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**"Designing for Explosive Safety"
The Explosive Components Facility
at
Sandia National Laboratories**

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Abstract

The Explosive Components Facility (ECF) is to be a new major facility in the Sandia National Laboratories (SNL) Weapons Program. The ECF is a self-contained, secure site on SNL property and is surrounded by Kirtland Air Force Base which is located 6-1/2 miles east of downtown Albuquerque, New Mexico. The ECF will be dedicated to research, development, and testing of detonators, neutron generators, batteries, explosives, and other weapon components. It will have capabilities for conducting explosive test fires, gas gun testing, physical analyses, chemical analyses, electrical testing and ancillary explosive storage in magazines.

The ECF complex is composed of a building covering an area of approximately 91,000 square feet, six exterior explosive service magazines and a remote test cell. Approximately 50% of the building space will be devoted to highly specialized laboratory and test areas, the other 50% of the building is considered nonhazardous (i.e. no energetic material). Critical to the laboratory and test areas are the blast-structural design consideration and operational considerations, particularly those concerning personnel access control, safety and environmental protection. This area will be decoupled from the rest of the building to the extent that routine tests will not be heard or felt in the administrative area of the building.

While the ECF is designed in accordance with the DOE Explosives Safety Manual to mitigate any off-site blast effects, potential injuries or death to the ECF staff may result from an accidental detonation of explosive material within the facility. Therefore, reducing the risk of exposing operation personnel to hazardous and energetic material is paramount in the design of the ECF.

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Introduction

The Explosive Components Facility (ECF), will be a new major facility in the Sandia National Laboratories (SNL) Weapons Program. The concept of the ECF is to consolidate the activities of four departments dispersed among a number of SNL facilities into one building, thus providing a more efficient capability for the weaponization of vital components in the federal arsenal. The consolidation of the Explosive Components Department, Neutronic Components Department, Power Sources Department and Weapons Evaluation Department will enhance and streamline the operation of each.

Hazards addressed in the design of the facility include explosives, pyrotechnics, propellants, lasers, microwaves, radioactive materials, neutrons, x-rays, toxic chemicals, reactive chemicals, hazardous waste and conventional industrial safety hazards. Explosives offer the potential for the highest severity accident occurring within the ECF and, therefore, will receive substantial attention in the design of the ECF.

The Explosive Components Facility Building will be a single story office/laboratory building occupying approximately 91,000 square feet (8,450 square meters) of area. The building is divided into two distinct functional areas; explosive and non-explosive. The explosive area will contain 47,000 square feet (4,370 square meters) of explosive laboratories and work areas. The explosive test area (with cells capable of containing detonations of 250 to 1,500 grams, TNT equivalent) will consist of approximately 12,000 square feet (1,110 square meters) and will contain firing bays, associated assembly rooms and mazes; an explosive aging area; a propellant area; a lithium cell battery abuse area; and an explosive staging area. The remaining 35,000 square feet (3,250 square meters) of the explosive area will consist of wet chemistry type labs, pyrotechnic labs, physical testing labs, and supporting operations areas for the firing bays.

The non-explosive area will contain approximately 44,000 square feet (4,090 square meters) of: office and light laboratory area; mechanical room and mechanical penthouse areas; and, support areas including computer room, storage rooms, conference rooms, multipurpose (vending and eating) room, and restrooms. The non-explosive laboratory areas include software and electronic laboratories, optic laboratories, and experimental assembly space. The service areas include the mechanical and electrical equipment room, shops, and raw stock storage, shipping and receiving room, and short-term storage space. A penthouse will be constructed and will contain the HVAC air handling equipment and utilities equipment. Since these are non-explosive spaces, standard construction techniques and operational considerations will be followed.

Codes and Standards

The Explosive Components Facility will meet the 1988 Uniform Building Code (UBC) requirements for Seismic Risk Zone 2B and the 1982 edition of the American National Standards Institute (ANSI) Standard A58.1 for minimum design loads, excluding seismic loads. Wind loading is based on an 81 mile per hour wind speed, an Exposure C, and an importance factor of 1.07. The entire roofing system will meet the Factory Mutual Class I system acceptance and I-90 wind uplift resistance requirements, as well as the Underwriter's Laboratory (UL) Class A membrane requirements. The requirements of the Department of Energy document, "Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards," UCRL-15910, will be used where they are more stringent than the UBC and ANSI requirements.

