basement (pit area)	43
Utility room	18
Other (walls, etc.)	64
B-854K	31
Equipment area	28
Other (walls, etc.)	3
B-854D	56
Equipment area	53
Other (walls, etc.)	3

Three electric concrete pit boxes (pull boxes) are located outside, and adjacent to the Control Building. These boxes are positioned at each wall opening to the cable trenches and have steel covers. The pit boxes are located such that shrapnel will not be projected into the Control Building in the event of an accidental explosion in a test cell.

A mechanical equipment room is located adjacent to the control room, and houses the air conditioning unit and other mechanical equipment which provide service for the Control Building.

The Control Building is configured with product of combustion (ionization) smoke detectors that transmit a fire alarm to the Site 300 Fire Station if activated. An audible fire alarm is located outside the main entrance to alert personnel when a detector has been activated. The alarm signal is also transmitted automatically to the Fire and Police Stations (B-870).

Vibration Test Building (B-854H)

The Vibration Test Building (see Fig. 4-4) is an irregular shaped structure that has a large open bay with a reaction mass located below the building with the top surface flush with the floor. The reaction mass is a large, rectangular, reinforced-concrete block. The large size and weight of the reaction mass prevents motion to the building during vibration tests. A vibration exciter, vibration slip table, and a thermal chamber are positioned atop the reaction mass (see Fig. 4-5). These components allow experimental packages to be tested at temperature while undergoing dynamic testing.

The walls, roof, and floor of 854H are constructed of reinforced-concrete; exterior walls are 0.3 m thick and the roof and floor are 0.2 m thick. This building is covered with earth to an approximate depth of 0.9 m above the roof, with a tapering overfill on three of the sides. Two reinforced-concrete

retaining walls open outward in front of the facility. The retaining walls provide a barrier for the earth overfill, and act as a shield to direct fragments and debris to the open canyon should an accidental explosion occur within the test cell.

The test cell is modified to accept a portable, HEPA-filtering system that is used during dynamic testing of items containing radioactive materials. The filtering system will pull 46 m/min airflow across the personnel entry door. The filtering system airflow is adjustable and will provide an exhaust capability of 113 m³/min from the test cell.

The floor of the test cell is covered with a vinyl floor covering. This resilient floor covering is approved for use in areas where explosives are handled and tested.

The vibration test cell contains a 4500 kg bridge crane that supports two, 1800 kg hoists. Crane coverage allows movement and placement of test assemblies in all parts of the cell. A 1800 kg boom crane, mounted on the wall near the equipment door, is used to unload and load test assemblies from carrier vehicles. The boom is mounted to allow a 180° arc of travel; i.e., to lift, and move, an item from outside the building, through the equipment door, and place it inside. A mobile crane (450 kg) is available for use in moving small equipment to and from the tunnel area of 854H.

Shock Test Building (B-854C)

The Shock Test Building, a long rectangular structure, houses the 0.46-m, Hydraulic, Gas-Energized (HYGE), pneumatically-operated device that is used to subject experimental packages containing hazardous or inert materials to linear acceleration and linear shock (see Fig. 4-6). The building consists of two structures: 1) a building that houses the HYGE and associated controls and 2) an addition that covers the concrete runway.

The original building has a steel frame with frangible, 39.7-mm-thick cement asbestos walls. The low pitched roof has built-up roofing on 50.8 mm-cement asbestos panels. The addition to the original building also has a steel frame, but uses metal panels for the walls and a gable type roof. A concrete floor has been added on each side of the raised runway. The room covering the runway is insulated. Two personnel and two equipment doors provide access to the interior test area.

The building has also been modified to accept the portable, HEPA-filtering system used for dynamic testing of assemblies containing radioactive materials.

The Shock Test Cell contains two 13600 kg bridge cranes and hoists which are used for movement and placement of test assemblies in the cell. Two outrigger hoists (900 kg) are attached to the crane base and are used for lifting and placement of small support items.

Vibration Test Building (B-854E)

This building is a rectangular shaped, steel frame structure having frangible walls and roof. The walls are 39.7-mm-thick cement asbestos panels and the flat, sloped roof is constructed of 50.8-mm-thick cement asbestos panels that have a covering of roofing tar and gravel. The reinforced-concrete foundation and floor is constructed in two parts. i.e., support for the steel I-beam frame, and an open pit area to house the large concrete block that supports the vibration and impact test machines (see Figs. 4-7 and 4-8). The building has a personnel door and an equipment entrance. The test cell is equipped with a 1300 kg bridge crane which supports two 650 kg chain hoists. A 454 kg beam hoist is available for lifting and movement of small equipment.

Shock Test Building (B-854F)

The Shock Test Building, a rectangular shaped, steel frame structure with frangible walls and roof, houses a vertical VYGE machine (see Fig. 4-9). The walls are cement-asbestos panels, 39.7-mm thick. The flat, sloped roof is constructed of 50.8-mm-thick cement-asbestos panels with a covering of roofing tar and gravel. The reinforced-concrete floor and foundation contains a pit area and tunnel for placement of test equipment and associated cables. A utility room is located adjacent to the test room. The test room has two personnel doors and an equipment entrance. An overhead bridge crane (4500 kg capacity) and two 1800 kg hoists provide for lifting and locating test items within the test cell.

Mechanical Equipment Buildings (B-854B and D)

The Mechanical Equipment Buildings (854B and D) are rectangular shaped and are similar in construction. Each building is a Butler type building; i.e., steel frame with metal roof and siding positioned on a concrete slab. One side of each building contains two vertical, corrugated plastic panels for daytime lighting. The buildings are not insulated. Each building is heated by an electric space heater. Conditioned air is provided by wall mounted air conditioning units. Ventilation is provided by two ventilation fans located in the roof. The mechanical equipment buildings have general purpose lighting and convenience outlets.

Mechanical Equipment and Shop Building (B-854G)

The Mechanical Equipment and Shop Building is a rectangular shaped, steel frame structure with metal roof and siding positioned on a concrete slab. Plastic "light" panels are installed near the eaves of the building. They provide for daytime lighting.

The building is divided into three rooms by composite walls; i.e., a wood frame with gypsum board on each side. The walls and interior roof area in two rooms are covered with plastic faced, thermal insulation whereas the other room's interior walls and roof area are bare. Heating is provided by electric space heaters. An air conditioning unit, wall mounted, is provided in the shop area for personnel comfort. The air conditioner unit in the mechanical equipment room provides for equipment cooling and personnel comfort. Ventilation is provided by two ventilator fans located in the roof above the mechanical equipment area, and one vertical gravity relief ventilator located in the shop room. These rooms have general purpose lighting and convenience outlets.

Utilities

The electrical utilities include:

- o Primary electric power supply system
- o Battery power

Primary Power -- Electric power is delivered at 115 kV to the Site 300 power station by PG&E. Power (12 kV) is then delivered by two feeders throughout the Site.

The 854 Complex is served by overhead power lines that lead to the two distribution transformer pads located 12 m west of the Control Building. Power distribution is underground from the transformer pad to the various facilities.

Battery Power -- The fire alarm panel in the Control Building has power supplied through a battery bank inverter when there is a power failure.

Piped Utilities

The piped utilities are:

- o Site 300 Water
- o Cooling water supply and return
- o Compressed air
- o Brine (trichlorethylene and tetra-2-ethyl butyl silicate)
- o Process oil

General practices in this Complex are that:

- o Reduced pressure backflow preventers are provided on all Site 300 water lines that enter areas of possible radioactive contamination.
- o Double check-valve backflow preventive are provided on all compressed air lines.
- o All branch circuits from the mains are valved in accordance with applicable building codes.

Lighting

Each of the test buildings (854C,E,F,H) contain illumination lamps which meet the electrical classification for hazardous locations of Class II, Division 1, Group G. The electrical convenience outlets also meet these specifications. The Control Building and the Mechanical and Shop Building have general purpose lighting and convenience outlets.

Exterior lighting is installed for building entrances and pedestrian and vehicular approaches to the Complex. These exterior floodlights provide both area illumination and an aid for perimeter security.

Communication

Telephones are located in each of the buildings in the Complex and at several locations in the Control Building.

An intercom/speaker system is installed in each of the test cells and the control building. These systems meet the electrical requirements for each respective building.

Environmental Maintenance Features and Their Controls

Air Conditioning and Heating

Heating and cooling are provided for operational control and comfort. Air conditioner-1, located in the mechanical equipment room (854A) provides conditioned air to the Control Building. Heating coils in supply ducts are controlled by space thermostats to achieve the desired temperature. Air conditioner-2, located in the mechanical equipment room (854H), provides conditioned air to the test cell. Heating coils in supply ducts are controlled by space thermostats to achieve the desired temperature and humidity control. (The heat pumps and condensers for these air conditioners are located outside of the building.) Each of the remaining buildings (854C,E,F) have self-contained air conditioning units or heat pumps to provide conditioned air.

Safety Control Features

General

Test operations conducted in the 854 Complex have a very low potential for accidents. However, accidents might happen that could cause varying degrees of risk to Laboratory personnel, to the public, and to the environment. The following paragraphs describe both equipment and procedures to protect the health and safety of employees and the public, and to minimize the possibility of damage to Laboratory and off-site property.

Explosives Safety

All equipment used to handle explosives must be certified. Cranes and hoists are operated and inspected according to the criteria given in the LLNL Health and Safety Manual Supplement 29.04B and Procedure No. 107 of the Site 300 Safety and Operational Manual titled "Explosive Handling Equipment".⁴⁻⁶ Explosion/ignition proof electrical equipment, which meet the requirements of the National Electric Code is used where applicable.

