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TRITIUM RESEARCH LABORATORY SAFETY ANALYSIS REPORT

D. A. Wright

Sandia Laboratories

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TRITIUM RESEARCH LABORATORY
SAFETY ANALYSIS REPORT

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ABSTRACT

Construction of the Tritium Research Laboratory (TRL) at Sandia Laboratories Livermore was completed in mid-1975. A nonreactor nuclear facility under DOE Manual Chapter 0531, it will achieve full operational status by late 1978. It is expected to involve a tritium inventory of 100 grams when fully operational. With changes in programmatic requirements the inventory could increase to 300 grams.

Design and operational philosophy has been evolved to keep radiation exposures to personnel and radiation releases to the environment as low as reasonably achievable. All stored tritium will be doubly contained in glove boxes and in DOT-approved shipping containers (12 grams per container) in the TRL vault. Each experiment will be doubly contained in a glove box and will be

limited to 10 grams of tritium gas. Specially designed solid-hydride storage beds may be used to store temporarily up to 25 grams of tritium in the form of tritides. The installed hardware includes a number of safety features, which enhance protection of the public, the laboratory personnel, and the environment. They include:

- double containment of gram quantities of tritium in glove boxes with controlled atmospheres,
- automatic decontamination systems for the removal of tritium from the glove boxes and vacuum effluents,
- an extensive tritium monitoring system which monitors the room air, glove boxes, and the stack effluent,
- a computer based control room where data are gathered and stored from the various monitoring devices, providing a complete, overall view of the condition of the facility,
- a once-through, high-flow ventilation system which moves air from clean areas to areas of increasing contamination potential.

To evaluate possible risks to the public or the environment, a review of the Sandia Laboratories Livermore (SLL) site was carried out. Considered were location, population, land use, meteorology, hydrology, geology, and seismology. An engineering firm specializing in geologic/seismic investigations was retained to study the SLL site, Livermore Valley, and the TRL. This report describes modifications and remedial concepts for strengthening the TRL structure and vital systems as recommended by this firm. Necessary modifications will be completed by early 1979; most were finished prior to the completion of this report.

The risks and the extent of damage to the TRL and vital systems were evaluated for flooding, lightning, severe winds, earthquakes, explosions, and fires. All of the natural phenomena and human error accidents were considered credible, although the extent of potential damage varied. However, rather than address the myriad of specific individual consequences of each accident scenario--such as vessel ruptures, valve or pump failure, pipe or container leaks, or procedural errors--a worst-case tritium release caused indirectly by an unspecified natural phenomenon or human error was evaluated.

The maximum credible radiological accident is postulated to result from the release of the maximum quantity of gas from one experiment. Thus 10 grams of tritium gas was used in the analysis to conservatively estimate the maximum whole-body dose of 1 rem at the site boundary and a maximum population dose of 500 man-rem. Accidental release of this amount of tritium implies a loss of integrity of both a primary container and the glove box. Simultaneous failure of two doubly contained systems is considered not credible. Nuclear criticality is impossible in this facility.

Based upon the analyses performed for this report, we conclude that the Tritium Research Laboratory can be operated without undue risk to employees, the general public, or the environment.

TRITIUM RESEARCH LABORATORY (TRL)
SAFETY ANALYSIS REPORT

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Glossary

Abbreviations

ALARA	As Low As Reasonably Achievable
CG _a	Concentration Guides for air
GPS	Gas Purification System {GPSS Supply lines GPSR Return lines
HT, T ₂	Tritium
HTO	Tritium Oxide
HVAH	High Velocity Air Hood
LEL	Lower Explosive Limit
LASL	Los Alamos Scientific Laboratory
LLL	Lawrence Livermore Laboratory
ML	Mound Laboratory
NWS	National Weather Station
PVT	Pressure-Volume-Temperature
QA	Quality Assurance
RMA	Radioactive Materials Area
SLL	Sandia Laboratory Livermore
SOI	Safe Operating Instruction
SOP	Safe Operating Procedure
SRP	Savannah River Project
SSMR	Source and Special Materials Representative
TRL	Tritium Research Laboratory
VERS	Vacuum Effluent Recovery System
USGS	United States Geological Survey

Appendices

- A. Geologic - L. Wight
- B. Geologic - URS/John A. Blume and Associates
- C. Tritium Accountability System
- D. Safe Operating Procedure No. 709 (To be revised)
- E. Quality Assurance Program
- F. Radioactive Waste Management Site Plan
- G. Preoperational Environmental Monitoring Report
- H. Occupancy-Use Readiness Review (MORT Analysis) Note: To be completed later
- I. Modification and Testing of Sandia Laboratories Livermore Tritium Decontamination Systems
- J. Comments on Safety Analysis Report from the Department of Energy

SECTION 1. INTRODUCTION

The purpose of the report is to meet requirement 059 of DOE Manual Chapter 0531 "Safety of Nonreactor Nuclear Facilities." It is also the intent of this report to provide management with a written objective analysis of the facility, describing any deficiencies and their possible remedies. Credible accidents that could have adverse effects on the facility, or off-site consequences, are examined in detail. Accidents having off-site, nonradiological consequences are not treated in this document.