In addition to these structural requirements, the portion of the ECF to be used for explosive laboratories and work areas is being designed to meet the requirements of: the "DOE Explosives Safety Manual" (DOE/EV/06194, Rev 4); the Department of the Army publication entitled, "Structures to Resist the Effects of Accidental Explosions" (TM5-1300); the Tri-Services Manual entitled, "Seismic Design for Buildings" (TM5-809-10); and the Department of Energy Order 6430.1A entitled "General Design Criteria." Building egress will conform to the applicable requirements of the National Fire Protection Association "Life Safety Code" (NFPA 101) and the DOE Explosives Safety Manual (DOE/EV/06194). Ladders, stairways and other working or walkway areas will be designed according to the requirements of the Code of Federal Regulations, Title 29, Part 1910, "Occupational Safety and Health Standards."

Operational Considerations and Activities

To develop an understanding of the operations conducted in the ECF, it is important to note that it is a research and development facility which functions differently than a production facility. As a research and development facility, the descriptions of activities are generically grouped in terms of "like" operations rather than a specific well defined industrial process even though, in practice, there are individual differences in equipment, hazards, and personnel. Each activity conducted is, however, required by Sandia policy and practice to be conducted in accordance with the guidelines of a Standard Operating Procedures (SOP) which outlines the required parameters for each operation as well as the mandatory safety precautions.

Specific activities to be conducted in the explosive area of the facility are grouped into the following categories:

1. Shipping, Receiving, and Storage of Explosives, Pyrotechnics and Propellants;
2. Physical and Chemical Testing of Explosives, Pyrotechnics and Propellants;

3. Neutron Device Research, Development and Testing;
4. Battery Research, Development and Testing; and
5. Stockpile Surveillance of Explosives, Pyrotechnics and Propellants.

Design Considerations

Functionally, the ECF has been designed to support and enhance the safety of the above listed activities through optimization of the use of space and structural materials. The design of the facility has made use of the grouping of "like" activities into functional areas which share the similar needs for blast mitigation and environmental protection. Such a design facilitates effective management controls regarding the overall safety of any given activity. The design concept of the ECF and the small quantities of explosives which will be present in the facility eliminate missile and blast pressure concerns for other buildings near the ECF. Firing pads are completely enclosed by blast walls which will contain all debris and missile hazards.

The non-explosive area of the building will be separated from the explosive area to minimize any adverse effects which would result from an accidental detonation within the explosive area. The laboratories adjacent to the non-explosive areas are designed for work with up to 10 grams of explosives. The maximum credible event is postulated to be 10 grams and the laboratory walls, to include the north wall, are designed to contain all fragments and overpressure from the postulated accidental detonation.

Explosive Laboratory Area

The roof and floor of the explosive laboratory areas will be of reinforced concrete which will be designed to withstand the effects of an accidental detonation equal to the maximum credible event that may occur in the particular laboratory area. Doors from all rooms opening into the corridor of the explosives area are oriented perpendicular to the corridor walls. In the event of an accidental detonation within the room, this arrangement will reduce the amount of debris entering the corridor to that allowed by the DOE Explosives Safety Manual.

The corridor of the explosive area will be utilized to transport up to 500 grams of explosives through the ECF. The explosives may be transported through this corridor only when packaged in Department of Transportation (DOT) approved or equivalent containers. The roof and floor of the corridor will be of reinforced concrete construction. Walls will be of the construction type dictated by adjacent room use. This corridor is considered to be an occupied area. A maximum credible event in an adjacent room will result in allowable overpressure and less than allowable levels of debris in this corridor.

Doors will be installed at the two area separation walls (fire walls) located in the corridor. The two area separation walls within the explosive area are required per the National Fire Protection Association "Life Safety Code" (NFPA 101). Doors will also be installed in the area separation wall between the explosive and non-explosive area (per NFPA 101). The latter wall is located at the south end of the two connecting corridors. To comply with the Uniform Building Code (UBC) requirements, these doors will be of three hour fire resistive construction. Due to the pressure anticipated in the corridor from an accidental detonation in a laboratory, all area separation doors (as well as the exterior doors) will be low pressure resistant doors in lieu of labeled fire doors. Although not UL tested fire doors, the pressure resistant (blast) doors will be of more substantial construction than the standard labeled fire door. Standard panic hardware will be used to facilitate exiting. Magnetic devices will be used to hold open the doors located in the corridor. Upon actuation of the alarm system, the magnets will release and the doors will close. The corridor doors will then be sprayed with water to prevent overheating. Initial overpressure from an accidental detonation will travel through the corridor prior to the doors closing.