The 854 Complex is designed for use in testing assemblies containing hazardous materials, one of which is high explosives. Although the possibility of an explosion always exists, the combination of directed frangible front wall construction and building location (far apart with an earth barricade) will prevent or minimize damage to adjacent buildings should an accidental explosion occur.

Fire Safety

The water for the sprinkler systems and the portable, spray damped HEPA filter system is supplied from the Site 300 cold water supply.

Electrically supervised shutoff valves are positioned at readily accessible locations. For additional assurance, these shutoff valves are administratively controlled and padlocked open by the Fire Department.

The fire alarm panel is located inside the Control Building. This panel has power supplied through the battery bank inverter. If there is an open or short circuit in the alarm circuit, a trouble light will be lit on the alarm panel. The smoke detectors and sprinkler alarms will cause a red "FIRE" light and a zone indicator light to illuminate on the panel. Both the trouble and fire conditions cause a buzzer to sound and an alarm signal to be transmitted automatically to the Fire and Police Stations (B-870). A remote annunciator panel is also located outside the Security fence adjacent to the road leading to the 854 Complex.

Electro-Mechanical Safety

Three types of tests are conducted at the 854 Complex; i.e. (1) an electro dynamic exciter system produces a desired acceleration force at various vibration frequencies, (2) a hydraulic/pneumatic shock tester accelerates and decelerates test items to create severe loading stresses, and (3) an elevated weight (when released) creates a severe loading stress at impact. It is unlikely that either electrical or pressure problems will be encountered during the various tests. An electrical system malfunction might cause a "run-away" condition; however, computer safety controls, control system alarms, safety interlocks, remote operating conditions, and operator monitoring while tests are in progress, will tend to minimize problems that develop.

Tests conducted in B-584H include placing a test package on the exciter/slip table, securing the package to the table, and vibrating the test package in a sinusoidal, random, or transient mode. A computer or analog

control system provides input to an amplifier, which in turn provides signal information to the exciter/slip table. The electrical information is converted into mechanical motions; i.e. vertical and horizontal displacements.

It is very unlikely that rupture of attachment bolts, and/or containment package will occur when testing; however, electrical systems could malfunction and could contribute to a "run-away" condition. Several electrical safety features are incorporated in the control network to minimize the effects of electrical fluctuations and deviations. Automatic shutdown of the exciter's power amplifier will occur if the input voltage, plate current, or rise time exceed preset values. Any deviations will cause an audible alarm at the Control Panel located in B-854A.

The present software programs include a check on gravity (G) loadings at the shaker table. If the accelerometer senses a signal above a preset G value, the computer will terminate the test. Sensors, located on the shaker, monitor upper and lower displacements, armature current, and thermal temperatures of coolant (shaker cooling oil). If any preset limits are exceeded, the amplifier will automatically shut down.

A RUN-SAFE switch is located inside the entrance to B-854H. This switch is part of an electrical interlock; i.e. if the switch is moved to SAFE, a light will come on, and power to the system will be removed. A closed circuit TV system is available to monitor the test. If any problems are observed, the test will be stopped. The Test Operator also monitors sounds from the cell; any unusual noises would warrant a termination of a test.

The primary hazard associated with the hydraulic, gas-energized (HYGE) machine in B-854C is high pressure associated with possible material failure. Four safety features have been incorporated in the system to prevent overpressure.

A four-stage compressor and associated pressure lines are equipped with "pop-offs" -- valves that open if preset values are exceeded. Pressure valves and limits, located in the Control Room, can also be set to control pressures in the system. A chain of pressure interlocks will prevent deviations in the pneumatic loading of the HYGE. If any safety valves (sensors) are activated, a light would illuminate at the Control Panel in B-854A. This light would identify the location of the problem.

A RUN-SAFE switch is located adjacent to the entrance to the HYGE Building. This switch is part of the interlock system, and must be in the RUN position to permit the arming/firing sequence. A change in switch position illuminates a light on the Control Panel in B-854A. A closed circuit TV system is used to monitor the condition of the test item before, during, and after a test.

Building 854E houses an exciter/slip table, which is similar in operation to the "table" in B-854H but smaller in size. Operational controls and safety features are basically identical as described for the B-854H vibration-shaker.

Building 854E also houses an "IMPAC" tester; a vertical, open frame device that supports a suspended carriage connected to a Bungee-Cord (a large rubber band). This test equipment produces high stress loadings when the carriage is released and pulled downward by gravity and the Bungee-Cord. The IMPAC tester is operated remotely from the B-854A Control Room. To preclude movement of the carriage prior to test, the hoist motors can be locked out, or the power cords can be disconnected.

A closed circuit TV system is used to monitor the test item on the exciter/slip table, or the IMPAC tester. If problems are observed, the test will be stopped.

Building 854F houses a vertical, 6 inch diameter HYGE, which is similar in operation to the 18 inch HYGE located in B-854C. Safety features and operational controls are basically identical to procedures described for the 18 inch HYGE.

A closed circuit TV system is used to monitor the test item before, during, and after a test.

Lightning Protection

Marginal lightning protection is provided for test cells 854C and E. These buildings are equipped with lightning air terminals that are bonded to the ground system, but building modifications have invalidated these systems. Building 854F does not contain external lightning protection. The lightning protection for these cells is being upgraded to meet AMCR 385-100.

The mechanical equipment buildings 854B, D, and G have steel frames, metal walls and roof, and are not required to have lightning protection.

Buildings 854A and H are both constructed of reinforced concrete, i.e., walls, roof, and floor. Instrumentation and control units are bonded to the grounding system. The construction of each building provides adequate lightning protection to personnel. A further description of the lightning protection afforded the 854 Complex is discussed under the Lightning Analysis in Section 6.

Radiation Safety

When specimens containing radioactive materials are being tested in a test cell, a portable alpha constant air monitor will be brought in. The detector will sense any change in the area radiation levels down to the maximum

permissible concentration in air (MPC_a) for Pu and transmit a signal to the Control Room, where an audible and visual alarm is located. Any rise in count rate is assumed to be a test item failure unless it can be established otherwise.

Effluent Controls

Airborne Effluents

The HEPA-filtering system is designed to control and contain radioactive materials if dispersed in test cells 854C, E, F, and H during testing. When a test is being conducted, a special exhaust system will be activated discharging all air from the room and any environmental chamber being used as part of the test, through High Efficiency Particulate Air (HEPA) filters. The HEPA filtered exhaust system is tested annually when moved to a new location and has a maximum allowable penetration of 0.03% for 0.7 micron particles. Test cell 854E has three HEPA filters connected in parallel. The portable system for 854C, F, and H is designed to exhaust air at $113 \text{ m}^3/\text{min}$ through two banks, with four filters per bank. All HEPA filters are protected from fire by automatic water spray dampers and filter face spray protection.

Liquid Effluents

The test cells are not equipped with floor drains. Liquid spills are mopped up, sampled if required, and disposed of according to Site 300 Procedure 400, Waste Disposal.⁴⁻⁵ Building 854A has a sanitary sewer leading to an underground septic tank and leaching field.

Solid Effluents

Solid wastes, which may be generated during operation of the test facility, are handled according to guidelines outlined in Procedure No. 400.

of the Site 300 Safety and Operational Manual, titled "Waste Disposal Procedures".⁴⁻⁵ Detailed disposal procedures for explosives, radioactive wastes, flammables (liquids, oily rags, etc.), plastic wastes, etc., are also contained in the procedure.

Security and Safeguards

The Dynamic Test Complex is surrounded by a 2.4-m-high security type fence. Access to the Control Building is through one set of gates. Each of the test buildings is in turn protected by a fence and an access gate. Personnel access to the test buildings is controlled by the Facility Supervisor.

The 854 Complex is located within the confines of the West Firing Area, and personnel access to and from the Complex is controlled from the West Control Post.

Security alarms are installed in Test Cells 854C,E,F,H and are connected to remote indicators located at the Police Master Console, B-870.

An external TV camera and intrusion alarms are used to detect attempted entry into the test cells.

Facility Disposition

The 854 Dynamic Test Complex at Site 300 can be restored to the public, or future occupants of the Site, if such restoration were to become desirable. Normally these buildings are free of any radioactive or explosive contamination. However, as part of the restoration process, these buildings will be monitored for all hazardous materials just to make sure that they are "clean". If any radioactivity is detected, this contamination will be removed using appropriate methods.

Fig. 4-1 Dynamic Test Complex B-854 Location at Site 300

Figure 4-2. Plan layout of the Dynamic Test Complex 854

Figure 4-3. Control room in 854A

Figure 4-4. Vibration Test Building 854H

Figure 4-5. Vibration exciter, vibration slip table, and thermal chamber in 854H

Figure 4-6. HYGE horizontal system in the Shock Test Building 854C

Figure 4-7. Vibration tester in 854E

Figure 4-8. Impact Tester in 854E

Figure 4-9. Vertical HV6E machine in 854F

SECTION 5 -- DESCRIPTION OF OPERATIONS

Introduction

The Dynamic Test Complex, Buildings 854A,B,C,D,E,F,G, and H, is administered and operated by the Weapons Test Group of the Weapons Engineering Division in the Mechanical Engineering Department. The principal operation associated with the Dynamic Test Complex is vibration and shock testing of units containing hazardous materials; i.e., explosives, radioactive materials, and when authorized, combinations of explosives and radioactive materials. *Plutonium and explosives are not permitted concurrently within a test assembly* or within a facility. Test units are subjected to horizontal, vertical, and torsional stresses under a simulated temperature environment.

The 854 Dynamic Test Complex has several large pieces of equipment that are used in vibration testing, i.e., 2 vibration shakers, 2 force (hydraulic gas energized machines (HYGE's), 1 impact machine, and 1 torsional machine. These test machines allow for a diversity of simulated test conditions and sizes of test geometries.