The doors located between the explosive and non-explosive area will be normally closed to control access to the explosive area and to control an allowable level of overpressure that would result from an accidental detonation in a laboratory or corridor. The exterior doors will be equipped with standard panic hardware for egress, and will be equipped with an access control device to control ingress. The rooms within the explosive area will be designed to control the effects of an accidental explosion and to protect personnel that may be located in adjacent rooms or in the corridors.

Explosive Test Area

Nine test firing bays are located at the rear of the explosives test area. Each firing pad cubicle will be designed to fully protect the operating personnel from the overpressure, hazardous fragments, and thermal effects of planned detonations within the firing pads. The walls, roof, and slabs-on-grade will be designed to accommodate repeated detonations without damage to the structure. Two door openings, equipped with blast doors, will be used to provide access control and full containment. The door opening in the rear (south) wall of each firing pad cubicle will be equipped with a pair of blast doors which will be designed to withstand the effects of the maximum credible event weight of 1000 grams. These blast doors provide ingress and egress for test equipment too large to be transported through the mazes.

The door opening located in the wall between each firing bay and its adjacent maze will be equipped with a single blast door. For economy now, eight of these doors will be designed to withstand the effects of charge weights that are less than 1000 grams. If future explosive testing requirements dictate a need for the firing pads to be used with charge weights in excess of the existing door design limit, the door openings may then be refitted with blast doors having a designed resistance of up to 1000 grams. In order to retain the

ability to test 1000 gram components, the ninth single blast door is designed to withstand the effects of a charge weight of 1000 grams. Each firing bay will contain the fragments and pressure of a planned detonation. Immediately following the detonation, the valve used to close off the exhaust system will be opened to exhaust the space of products of combustion. The exhaust stack will discharge at a height of seven feet above the roof.

During "set-up" activities associated with a test on a firing pad, the pair of blast doors at the rear of the firing bay will be secured. However, the blast door between the maze and the firing bay may be open to facilitate transporting the experiment from the assembly room to the firing bay. If an accidental detonation occurs while transporting the experiment, the DOE overpressure and fragment criteria may not be met at the maze opening. Preliminary calculations show that the criteria will be met at a distance of 9.2 feet (2.8 meters) from the maze into the support area.

Adjacent to the firing pads are two rooms which will each contain a test firing chamber. Each chamber will be designed and proof tested to contain the effects of repeated test involving up to 1000 grams of TNT equivalent explosives. Two concrete pedestal foundations will be constructed in a pit below grade for each test firing chamber. The floor of the test firing chambers will be at the same elevation as the finished floor of the ECF. The walls, roof, and slab-on-grade for these two rooms will be of the same level of design as the firing pads. The doors between these rooms and adjacent mazes will be of hollow metal construction in lieu of blast doors since the firing chambers are designed to fully contain the effects of the blast. Experiments will be transported from the assembly room to the test firing chambers in Department of Transportation (DOT) approved, or equivalent, containers.

Since planned detonations will occur within either an enclosed test firing pad or inside of a test firing chamber, there will be no blast overpressure wraparound produced. This test firing pad arrangement will permit set-up activities to continue at other firing pads while testing in a nearby pad is in progress. However, set-up and testing will not occur simultaneously on firing pads that use the same assembly room.

The assembly rooms are explosive assembly areas where the floor, roof, and three walls are constructed of reinforced concrete. The concrete will be designed to withstand the effects of a 1000 gram detonation. A drywall partition will serve as the rear (south) wall of the assembly room and will contain an access door. This door and the exterior door located in the south wall of the building will be of hollow metal construction. Overpressure due to an accidental detonation in the assembly room will cause the room door (if closed) to blow-out into the adjacent maze, and will also cause damage to the drywall partition. The overpressure will then be vented through the mazes and may blow-out the exterior door. A reinforced concrete fragment containment wall and roof located outside the exterior door will contain the exterior door and other fragments produced by the accidental explosion and overpressure.