Most of the materials undergoing test pose potential overpressure (HE detonation) and radiological problems if an accident occurred. Operations within the Complex are governed by Site 300 Operational Safety Procedures. These procedures are contained in the Site 300 Safety and Operational Manual,⁵⁻¹ which provides safety instructions to personnel at Site 300. All documents in Manual have been assigned review or expiration dates to keep them viable.

Quantities and Types of Materials

A variety of materials and equipment have been tested using the facilities available in the 854 Complex. Nearly all test components are encased.

Authorized materials include explosives, beryllium, radioactive materials, and other items outlined in Procedures No. 121 and 654, Site 300 Safety and Operational Manual.⁵⁻¹ An operating limit of 36 kg of explosives is permitted in 854C,E,F, and 43 kg in H cells.

Fissile material use is outlined in Procedure 121, Hazardous Materials Control at Site 300. Plutonium and explosives are not permitted concurrently within a test assembly or within a facility. Occasionally enriched uranium is tested in the presence of high explosives. This requires special written procedures. Safety requirements for activities involving plutonium and enriched uranium are given in Tables 5-1 and 5-2. Combinations of explosives, radioactive materials, and other hazardous items are rigidly controlled, and may only be assembled and tested when all prescribed guidelines and Operational Safety Procedures have been reviewed and authorized by the Director's Office. Procedure No. 132⁵⁻¹ details the requirements for these assemblies.

Material Flow

Movement of test assemblies and related test equipment in and out of the 854 Complex is controlled by the Facility Supervisor. Within the test cell, materials are only moved from one work station to another by an authorized individual under the direction of the Facility Supervisor.

Detailed procedures are required when classified, hazardous, or special materials are being tested and stored in the 854 Complex. A Buddy System (part of the LLNL Site 300 personnel assurance program), Procedure No. 131,⁵⁻¹ is used as a precautionary measure to ensure that actions of any one person will not compromise fissile material. This system is used whenever fissile material is present at Site 300, and remains in effect until the material has been turned over to the appropriate agency authorized to transfer the material from the Site. A coordinated effort between the Security Department and the Facility Supervisor provides positive control for all test units during normal and offshift operations.

Operational Safety Procedures

An Operational Safety Procedure (OSP) is a published guideline for performing tasks safely and is prepared by the participants for special operations. These procedures provide detailed guidance on safety responsibility, permissible operations, material controls, descriptions of the facility's safety systems, personnel controls, etc. All work accomplished within the Dynamic Test Complex is governed by Procedures No. 600 and 654⁵⁻¹.

Changes and modifications to existing procedures are coordinated between the Site 300 Weapons Test Group Representative, Site 300 Hazards Control Safety Team Leader, and the Facility Supervisor.

A supplemental OSP is prepared when a specific, potentially hazardous experiment, material, test, or operation is not covered by an existing OSP. This supplemental OSP is also a coordinated effort between responsible participants. Reviews and approvals are described in the Site 300 Safety and Operational Manual's Safety and Management Program section.

Table 5-1. Safety Requirements for Several Activities Involving Plutonium

Activities	<u>Two metal containment barriers</u>	<u>Pressure vessels prohibited</u>	<u>HEPA filters required with 150 ft/min</u>	<u>Sprinklers required</u>	<u>Fireloading less than 1 lb/ft²</u>	<u>DOT approved shipping container necessary</u>
Transportation	Yes	No	No	No	No	Yes
Receiving and Inspection	Yes	No	No	Yes	Yes	No
Storage	Yes	No	No	No	Yes	Yes*
Thermal Test	Yes	Yes	No	Yes	Yes	No
<u>Dynamic Test</u>	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>	<u>No</u>

Table 5-2. Safety Requirements for Several Activities Involving Enriched Uranium

Activities	<u>Sprinklers required</u>	<u>Fire loading less than 1 lb/ft²</u>	<u>DOT approved shipping container necessary</u>	<u>Satisfy Procedure 132 (with H.E. present)</u>
Transportation	No	No	No	Yes
Receiving and Inspection	Yes	Yes	No	Yes
Storage	No	Yes	Yes*	Yes
Thermal Test	Yes	Yes	No	Yes
<u>Dynamic Test</u>	<u>Yes</u>	<u>Yes</u>	<u>No</u>	<u>Yes</u>

*DOT approved shipping container not required for storage at Building 822 A,B,C, and D concrete vaults.

Operations

This particular test complex was designed to vibrate or shock assemblies to check structural integrity and to observe and evaluate the behavior of components when subjected to a simulated operational environment. The large reaction mass allows a great flexibility in the shape, size, weight, etc., of various test assemblies. The test cell is equipped to lift and position test assemblies; a 4500 kg bridge crane allows the positioning and movement of large test items from handling dollies, trucks, etc. A small, portable, mobile crane is used for lifting and for utility work.

The frequency of vibration and shock tests at the 854 Dynamic Test Complex varies. A biweekly schedule, published by the Weapons Test Group, provides information on test programs for the 854 Complex. Some tests may last several days, whereas other tests may last only a few hours. Since program requirements do vary, some scheduled tests are deferred, and others are inserted.

A typical test program consists of the following plans, test preparations, and data gathering activities:

- o Prepare and review test plan
- o Match Test Cell capabilities with test requirements
- o Prepare supplemental DSP (as required)
- o Attach assembly and actuator to table
- o Attach instrumentation cables as specified
- o Activate HEPA filtered exhaust system (if required)
- o Activate closed circuit television and begin test
- o Provide Test Engineer with recorded data.

If a hazardous condition is anticipated or occurs during testing, a coordinated discussion between the Facility Supervisor, Test Engineer, and Hazards Control will be held to evaluate the situation and develop special procedures.

Equipment and Facility Inspection

Three related inspection programs exist at Site 300 to minimize equipment failure and to review safety procedures. Plant Engineering follows a schedule of inspections. Such items as hoists, emergency generators, filters, lightning detection, etc. are inspected and tested according to written guidelines.

Operating personnel perform inspections of all running equipment prior to and during testing.

Hazards Control personnel follow an inspection schedule to evaluate facility operations, safety guidelines, and regulatory compliance.

Waste Handling and Disposal

Occasionally, scrap and solid waste are left over when testing is completed. The total quantity of waste material is estimated at less than 1 m³/yr.

Uncontaminated and decontaminated waste materials are sent to the Site 300 burial pit. Normally, this facility does not generate any radioactive waste; however, if radioactive waste is involved, Hazards Control assists in preparing instructions for disposal according to Procedure No. 400, paragraph D.5-1

Toxic Materials

Toxic (nonradioactive) materials are sometimes encountered in operations at the 854 Complex. These materials may include solvents, vapors, liquid nitrogen, and, in a very rare case, beryllium. Protective clothing and respiratory protection are available for cleanup.

The Industrial Hygiene program for Site 300 includes standards and guidelines for the handling, storage, and control of all toxic materials. In addition, operational checks of ventilation systems, including HEPA filters and local exhaust systems, are conducted periodically.

Quality Assurance

Although no written quality assurance program exists for this Complex, there is an informal QA program that includes on-the-job training for new personnel, preventative maintenance, and supervision that makes sure that operations are performed as stated in procedures. The Weapons Engineering Division has agreed to formalize the QA program in writing.

References

- 5-1. Site 300 Safety and Operational Manual, Reprint, M-091, 1 March 1978.

SECTION 6 -- SAFETY ANALYSIS

Introduction

This section presents and analyzes potential accidents deemed credible for the 854 Complex. Some accidents are discussed only to establish that their probability of occurring is very low.

Accidents are divided into two parts: acts of nature (earthquake, tornado, lightning, flood) and those caused by human error (criticality, spill, explosion, fire).

Acts of Nature

Seismic, Tornado, and Extreme Wind Analysis

When the safety assessment was first started, it was thought that the 854 Complex was a critical facility and that the possible fence-line radiation dose resulting from an accident could exceed 500 mrem. Therefore, seismic, tornado, and extreme wind analyses of this facility were performed to determine if it could meet the criteria established for critical facilities at Site 300. The results of these analyses for the 854 facilities are included in Appendice 6A and 6B. However, recent calculation (included in this section) indicate that an accident involving radioactive materials at this complex would not result in fence-line radiation doses greater than 500 mrem (effluent dose limit specified in ERDAM 0524 and as prescribed in DOE Order 5480.1). Thus, this is not a critical facility. No structural improvements are recommended for this facility based on the structural analyses and radiation dose calculations.

Lightning Analysis

Thunderstorms occur less than five days per year in the Site 300 area, are not intense, and normally do not last more than one-half day per storm.

The actual number of lightning strikes per unit area has been approximated by Sunde⁵⁻¹ as $0.1/\text{km}^2$ per thunderstorm day. This can be applied to a calculation of the probability of a lightning strike in/near the 854 Complex.

Assuming the area of concern (854 Complex) is approximately $1.1 \times 10^{-3} \text{ km}^2$, the recurring interval of a strike in the area becomes

$$\begin{aligned} P &= 5 \text{ storms/yr} \times 1/2 \text{ day/storm} \times 1.1 \times 10^{-3} \text{ km}^2 \times 0.1 \text{ strikes/km}^2\text{-day} \\ &= 2.75 \times 10^{-4} \text{ strikes/year or 1 strike in 3600 years.} \end{aligned}$$

It is interesting to note that four lightning strikes have been recorded at Site 300 in the last ten years; however, none have occurred in the 854 area. Using the above factors and the area of Site 300 (27 km^2), we can calculate the expected number of lightning strikes, and compare with actual strikes to see if the calculation is, at least, conservative.

$$P_{\text{theoretical}} = 5 \text{ storms/year} \times 0.5 \text{ day/storm}$$

$$\times 0.1 \text{ strike/km}^2\text{-day} \times 27 \text{ km}^2$$

$$= 6.75 \text{ strikes/year}$$

which is much higher than observed; i.e.

$$P_{\text{observed}} = 4 \text{ strike/10 years}$$

$$= 0.4 \text{ strikes/year}$$

Thus the predicted value is approximately 17 times more conservative than that observed based on 10 years of observation.

The 854 Complex is served by overhead power lines that terminate at the distribution transformer pad. The power line is fused and bypassed to ground by lightning suppressors before entering the distribution transformer. Power distribution goes underground from the transformer pad to the various buildings. The power system is adequately protected from lightning strikes.

Three of the Test Cells (854C,E,F) have steel frame construction that is tied to the ground system. Lightning protection in these cells is being upgraded to meet AMCR 385-100. Test Cell 854E also has two, metal covered wood frame buildings, which extend well above three of the existing lightning terminals. The Control Building (854A) has heavy reinforced concrete walls, roof, and floor that provide good structural protection for personnel from lightning. Instrumentation and control racks are well bonded to the building ground system. Power for the 854 area pole-mounted, security lighting system is obtained from the 854A utility room power panels.

The mechanical equipment buildings have steel frames and metal walls that should provide adequate lightning protection for the equipment they contain.

Building 854H has reinforced concrete walls, roof, and floor and is earth covered on the top and three sides. It should provide good lightning protection to personnel.

Flooding Analysis

It is extremely unlikely that flooding of any building at the 854 Complex will ever occur. The terrain at Site 300 consists of hills, connecting plateaus, and numerous drainage ravines. Test complexes are located at the upper elevations and are isolated from adjacent test facilities by natural

terrain barriers. The 854 Complex is situated near the crest of a knoll having an elevation of 260 m. In general, the terrain slopes downward from the 854 Complex in all directions. Runoff from the 854 area is generally in a southerly direction and ultimately flows into Corral Hollow Creek, which is at an elevation of 150 m.

Human Error

Plutonium, Uranium or Beryllium Spill

A spill, as used here, is any unplanned loss of control of plutonium, uranium, or beryllium in any form. Even though a spill is unlikely, possible releases of these materials are considered. It must be emphasized that the postulated releases are considered to be extremely remote. There are no planned (non-accident) releases of radioactivity from the 854 Complex. In fact, there are no planned releases of fissile materials at Site 300. The only possible releases would be from an accident. The safeguards, which have been built to minimize the occurrence and consequence of accidental release of radioactive material, meet the as low as reasonably achievable (ALARA) criteria established in DOE Order 5480.1A and by LLNL. Any time fissile materials or H.E. are to be tested at Site 300, a special operational safety procedure is required.

Accident Scenarios -- Potential accidents believed to be possible at Site 300 that could result in the release of U-235 or Pu-239 are only those involving physical shock to the assembly such as an earthquake caused collapse of a test cell or detonation of high explosives (HE). A plutonium - HE explosion is not considered since plutonium and HE are not permitted concurrently in the same

area at Site 300. (The exception to this policy as stated in Procedure No. 132⁵⁻¹ is that explosive actuating devices are sometimes located in assemblies containing fissile materials. An accidental detonation will not effect the safe containment of the fissile material within the assembly.) Also, plutonium is encased in at least two sealed barriers. A major fire is not considered credible due to the very low fire loading and the lack of ignition sources.

An accident that disperses plutonium at the 854 Complex is considered extremely remote due to the low fire loading, absence of H.E., and the strong structures. However, we have included an accident involving plutonium to show what the maximum offsite radiation dose could be. In this unlikely accident scenario, it is assumed that the metal barriers of a test assembly containing four kilograms of plutonium are somehow breached, exposing the plutonium to the atmosphere. We then assume it oxidizes at a rate of $0.1 \text{ mg/cm}^2/\text{hr}$, the maximum low-temperature oxidation rate reported in the Plutonium Handbook by Wick.⁶⁻² With respect to the fraction of the oxidized material that becomes airborne, we have chosen the value of 0.05% suggested by Mishima and Schwendiman.^{6-3,6-4} It is further assumed that the accident causing the plutonium to be exposed to air also destroys the test cell ventilation system. Hence the released particles are available to the environment and are transported by the winds occurring at the time. All of the released particles are assumed to be respirable. Using the above assumptions, the release rate is calculated to be 700 pCi/sec.

At Site 300, it is permissible to conduct experiments involving high explosives (HE) and U-235 but never under conditions that can result in a nuclear yield. An accident involving U-235 assumes that a sufficient mass of

high explosives (HE) detonate very close to 35 kg of U-235. Based on the unpublished data of A. J. Toy⁶⁻⁵, it is assumed that less than 5% of the uranium is finely divided into particles of respirable size, that the roof of the building immediately fails, and that the uranium and HE debris mix thoroughly, forming a puff initially centered at 160m with a radius of 14m.

Dose Calculations -- The modified CPSC⁶⁻⁶ code of Peterson et al was used to calculate Pu-239 doses while the IPSCT code of Peterson was used to estimate U-235 and beryllium doses resulting from a puff generated by a high explosives accident.⁶⁻⁵ Fifty-year dose commitments were calculated for plutonium and uranium inhalation for meteorology conditions that will be exceeded only 5% of the time based on hypothetical releases at each of the test complexes. Dose equals the product of (release) x (atmospheric dispersion factor, x/Q) x (dose conversion factor). Beryllium exposure was calculated using the same 5% worst case meteorology.

Plutonium Lung Dose -- The exposures from a Pu-239 release were time-integrated for 8 hr, the assumed release period. The dose conversion factor (0.33 mrem-m³/pCi-hr) of Bennett (HASL-278⁶⁻⁸) was used. The largest dose which can be exceeded only 5% of the time from 854, is calculated to occur in summer at the site boundary 1130 m west of Test Complex 854:

$$\begin{aligned} \text{Dose} &= (700 \text{ pCi/sec})(8\text{hr})(2.3 \times 10^{-4} \text{ sec/m}^3)(0.33 \text{ mrem-m}^3/\text{pCi-hr}) \\ &= 0.42 \text{ mrem, which is well below the maximum value of 500 mrem} \\ &\quad \text{annual effluent dose limit specified in ERDAM 0524.} \end{aligned}$$

Uranium Lung Dose -- Five percent of 35 kg (5% of 35 kg) was used as a source term to calculate doses integrated during puff passage. The U-235 lung dose conversion factor from inhalation, 0.049 mrem/pCi inhaled, was taken from Regulatory Guide 1.109.⁶⁻⁹ The x/Q (concentration at receptor/release

rate at source) of 10^{-3} s/m^3 was obtained from the IPSCT⁶⁻⁷ code. The specific activity of U-235 is $2.16 \times 10^6 \text{ pCi/g}$. Hence 5% of 35 kg represents $3.8 \times 10^9 \text{ pCi}$. Assuming a breathing rate for an adult of $20 \text{ m}^3/\text{day}$ ($2.31 \times 10^{-4} \text{ m}^3/\text{sec}$),⁶⁻¹⁰ then the largest dose which can be exceeded only 5% of the time from 854, was calculated to occur in summer 3400m southeast of the 854 complex (3400 m was used instead of the nearest site boundary because of the H.E. detonations which caused the release to be well above the ground.)

$$\text{Dose} = (3.8 \times 10^9 \text{ pCi})(10^{-3} \text{ s/m}^3)(2.31 \times 10^{-4} \text{ m}^3/\text{s})(4.9 \times 10^{-2} \text{ mrem/pCi})$$

$$= 43 \text{ mrem.}$$

This value is well below the maximum value of 500 mrem annual effluent dose limit specified in ERDAM 0524.

Beryllium Lung Dose -- Based on the unpublished work of A. J. Toy,⁶⁻⁵ it is assumed that less than 0.5% of the 20 kg of beryllium becomes airborne. This was used as a source term to calculate the dose during the puff passage. Assuming the same meteorology and breathing rate used above for the uranium dose calculations, the beryllium calculation is as follows:

$$\begin{aligned} \text{Dose} &= (10^{-3} \text{ x/m}^3) \times 10^8 \mu\text{g} \\ &= 10^5 \mu\text{g s/m}^3 \quad \text{or} \quad \frac{10^5 \mu\text{g s/m}^3}{60 \text{ s/min}} \\ &= 1700 \mu\text{g min/m}^3 \end{aligned}$$

This value is slightly more than the maximum value of $1500 \mu\text{gmin/m}^3$ total for a 10 to 60 min beryllium exposure recommended by NIOSH⁶⁻¹¹ for repeated exposures. Since an accident would result in a single exposure, health effects would be minimal.

Nuclear Criticality

Before starting the discussion of nuclear criticality hazards, two definitions are needed to establish the difference between explosives and explosive accessories. Explosive accessories are explosively actuated devices such as explosive switches, explosive valves, explosive bolts, etc., that are designed and joined with assemblies, devices, or systems containing fissile material such that their planned or accidental actuation will not affect the safe containment of the fissile material within the assemblies, devices or systems.

Explosives or High Explosives are generic terms whose meaning in this Nuclear Criticality section correspond to their usual meanings in technical discourse.

Three classes of assemblies that contain fissile material and explosives or explosive accessories are tested in the Building 854 Complex: (1) U-235/High Explosive, (2) U-235/High Explosive/High Explosive Accessories, (3) Fissile Materials other than U-235/High Explosive Accessories.