The walls, floor and roof of each maze will be constructed of reinforced concrete which will be designed to withstand the effects of a 1000 gram detonation. Mazes will be used in lieu of installing blast doors in the wall between the assembly areas and their support areas. These mazes will have a configuration which will cause a loss of the energy released by a detonation; thus, causing pressure decay. At the openings between the mazes and the support areas, the overpressure caused by an accidental detonation within the assembly room will be reduced to no more than 15 psi (103 KPa) as required by Chapter VI of the DOE Explosives Safety Manual. It will also limit the missiles (hazardous fragments), that may be present at the maze opening, to those that will impart no more than 58 ft-lbs (79 J) of impact energy as required by the DOE Explosives Safety Manual.

A sidewalk and service drive will be located at the rear (south side) of the ECF Building. Access to this drive will be through vehicle gates in the security fencing which encloses that portion of the rear of the building. Access will be administratively controlled by the ECF Safety Officer and will be permitted only during scheduled periods.

Ancillary Test Area

A Remote Test Cell (RTC) will also be located south of the building. The RTC will be used by the Neutronic Components Department for their work with neutron generators, and for a once-a-year Stockpile Integrated Laboratory Test (SILT) which will involve a kilogram quantity of a beryllium/depleted uranium system. Testing will be performed remotely with controls located inside the ECF. The structure will totally contain the fragments and overpressure of a planned 250 gram TNT equivalent detonation.

On-Site Explosive Storage

On-site storage of explosives for testing will be provided in six earth covered service magazines. Each magazine will contain approximately 480 square feet (44.6 square meters) of interior floor area and will be of reinforced concrete construction. An aproned slab-on-grade will serve as the floor and foundation for the one foot thick walls and roof. An interior height of 12 feet (3.7 meters) will accommodate the access door which will have dimensions of seven feet high and three feet wide. The door will open into a maze that will have an opening into an exterior sidewalk and service drive. The maze is utilized to attenuate the blast effects in the event of an accidental detonation within the magazine. The maze will also be utilized to "catch" the magazine door and prevent it from becoming a missile. In the front wall of the maze (face of the structure), will be a 3/4 inch (19 mm) thick steel access panel covering an opening that is five feet wide and seven feet high. This access opening will allow installation and removal of the non-propagating cabinets which will be used in each magazine. The magazines are spaced seven feet apart with three magazines on each side of the service drive. The exterior openings of opposite magazines will be offset to allow the reinforced concrete retaining wall (which includes

the front wall of the maze) to contain fragments or debris from an accidental detonation within the magazine. The front maze wall will serve as the first line of containment for the access door and any fragments or debris.

Each magazine will contain two rows of non-propagating cabinets (ten to a row) which will be installed back-to-back. The fronts, sides and tops of the cabinets will be at least two feet clear ("stand-off" distance) of the magazine walls and roof. The bottom of the lowest cabinet will be located one foot clear of the floor. A cabinet will contain up to a 2,268 gram (5.0 lbs.) TNT equivalent charge. Each magazine will be designed for a maximum credible event of 2,268 grams. The cabinet system has been proof tested with 2,948 grams (6.5 lbs.) TNT equivalent charge. The proof test demonstrated the non-propagation of the detonation from the donor unit to the receptor units. The proof test was conducted with primary explosives, secondary explosives and propellants located within the receptor units. Details of the design, construction and testing of the non-propagating cabinet system is contained in SAND90-1906A.

The magazines will be accessed by way of the service drive at the west end of the ECF Building. Access through the ECF perimeter fence will be by way of a motorized gate located north and west of the front entrance to the building. An interior manual gate will be located at the southwest corner of the ECF Building and will be opened by operating personnel for final access to the service magazine area. Access to the magazines will be administratively controlled by the ECF Safety Officer.

Safety Systems and Access Control

The SNL Lightning Early Warning (LEW) System warns personnel that an electrical storm (high potential gradient) is approaching. The LEW stations, which are located throughout the SNL facilities, measure and indicate the potential for electrical discharge. Remote local stations are also supported by the system. A master LEW station will be established in the ECF with repeater stations at selected locations throughout the explosives work area. The master LEW station will be located in the control room of the ECF. Sensing probes and antennas will be located around the perimeter of the ECF property.