U-235/High Explosive assemblies are subjected only to environmental tests in which it is not planned to detonate the high explosive. Environmental testing and movement of U-235/High Explosive assemblies is allowed only after a hazard analysis is made for each specific system, and it has been determined that a nuclear yield cannot possibly occur even if the high explosive detonates (this claim must be certified by the "A" or "B" Division Leader or his designated alternate). Each test plan is reviewed by the appropriate Program Division Leader and approved by that Program's Associate Director.

U-235/High Explosive/High Explosive Accessories assemblies may be subjected to environmental testing with or without actuation of the explosive accessories only after a hazard analysis is made for each specific system and it is determined that; (a) a nuclear yield cannot possibly occur even if the high explosive detonates (this claim must be certified by the "A" or "B" Division Leader or his designated alternate), or (b) the high explosives in the system will not be detonated by actuation of the explosive accessories. Each test plan is reviewed by the appropriate Program Division Leader and approved by that Program's Associate Director.

Fissile materials other than U-235 may not be assembled or located in the same cell with high explosives. Subcritical configurations of fissile materials other than U-235 may be assembled with explosive accessories and subjected to environmental testing with or without actuation of the explosive accessories only after a hazard analysis is made for each specific system and it is determined that (a) the fissile material cannot possibly be dispersed by the actuation of the explosive accessory and (b) even if an accidental dispersal should occur, the fissile material will be contained within a secondary container, or in the worst case, within the facility. Each test plan is reviewed by the appropriate Program Division Leader and approved by that Program's Associate Director.

The rules and hazard analyses outlined in the previous three paragraphs serve to prevent explosively assembling a subcritical configuration of fissile material into a supercritical configuration. The probability of changing a subcritical configuration into a supercritical configuration by accidental introduction of moderating materials (e.g. water) is negligible because of a double containment requirement for the fissile materials in a test assembly.

The previous paragraphs discuss generally applicable constraints imposed on testing by nuclear criticality considerations. As a further precaution, each proposed operation with fissile materials is covered by a written Operational Safety Procedure, which is evaluated by members of the Criticality Safety Office.

Explosions

Various types of explosions were considered using information in Sections 4 and 5. Among these explosion sources were flammable liquids, flammable gases, combustible dusts, and explosives. The design, location, and operations associated with the buildings in this Complex will tend to minimize the effects of any explosion.

Flammable Liquids -- A possibility exists that a small quantity (pint) of flammable liquid such as acetone, methyl alcohol, or similar volatile solvent would be used for cleaning during the preparation of equipment for test. (All flammable liquids will be removed from the test cell before the test specimen is brought into the test cell.) If the pint of acetone was spilled, and complete evaporation occurred, the vapor would occupy approximately 1.83m^3 . Building 854C has an open volume of 1650m^3 . The ratio of acetone vapor to air volume is about 0.1%. Since the lower explosive limit for acetone (by volume) is 2.6%, it would actually require more than three gallons of acetone to create an explosive gas - air mixture in the entire test cell.

Ventilation air would also aid in reducing any vapor concentration. Sources of ignition in each cell are minimal since electrical fixtures and controls use Class II electrical equipment. Thus, it is estimated that an explosion, which could occur as a result of using (or spilling) small quantities of flammable liquids, is highly unlikely.

Flammable Gases -- There are no significant quantities of flammable gases (hydrogen, methane, propane, etc) used in the 854 Complex.

Combustible Dust -- An explosion may occur in a room whenever the concentration of finely divided combustible materials (dusts) exceed their lower explosive limit and some form of ignition source is available. Whether or not a dust cloud will ignite is governed by the size of particles in it, dust concentration, impurities present, oxygen concentration, and the strength of the source of ignition.

None of the operations planned for the 854 Complex will produce dusts. There is a very remote possibility that some substances used in a test program could fail, and produce a finely dispersed lint, dust, metal, etc. Since each test cell is configured with Class II electrical equipment (dust ignition proof), ignition sources are minimal.

Explosives -- If an explosion occurred during a test, damage to a test cell would occur. The magnitude of the damage would vary depending on the quantity of explosives involved. A consequence of any explosion would be the failure of the frangible portion of the building. Debris would be scattered inside the cell, and in a cone shaped pattern away from the frangible wall. No irreparable damage would be sustained by adjacent buildings in the Complex.

The Control Building (854A) was designed to withstand overpressures generated from an accidental detonation of 90 kg of explosives from any test cell in the Complex.

A comparison of structural features for the Control Building (854A) and Control Building (836A at Site 300) shows many similarities; reinforced concrete walls, floors, and roof supported on steel beams. A 1973 study by

Baker and King⁶⁻² for 836A showed an amount of explosives exceeding 9500 kg could be tested in an adjacent test cell, and only door modifications were required to the basic structure. It is reasonable to assume from analysis of Control Buildings, location of Test Cells, etc. that 200 kg of explosives could be tested in the 854 Complex with negligible damage to the Control Room, if an explosion occurred in any of the four test buildings.

In summary, the 854 Complex was designed for testing of certain hazardous materials. Although the possibility of an explosion always exists, the combination of building locations, types of construction, and administration of operation will prevent personal injury and minimize physical damage to facilities.

Fire

General -- It is extremely unlikely that a fire would ever occur during a dynamic test and pose a threat to an item containing explosives and/or radioactive materials. Electrical equipment are configured with redundant cut-off features to limit current and/or voltage, electrical fixtures and wiring in test cells have a rating of Class II (used in the presence of combustible dust), and potential ignition sources are removed/modified to meet safety guidelines.

The overall fire hazard analysis, for each of the test cells in the 854 Complex, considered four areas: (1) fire potential, (2) response to an alarm, (3) problems in fire fighting, and (4) a postulated fire that might occur during the preliminary setup, and check-out of test equipment.

Characteristics Affecting Fire Potential -- Access, building construction, ventilation, and fire alarm systems for the '854' test cells are discussed in Section 4. In addition, the following items also affect fire potential:

- o Fuel loading in the cell is relatively low, the maximum is 4.9 kg/m².
- o Flammable liquids kept to a minimum and stored in safety cans.
- o Minimal external fire exposures to the Test Cell.
- o Contained explosives present during a test.
- o Fire extinguishers in each room (test cell) and mechanical equipment room.

Collectively, these items contribute to a very low fire loading; i.e. the potential for a fire is extremely low.

Fire Department Response -- When a fire alarm is received i.e. automatic, telephone, verbal, etc., the Fire Department at Site 300 responds within 10 min.

A response time of 10 min., or less, by the on-site fire department, augmented by 'first-aid' fire suppression equipment at the cells, ensures a relatively high degree of protection for the 354 Complex. In addition, test cells are characterized by a low population (less than five operating personnel with a test item), affording quick and rapid evacuation in the event of fire. Life safety threats are minimal.

Response levels, and available equipment, are listed in Table 6-1. The Senior Officer may call for additional help after he has evaluated the situation.

Fire-Fighting Problems -- There are no major fire-fighting problems in the 854 Complex unless explosives are present. The fire loading is low for each of the facilities. These factors, coupled with the early warning smoke detection (or wet pipe sprinkler activation) and subsequent response by the Fire Department, make the possibility of a fire extending beyond a single facility very remote.

When explosives are present in a test cell, the firemen will observe the precautions as outlined in the Response Plan for Fire In an Explosives Area.⁶⁻¹³ No reentry will be made into any facility until a cooling off period has been observed. The interim will be used to review all relevant facts associated with the alarm and/or test.

Fire Analysis -- T. J. Harmathy⁶⁻¹⁴ has developed an equation to describe the duration of a ventilation controlled fire, where duration is defined as the time interval from flashover to when the average gas temperature diminishes to 80% of the maximum gas temperature.

$$t = 5.76 \times G_o / U_a$$

t = Fire duration, in seconds

G_o = Fuel loading, in kilograms (fuel load is paper, cardboard, wood)

U_a = Flow rate of air supply, in kilograms per second

If we assume a hypothetical case where the fire loading is approximately 4.9 kg/m², a ventilation rate of 2.32 kg/s, and a cell area of 123 m², the hypothetical fire duration is about 25 minutes. Assuming the failure of the automatic smoke detectors and sprinklers, the passive containment system (walls, roof, floor) in the Test Cell should remain intact during the short period of the fire. It is unlikely that any fire would even occur in any building at the 854 Complex (or last more than a few minutes) since the fire loading is so low, and sources of ignition are extremely remote.

Table 6-1. Fire Department Response Levels, Site 300

First Alarm	LLL	F-71	1000 gpm pumper
	LLL	F-3	1000 gpm pumper/50 ft. elevating platform
	LLL	Command Car	Chief Officer
Second Alarm	LLL	F-72	750 gpm pumper
	Livermore	E-23	1000 gpm pumper
		C-1	Chief
	Alameda County	E-1	1000 gpm pumper
	Ambulance		Fremont ambulance
Third Alarm	VA Hospital	EZ1	750 gpm pumper
	OES	R-1	Heavy Duty Rescue

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SECTION 7 -- ENVIRONMENTAL MONITORING PROGRAM

Introduction

General

A monitoring program is continually maintained at Site 300 to detect and document changes in environmental levels of radioactive and nonradioactive materials. Environmental monitoring consists of: (1) air sampling at perimeter locations, (2) vegetation collection on and in the vicinity of Site 300, (3) collection of water samples from wells, surface sources, and rainfall, and (4) collection of soil samples from locations near the firing bunkers. The results of these programs are contained in the Lawrence Livermore National Laboratory Annual Environmental Monitoring Report UCRL-50027-80.

Sampling

Air Sampling

Airborne radioactivity is measured at ten locations around Site 300. The samplers use Whatman 41 cellulose filters and are operated at an average flow rate of 700 μ /min. Air filters are changed on a weekly basis. These samples are analyzed for gross alpha and gross beta activity. A monthly composite is counted for specific gamma-emitting radionuclides by Ge(Li) spectroscopy. A monthly composite, by location, is also analyzed for beryllium using atomic absorption. Plutonium and uranium analyses are made on the monthly composite using radiochemical methods.

Vegetation Sampling

Vegetation samples are collected at monthly intervals from seven locations on and around Site 300. These samples are freeze dried, and selected material intake is determined by liquid scintillation counting.

Water Sampling

The water sampling program consists of several sources: surface water, rainfall, and deep wells. The surface water (creeks) are sampled on a quarterly basis as available; the wells are sampled quarterly; and the rainfall is sampled on a monthly basis. All water samples are analyzed for gross alpha and beta activities using a gas proportional counter.

Soil Sampling

Soil samples are taken annually at twelve locations at Site 300. These samples are taken to determine the perturbation in the $^{235}\text{U}/^{238}\text{U}$ ratio of the soil. These measurements are made by mass spectrometry. Gamma spectroscopy on these samples also provide data on other radionuclides. Plutonium and cesium-137 analyses are also performed.

SECTION 8 -- RISK ASSESSMENT

The information contained in Sections 3 through 7 of this document provides the foundation for this risk assessment. Credit is taken for all mitigation features. Of major concern at the 854 Complex were the possibility and consequences of large releases of radioactive materials and beryllium. However, it was determined in the Accident Analysis Section that:

- 1) a plutonium - HE explosion is not credible since plutonium and HE are not permitted concurrently in the same area at Site 300. (The exception to this policy as stated in Procedure No. 132⁵⁻¹ is that explosive actuating devices are sometimes located in assemblies containing fissile materials. An accidental detonation will not effect the safe containment of the fissile material within the assembly.)
- 2) a major fire involving plutonium, uranium, or beryllium is not credible due to the very low fire loading and the lack of ignition sources.
- 3) An accidental HE detonation would not disperse enough uranium or beryllium to result in a radiation lung dose greater than 43 mrem or a beryllium lung dose exceeding 1700 $\mu\text{g min/min}^3$. This is well below the 500 mrem annual effluent off-site radiation dose limit specified in ERDAM 0524 and only slightly exceed the 1500 $\mu\text{g per min/m}^3$ off-site limit for beryllium as recommended by NIOSH for repeated exposure. Since an accident would result in a single exposure, health effects would be minimal.

The various hazards associated with Acts of Nature and Human Error have been summarized in Table 8-1. Low hazards are those that present minor on-site and negligible off-site impacts to people in the environment.

Moderate hazards are those that present considerable potential on-site impacts to people or the environment, but at most only minor off-site impacts. High hazards are those with the potential for major on-site or off-site impacts to people or the environment.

All but one of these hazards is classified as low per DOE Order 5481.1A. The exception is the intrinsic hazard associated with the handling of explosives. Even though an accidental detonation is not likely to occur, it could result in major damage to the facility, the equipment in it, and even a few injuries or fatalities. Thus, there would be considerable on-site impact from a detonation with only a minor off-site impact to the environment.

Therefore, the 854 Complex is classified as a moderate hazard facility per this analysis and the guidance provided by DOE Order 5481.1A..

Table 8-1. Summary of Safety Evaluation

<u>Potential Hazard</u>	<u>Mitigating Features</u>	<u>Consequences of Failure Feature of Mitigating</u>	<u>Level of Risk</u>
Acts of Nature	These facilities can withstand hazards due to the acts of nature that are postulated for Site 300. Steel frame buildings, electronic racks bonded to ground systems, and lightning suppressors on light and telephone circuits provide lightning protection. These facilities are located 250 m above Corral Hollow Creek.	If structure or equipment fail due to an act of nature, a small amount of radioactive material might be released. Lung dose calculations show up to 0.42 mrem for plutonium.	Low
Earthquake			
Tornado			
Extreme Wind			
Missile			
Lightning			
Flood			
Human Error	Pu and HE not permitted in same area. Pu doubly encased in sealed containers. Facilities are sprinkled, have low fire loading, lack ignition sources, and have dust ignition proof electrical fixtures. Earthen berms separate facilities. These facilities are located in a remote area. Only small quantities of flammable liquids are permitted in test cells and and no flammable gases are present. None of the operations produce dust. Signs are posted and administrative controls are enforced.	If an HE explosion occurred due to a human error or equipment failure, the lung dose calculations shows a maximum of 43 mrem for uranium and 1700 $\mu\text{g min/m}^3$ for beryllium. The radiation doses are well below the 500 mrem annual effluent dose limit specified in DOE M 0524. The beryllium dose is slightly more than the 1500 $\mu\text{min/m}^3$ recommended by NIOSH for repeated exposures. Since an accident would result in a single exposure, health effects would be minimal.	Low risks for all hazards except the remote possibility of an HE detonation. This might cause a few injuries or even fatalities.
Plutonium Spill			
HE Detonation Involving Uranium and/or Beryllium			
Nuclear Criticality			
Explosions			
Fire			

SECTION 9 -- SUMMARY OF FINDINGS AND RECOMMENDATIONS

This section summarizes the finding and recommendations of this safety assessment for the 854 Complex.

Findings

- o The results of the seismic and wind analyses indicated that the 854 facility is structurally sound. No structural improvements are necessary..
- o The analysis of the lightning protection systems indicated that they are less than adequate in some areas. They are in the process of being upgraded to meet AMCR 385-100.
- o The existing fire protection system at these facilities is adequate. No modifications are necessary.
- o The design and location of these facilities are adequate for handling explosives.
- o Because explosives are handled here, the 854 Complex is classified as a moderate risk facility by DOE Order 5481.1. This means that these facilities may present significant on-site impacts to people and the environment, but at most only minor off-site impacts.

Recommendations

- o Formalize the existing Quality Assurance Program in writing.

APPENDIX 6A

SEISMIC, TORNADO AND WIND ANALYSIS

OF

BUILDING 854H SITE 300

The seismic, tornado, and wind analysis for Building 854H in this appendix was extracted from the seismic, tornado, and wind analysis of Buildings 836C and 854H written by David Kai Tu. Thus references to facilities other than those in the 836 complex have been deleted.

(May 1, 1978)

SEISMIC, TORNADO, AND WIND ANALYSIS
OF BUILDING 854H
AT SITE 300

David Kai Tu
April 1978

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- IV. REFERENCES

SEISMIC, TORNADO AND EXTREME WIND ANALYSIS
OF BUILDING 854H

I. INTRODUCTION

Several structures at Site 300 have been identified as critical facilities. A critical facility is defined as a structure which contains material that potentially may become an off-site hazard in the event of certain natural disasters; namely, tornadoic or extreme winds and strong motion earthquake. In compliance with the Department of Energy's request, a safety analysis of each of the identified critical facilities is being conducted. As part of that safety analysis study, each of the facilities' structural integrity must be assessed for those extreme geological and meteorological events named.

This report summarizes the analytical investigation of the structural response of Building 854H, subjected to a safe shut-down earthquake and to 10^{-4} probable extreme wind. The purpose of the investigation is to discover deficiencies (if any) within each of the building's lateral force resisting system and its structural components. The study concludes with recommendations for the upgrading of the structure to adequately resist the SSE and extreme wind events.

II. SEISMIC, TORNADO AND EXTREME WIND HAZARDS

Safe-Shutdown Earthquake--The safe-shutdown earthquake (SSE) is based on the geological investigation conducted by Lawrence Livermore Laboratory of the land area surrounding the 834, 836, and 854 Complexes. The investigation is summarized in a report entitled A Geological and Seismological Investigation for the 834, 836 and 854 Building Complexes at LLL's Site 300¹, written by Thorpe and Wight.

The study identifies several major faults and minor faults which are considered active within or around Site 300. These faults are delineated in Figure 1 and Figure 1a. Due to the close proximity of the active faults, a peak ground acceleration of 0.3g was predicted for the area. The characteristic of the worst possible earthquake defined as a safe-shutdown earthquake is that earthquake which produces the maximum vibratory ground motion for which structural systems and components necessary for the safe operation of the facility must remain functional. The response spectra for 2%, 5% and 10% critical damping are shown in Figure 2.

Figure 2 SSE response spectra for the 834, 836 and 854 complexes

Tornado and Extreme Wind - The tornado and extreme wind criteria for Site 300 were developed by McDonald, Mehta and Minor, Consulting Engineers. The criteria and the information supporting the criteria are documented in the report entitled Development of a Design Basis Tornado and Structural Design Criteria for Lawrence Livermore Laboratory's Site 300, California².

Figure 1a. Geologic Section through Site 300
(Section A-A, Figure 1)

The postulated tornado and extreme wind parameters are shown in Table 1. The tornado criteria is based on a recurrence interval of 1×10^{-6} occurrence per year, while the extreme wind parameters is determined on the basis of a recurrence interval of 1×10^{-4} occurrence per year. This is consistent with DOE Design Criteria Manual. The effective velocity given in Table 1 accounts for a 10 per cent increase in the wind speed because of the channeling effect of the terrain at Site 300.

TABLE 1

Tornado and Extreme Wind Parameters

Tornado	
Rotational Plus Translational Speed	102 mph
Pressure Drop	None
Extreme Wind (straight wind)	
Velocity below 30 ft.	121 mph
Wind Borne Missile	
Wood 2" x 4" x 12', 20 lbs.	70 mph

For the selected levels of risk, the extreme wind criteria dominates; therefore, the structural integrity of Building

054H was checked for extreme wind only. Wind loads are calculated based on recommendations of ANSI A58.1-1972 Standards³.