Indicator lights and digital readouts of the potential gradient will be displayed at locations throughout the interior of the building. These lights will receive signals from a control panel located adjacent to the terminal cabinet. When the potential for lightning is less than 1,500 volts/meter, a green light will be displayed. When the potential for lightning is between 1,500 and 2,000 volts/meter, an amber light will be displayed. A red light will turn on when the potential exceeds 2,000 volts/meter. Personnel will consult this system prior to conducting planned detonations in the firing pads.

The Fire Control System (FCS) will safely protect personnel during hazardous operations. The FCS will ensure that the hazardous area (firing pads, gas gun, etc.) has been cleared and will provide a visual/audible warning system to prevent personnel from entering the hazardous area. The FCS master control station will be located in the control room. Access to the general area will be controlled from this station. The station panel will contain alarm point status lights for each of the hazardous operation areas located throughout the ECF.

Local control stations will be established at hazardous operation areas throughout the ECF. Each station will control access to its area. If a person enters the hazardous area, the controls will turn off the operation. System controls include electric dead bolts and locks, rotating red flashing lights, audible alarms, panic switches, limit switches, master and local control panels, and a programmable controller.

A permit signal will be sent from the master control to the local control station after the general area has been cleared and all controls activated. At that time, the local control station will ensure that all controls are activated and will then give a permit signal to the local firing control, gas gun or laser control circuit. Panic switches will be located at key points throughout the explosive test area. The panic switches will terminate the firing sequence in the event of an emergency. Indicator lights and audible alarms will be installed near the interior and exterior doors of each firing pad, gas gun and test firing chamber. The lights and audible alarm will indicate that the firing pad, gas gun or test firing chamber is in use and ready to fire.

Provisions will be made in the FCS to allow the future installation of closed circuit television as another system control.

In addition to the FCS, the movement of personnel within the ECF will be controlled to mitigate the exposure of casuls to the hazardous operations within the building. Personnel Access Control (PAC) will be provided by a key pad and magnetic card reader located adjacent to the entrance of the controlled doors throughout the hazardous areas of the ECF. The key pads and magnetic card readers will be wired to the PAC host computer located in the computer room. Access to the hazardous areas will be permitted by using a numeric code or the magnetic strip on the Sandia badge. Emergency access to the controlled areas will be provided by special badges placed in strategic locations throughout the ECF or a special key pad code made available to all ECF personnel. The use of a special badge or key pad code will alarm the PAC.

All explosives and flammable material laboratories will contain a static ground bus to which static free benches, metal shelving, and personnel grounding wrist bands will be connected. This grounding system will help prevent the accumulation of static electricity on equipment, on materials being handled, or on operating personnel. The static ground bus will be connected to the building grounding system and the lightning protection

system in accordance with requirements of the DOE Explosives Safety Manual and the DoD Ammunition and Explosives Safety Standards manual.

Environmental Impact

Because of the structural integrity of the facility and the relatively small amounts of explosives, toxic materials and radioactive materials present in the ECF, there is little opportunity for impact to the environment or to the general public. Therefore, normal operations will present negligible impact because of the small amount of hazardous materials present in the facility, the presence of engineering and administrative controls preventing their release, and the distance to other facilities or persons outside of the ECF. However, annual soil sampling and analysis will be performed at various sites surrounding the ECF to assure the continued protection of the public and the environment.

Conclusion

By both intent and design, the ECF will comply with all existing and applicable DOE, Air Force, industry consensus, state, federal, and local codes, standards, criteria, statutes and regulations. Compliance is assured through multiple layers of design and procedure reviews by both Sandia and DOE. Once the facility is constructed and operating, additional periodic reviews of ECF activities will be conducted to assure continued compliance with current criteria. The risk of exposing operating personnel to hazardous materials and high energy components has been addressed in the design of the facility as has the risk of off-site impact to the environment and to the public. Based on the types of hazards, quantities of hazardous materials, facility design, engineering controls, and administrative controls employed in the design and use of the ECF, the risk to members of the public and to the environment from this facility will be negligible. Overall risk of operating the Explosive Components Facility has been reduced to a level that is as low as reasonably achievable for an energetic materials facility.

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