IV. EVALUATION OF BUILDING 854H

Building Description--Building 854H has plan dimensions of 43 ft. long, 45 ft. wide and 24 ft. high. The structure is reinforced concrete. The lateral force resisting system of the building consists of series of columns in-filled with 12 inch thick shear walls. Wing walls, acting as retaining walls for the covering soils, extend outward from the front of the building. A large sliding steel door provides access to the interior of the structure.

The building is used for thermal and vibration testing of hardware specimens. The floor of the testing room is a monolithic reinforced concrete block 24 ft. long, 14 ft. wide, and 2 ft. thick. The foundation of the building is slab on grade with continuous footings to support the walls. The footings are tied to walls by steel dowels. The roof of the test room is an 8 inch thick reinforced concrete slab. The roof of the remainder of the building is a 12 inch slab supported on reinforced concrete girders. Plans, elevations and details of Building 354H are shown in Figures 8 thru 10.

Analytical Procedure--Building 854H was evaluated for its ability to resist the safe shut-down earthquake and the 1×10^{-4} wind which was described earlier. The roof system was taken to be rigid and have the ability to transfer lateral and torsional loads to the shear walls. As reported in the geological study by Thrope and Wight.

Figure 8: Building 854H--Elevations

Figure 9: Building 854H--Plan and Cross-Sections

Figure 10: Building 854H--Cross-sections

Building 854H is situated on bedrock. Therefore, only the covering soil interaction with the structure was considered.

A two dimensional finite element analysis was conducted. The computer program PLUSH was used to perform the analysis. Bedrock was taken to be at the foundation level of the building.

Figure 1) shows the finite element model for shaking in the longitudinal direction of Building 854H. In-filled shear walls were modeled as plate elements. The walls perpendicular to the direction of motion and the columns were modeled as beam elements. Another block of elements were used to represent the soil covering the building. Soil element nodes and structured element nodes were tied together to incorporate the forces transmitted through the soil structure interface.

Since no soil properties were available, the following properties were assumed based upon our experience:

Soil unit weight = 120pc.f

Poisson's Ratio = 0.4

The 5% response spectrum (Figure 2) was used for the input to the dynamic analysis.

The results from the dynamic analysis were added to the static load conditions. The superimposed stresses were compared with ultimate stress capacity of the structural elements.

Wind effects were investigated in conjunction with seismic loading. Seismic loadings governed except for suction of the front wall.

SOIL MASS ELEMENTS

RETAINING WALL AND SHEAR WALL ELEMENTS

REPRESENTATIVE BEAM ELEMENTS

PRELIMINARY
NOT FOR PRODUCTION

Figure 11: Building 854H--Finite Element Model

Results of the Structural Analysis--The results obtained from the analysis are summarized and tabulated in Table IV and V. Table IV summarizes the factors of safety for shear stress conditions. Table V summarizes the factors of safety for shear wall transverse bending.

Table IV

Summary of Factors of Safety for Shear Stress Conditions

<u>Elements</u>	<u>Factors of Safety*</u>
North Wall	3.47
South Wall	3.68
East Wall	1.20
West Wall	1.20
Roof	3.4
Foundation	3.13

$$\text{*Factor of Safety} = \frac{\text{Ultimate Shear Stress, } V_{ult}}{\text{Actual Shear Stress}}$$

Ultimate shear strength of wall was calculated as: $V_{ult} = V_c + V_s$

where $V_c = 2 f'_c$

and $V_s = \frac{A_v f_y}{b_w s}$

A_v = area of steel bar

f_y = 60,000 psi

b_w = thickness of wall

s = spacing of steel bars

Table V

Summary of Transverse Bending Factors of Safety

<u>Element</u>	<u>Factors of Safety*</u>
North Wall	1.72
South Wall	2.27
East Wall	2.38
West Wall	2.38
Roof	5.87
Foundation	3.52

$$\text{*Factor of Safety} = \frac{\text{ultimate moment capacity}}{\text{actual moment}}$$

The results show that the dynamic stresses induced in the structural members are very low in comparison to the strength of the structural members. Since the configuration of the structure is similar about the principal axes, it was reasonable to determine the stresses due to shaking in the short direction by the results from the longitudinal shaking. The analysis of the structure for shaking in the longitudinal direction is considered to be the worst case because of the larger contribution of the soil mass.

No missile penetration analysis was performed on the front wall or sliding steel door. For information on missile impact test results, see Appendix A.

Conclusions and Recommendations--Building 354F is more than adequate to resist the postulated SSE and the 1×10^{-4} extreme wind. No structural modifications are required and no operation conditions need be imposed during high winds.

IV. REFERENCES

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APPENDIX 6B

SEISMIC, TORNADO AND WIND ANALYSIS

OF

BUILDING 854C, E, and F SITE 300

The seismic and wind analysis for Building 854C, E, and F in this appendix was written by David Kai Tu.

(November 29, 1977)

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SEISMIC, TORNADO AND EXTREME WIND ANALYSIS OF BUILDING 854C, 854E AND 854F

I. INTRODUCTION

Several structures within the 854 complex at Site 300 have been identified as critical facilities. A critical facility is defined as a structure which contains material that potentially may become an off-site hazard in the event of certain natural disasters; namely, tornadoic or extreme winds and strong motion earthquake. In compliance with the Department of Energy's request, a safety analysis of each of the identified critical facility is being conducted. As part of that safety analysis study, each of the facility's structural integrity must be assessed for those extreme geological and meteorological events named.

This report summarizes the analytical investigation of the structural response of Buildings 854C, 854E and 854F, subjected to a safe shut down earthquake and to 10^{-4} probable extreme wind. The purpose of the investigation is to discover deficiencies (if any) within each of the building's lateral force resisting system and its structural components. The study concludes with recommendations for the upgrading of the structure to adequately resist the SSE and extreme wind events.

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The study identifies several major faults and minor faults which are considered active within or around Site 300. These faults are delineated in Figure 1 and Figure 2. Due to the close proximity of the active faults, a peak ground acceleration of 0.8g was predicted for the area. The characteristic of the worst possible earthquake defined as a safe-shutdown earthquake is summarized as an acceleration response spectrum. A safe-shutdown earthquake is that earthquake which produces the maximum vibratory ground motion for which structural systems and components necessary for the safe operation of the facility must remain functional. The response spectra for 2%, 5% and 10% critical damping are shown in Figure 3.

Figure 3. SSE response spectra for the 834, 836 and 854 complexes

Tornado and Extreme Wind - The tornado and extreme wind criteria for Site 300 were developed by McDonald, Mehta and Minor, Consulting Engineers. The criteria and the information supporting the criteria are documented in the report entitled Development of a Design Basis Tornado and Structural Design Criteria for Lawrence Livermore Laboratory's Site 300, California².

Figure 1. Geologic map of Site 300

Figure 2. Geologic Section through Site 300
(Section A-A, Figure 1)

The postulated tornado and extreme wind parameters are shown in Table 1. The tornado criteria is based on a recurrence interval of 1×10^{-6} occurrence per year, while the extreme wind parameters is determined on the basis of a recurrence interval of 1×10^{-4} occurrence per year. This is consistent with DOE Design Criteria Manual. The effective velocity given in Table 1 accounts for a 10 per cent increase in the wind speed because of the channeling effect of the terrain at Site 300.

TABLE 1

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Velocity below 30 ft.	121 mph
Wind Borne Missile	
Wood 2" x 4" x 12', 20 lbs.	70 mph

For the selected levels of risk, the extreme wind criteria dominates, therefore, the structural integrity of Building 854C, 854E and 854F were checked for extreme wind only. Wind loads are calculated based on recommendations of ANSI A58.1-1972 Standards⁴.

III. EVALUATION OF BUILDING 854C

Building Description - Building 854C consists of four structural sections aligned in a southeasterly - northwesterly direction. At the southeast end of the building is a reinforced concrete reaction block and at the opposite end of the building is an earth covered eight-foot diameter concrete pipe used to extend the experimental test track. Since both of these structural sections are non-essential to insure containment of radioactive materials located in the building, their structural integrity are not considered in this investigation.

Located between the reaction block and concrete pipe are two steel framed structures housing the remaining experimental test structure.

The one steel framed structure situated next to the reaction block is 16' - 6" wide by 20' - 9½" long with the height of the structure varying from 14' - 4" to 15' - 4". The structure is enclosed with frangible transite panels designed to blow out in a high explosive accident.

The lateral force resisting system in the long direction of the building is comprised of two rigid steel frames with pinned type connections for the column to foundation attachments. In the short direction, the lateral force is resisted by 5/8" diameter diagonal cross-bracings with initial pretension load of 1000 lbs.

The remaining structural section of Building 854C is approximately 20' wide by 80' long with a maximum height of 13'. The prefabricated steel framed structure is covered with galvanized steel siding and roofing. The lateral force resisting system in the short direction is comprised of five portal frames which are pinned at the supports. In the long direction, the lateral force resisting system consists of ½" diameter diagonal cross-bracing with additional lateral force resistance being provided by the girts, purlins and steel siding.

There are no structural connections between the two structures. To simplify the analysis, the transite covered steel framed structure and the galvanized steel covered framed structure is assumed to act independently. No structure to structure interaction is considered.

Plans, elevations and structural details for Building 854C are shown in figure 4.

Analysis Procedure - The transite panel and galvanized steel covered sections of Building 854C were investigated for their ability to resist the safe-shutdown earthquake and the 1×10^{-4} wind which were described

Figure 4: Plans, Elevations and Structural Details of Building 854C

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earlier. SAP IV⁴, a linear elastic structural analysis computer program is used to perform the dynamic (earthquake) and static (wind) load analysis. It is assumed that the structural motions in the two principal directions of the building are uncoupled from each other. The dynamic analysis used the response spectrum approach with a value of 5% critical damping assumed for the structure. For the wind analysis, the wind loads are calculated and applied at the roof level as an equivalent static force. The two structural sections were modeled as assemblages of beam and truss type elements.

Results of the Structural Analysis (Transite Panel Covered Section) - The results obtained from the analysis are summarized in Table 2 through 4. Seismic loadings were found to govern for the lateral loads. Factors of safety are based on allowable stresses. When the factor of safety based on allowable stress values is less than 1.0, the factor of safety based on yield stress is shown in parenthesis.

TABLE 2
Fundamental Period

Description	Period (sec)
Short Direction (Diagonal Cross-bracing)	.1864
Long Direction (Rigid Frame)	.9336

TABLE 3

Factors of Safety of Structural Elements

Description	Location	Factor of Safety
<i>Short Direction</i>		
W 8 x 10	Roof Girders	47.0
5/8" O.D. Rods	Exterior Walls	(.69)
<i>Long Direction</i>		
W 8 x 10	Roof Girders	(.57)
W 6 x 15.5	Columns	(.73)
<i>Misc. Structural Elements</i>		
W 8 x 10	Roof Supporting Members	(1.16)
WT 4 x 5	Vertical Wall Supports	1.69
L2½ x 2 x 5/16	Vertical Wall Supports	1.37

TABLE 4

Factors of Safety of Structural Connections

Description	Factor of Safety
W 8 x 10 - W 8 x 10	1.32
WT 4 x 5 - W 8 x 10	4.4
L2½ x 2 x 5/16 - W 8 x 10	4.4
W 16 x 15.5 - Foundation	.75

Conclusions and Recommendations - The results of the structural analysis indicates the lateral force resisting system is inadequate to resist the postulated SSE. The following recommendations are made:

- : Replace diagonal tie rods with tie rods of the same diameter and a minimum yield strength of 80,000 psi
- : Tie rod connection details should be redesigned to allow development of higher loads
- : Structural tees should be welded to the interior flanges of the W 8 x 10 girders and W 6 x 15.5 columns with moment connection details for the beam to column connections.
- : Column to foundation connections should be reinforced to take higher shear loads

No missile penetration analysis was conducted but because the exterior walls of the structure are constructed of transite panels, it is highly probable that the postulated missile (Table 1) could penetrate the structure. Upgrading of the exterior wall systems, with regard to missile penetration is required if operational capability during severe winds is necessary.

Results of the Structural Analysis (Galvanized Steel Covered Section) - The results obtained from the analysis are summarized in Table 5 through 8. The wind load governs in the short direction of this structural section of Building 854C. Seismic load governs for the long direction. Factors of safety are based on allowable stresses. When the factor of safety based on allowable stress is less than 1.0, the factor of safety based on yield stress is shown in parenthesis.

TABLE 5
Fundamental Periods

Description	Period (sec)
Short Direction (Rigid Frame)	.1437
Long Direction (Diagonal Cross-bracing)	.1802

TABLE 6
Factors of Safety of Structural Elements and Connections

Description	Location	Factor of Safety
Short Direction (Rigid Frame)		1.02
Long Direction		
1/2" O.D. Tie Rods	Exterior Walls	(.59)
Purlins	Roof Supporting Members	4.33
Connections		
Column - Foundation		.86

Conclusions and Recommendations - The results of the structural analysis shows that the rigid frames spanning the short direction of the structure are adequate to resist the postulate SSE and extreme wind.

The diagonal rod braced lateral resisting system in the long direction is found to be inadequate to resist the postulated SSE. The following recommendations are made:

- : Replace diagonal tie rods with tie rods of the same diameter and a minimum yield strength of 100,000 psi.
- : Tie rod connection details should be redesigned to allow development of higher loads.
- : Column to foundation connections should be reinforced to take higher shear loads

No missile penetration analysis was conducted but because the structure are enclosed with only galvanized steel sidings, it is highly probable that the postulated missile could penetrate the structure. Upgrading of the exterior walls, with regard to missile penetration is required if operational capability during severe winds is necessary.

IV. EVALUATION OF BUILDING 854E

Building Description - Building 854E is a one story, steel-framed structure with plan dimensions of approximately 30' by 20', with the height varying from 17' to 18'. The structure is enclosed with frangible transite panels.

The lateral force resisting system in the short direction of the building is two 3/4" O.D. diagonal rod braced exterior walls. In the long direction, the lateral resisting system consists of two rigid steel frames. The roof loads are transmitted to the respective lateral force resisting system by two rod braced roof systems, one using 3/4" O.D. rods and the other using 3/4", 7/8" and 1" O.D. rods.

Plans, elevations and structural details of Building 854E are shown in Figure 5.

Analysis Procedure - Since Building 854E is a relatively simple one story box system, the equivalent static method is used to evaluate the effects of a strong motion earthquake. The equivalent static method is a representation of the maximum inertial forces induced by dynamic motions. The inertial forces induced by the ground motions are replaced by equivalent loads statically applied at the roof levels. It is assumed that the structural motions in the two principal directions of the building are uncoupled to each other. For the wind analysis, the wind loads are calculated and applied to the roof level as equivalent static forces.

Results of the Structural Analysis - The results obtained from the analysis are summarized in Tables 7 and 8. Seismic loadings are found to govern in all cases. Factors of safety are based on allowable stresses. When the factor of safety based on allowable stress is less than 1.0, the factor of safety based on yield stress is shown in parenthesis.

TABLE 7
Fundamental Period and Response Spectra Value

Description	Period (Sec)	Sa (g) -5% Damping
Short Direction (Diagonal Cross-bracing)	.258	1.95
Long Direction	1.47	.53

TABLE 8
Factors of Safety of Structural Elements and Connections

Description	Location	Factor of Safety
Short Direction		
3/4" O.D. Rods	Exterior Walls	(.40)
Long Direction		
W 10 x 15	Roof Girders	(.57)
W 8 x 20	Columns	(.74)
Foundation Connection		
3/4" O.D. Bolts	Anchorage	.42

Conclusions and Recommendations - The results of the structural analysis indicates that Building 854E's lateral force resisting system is inadequate to resist the postulate SSE. The following recommendations are made:

- : Replace diagonal tie rods with tie rods of the same diameter and a minimum yield strength of 100,000 psi.
- : Tie rod connection details should be redesigned to allow development of higher loads.
- : Cover plates should be welded to the flanges of the W 8 x 20 columns.
- : Structural tees should be welded to the interior flanges of the W 10 x 15 girders.
- : Column to foundation connections should be reinforced to take higher shear loads

No missile penetration analysis was conducted but because the exterior walls of the structure are constructed of transite panels, it is highly probable that the postulated missile (Table 1) could penetrate the structure. Upgrading of the exterior wall systems, with regard to missile penetration is required if operational capability during severe winds is necessary.

V. EVALUATION OF BUILDING 854F

Building Description - Building 854F is a one story steel frame structure with plan dimensions of approximately 21' by 48' by 20' high. Attached to the west portion of the building is a smaller mechanical equipment shed. The total structure is enclosed with frangible transite panels.

The lateral force resisting system in the short direction (North-South) of the building consists of four rigid steel frames. In the long direction (East-West) are two 3/4" O.D. diagonal rod braced exterior walls. The roof loads are distributed by two diagonal rod braced systems, one using 3/4" O.D. rods and the other using 5/8" O.D. rods.

Plans, elevations and structural details for Building 854F are shown in Figure 6.

Analysis Procedure - SAP IV is used to evaluate Building 854F for SSE and extreme wind loads. The structural motions in the two principal directions of the building are assumed to be uncoupled. The 5% response spectrum curve is used in the dynamic analysis. The modal displacements and forces are combined by the square root of the sum of the square (SRSS) scheme. For the wind analysis, the wind loads are calculated and applied at the roof as an equivalent static force.

Results of the Structural Analysis - The results obtained from the analysis are summarized in Tables 9 and 10. Seismic loads are found to govern in all cases. Factors of safety are based on allowable stresses.

When the factor of safety based on allowable stress is less than 1.0, the factor of safety based on yield stress is shown in parenthesis.

TABLE 9
Fundamental Period

Description	Period (Sec)
Short Direction (N-S) (Rigid frame)	1.04
Long Direction (E-W)	.48

TABLE 10
Factors of Safety of Structural Elements

Description	Location	Factor of Safety
Short Directions (N-S)		
W 8 x 24	Columns	(.71)
W 6 x 15.5	Columns	(.53)
W 12 x 27	Roof Girders	(1.10)
W 8 x 10	Roof Girders	(.4)
Long Directions (E-W)		
W 8 x 24	Columns	(.42)
3/4" A. D. Rods	Exterior Walls	(.38)

(Table 10 cont.)

(cont. Table 10)

Description	Location	Factor of Safety
Foundation connection		
1" O.D. Bolts	Anchorage	.7

Conclusions and Recommendations - The results of the structural analysis indicates that Building 854F's lateral force resisting system is inadequate to resist the postulate SSE. The following recommendations are made:

- : Replace diagonal tie rods with tie rods of the same diameter and a minimum yield strength of 100,000 psi.
- : Tie rod connection details should be redesigned to allow development of higher loads.
- : W 8 x 24 columns should be built up with structural tees and cover plates in both the strong and weak axes.
- : Structural tees should be welded to the interior flanges of the W 6 x 15.5 columns and W 8 x 10 beams of the rigid frame on the west end of the building.
- : Column to foundation connections should be reinforced to take higher shear loads.

No missile penetration analysis was conducted, but because the exterior walls of the structure are constructed of transite panels, it is highly probable that the postulated missile (Table 1) could penetrate the structure. Upgrading of the exterior wall systems, with regard to missile penetration is required if operational capability during severe winds is necessary.

VI. REFERENCES

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