The report comprises 8 sections and 8 appendices. A summary of the report and any recommended remedial actions are included in Section 2. Section 3 is a description and safety assessment of the Sandia Laboratories Livermore (SLL) site. Sections 4 and 5 describe the facility and, briefly, the operations performed in each lab. Maximum credible accidents are hypothesized and analyzed in Section 6. The breadth and scope of the environmental monitoring program is covered in Section 7. Emergency plans for the protection of employees during an accidental tritium release is included in Section 8.

SECTION 2. SUMMARY OF THE SAFETY ANALYSIS FOR THE TRITIUM RESEARCH LAB, BUILDING 968

Introduction

This section is a summary of the major topics discussed in Sections 3-8. Specifically, the report provides documentation describing:

- a. the nonreactor nuclear facility site and risks associated with accidents from natural phenomena and human error,
- b. safety related design criteria and the control and containment of tritium,
- c. the projected effluent quantities, waste handling and environmental monitoring program,
- d. the quality assurance program and the engineered safety systems which allow for safe operation or safe shutdown during an accident,
- e. the radiological consequences of an accident and the essential emergency plans.

Summary of Section 3. Description and Safety Assessment of Site

About 100,000 people live in the Livermore-Amador Valley, mostly in the cities of Livermore, Pleasanton and Dublin. Land around the SLL site is used primarily for agriculture, such as cattle grazing and vineyards. The San Francisco-Oakland Bay Area, which lies 30 to 60 km to the west of SLL, has a population of approximately 3,700,000.

The safety assessment of the site includes an analysis of those existing conditions, both natural and man-made, that affect the design and operation

of the facility. A geological analysis of the SLL site and a study of the seismic history of the area was performed by an engineering firm specializing in such analyses.

Seismic and geologic studies have provided ground motion parameters for use in earthquake-resistive design and analysis of the TRL and have evaluated possible fault rupture hazards. These studies have shown that the probability of exceeding certain values of peak ground acceleration for a 30-year period ranges from 17% at .27g to 50% at .13 g. Estimated peak ground acceleration due to the maximum potential earthquake is 0.5g. The estimated maximum potential earthquake is an event of magnitude 5.7 located on the Tesla fault immediately adjacent to the SLL site.

A nearby fault reported by Herd (USGS), called the Las Positas fault, could not be substantiated as a structure capable of generating a moderate-sized (magnitude 5 to 5.9) or larger earthquake. No evidence was found of any fault passing near enough to the TRL to create a hazard due to ground surface rupture.

Severe weather is rare in the Livermore Valley and the greatest recorded rainfall in a 24 hr period is about 3.5 inches. During a 72-hour period, the maximum probable rainfall that might fall in the valley drainage area could cause local flooding but without significant impact on the TRL. Wind damage from high winds is uncommon in the Livermore area and the probability of a tornado occurrence has been estimated to be about 10^{-6} per year for the valley.

Summary of Section 4. Facility Description

The Tritium Research Laboratory (Bldg 968) is a single story structure 24 m wide by 55 m long, with a detached equipment room of approximately 111 m² for heating, cooling and other plant services. The facility space is divided into 9 laboratories, 2 office areas, a storage vault, a control room, a shop, a tritium gas purification equipment room and 8 miscellaneous rooms. A most important feature of the laboratory is the gas purification system (GPS) housed in room 115A. This system, which is a state-of-the-art gaseous effluent control system, is described in detail in Section 4.

The building is functionally divided into two zones, an office area where hazardous materials are prohibited and a radioactive materials area. Ventilation flow is from clean areas to areas of increasing contamination potential. The Radioactive Materials Area (RMA) is separated from the rest of the facility by two sets of double doors. Exhaust air and RMA room air is continuously monitored for tritium by an airborne tritium monitoring system.

The alarm systems for the TRL include fire alarms, radiation alarms, ventilation alarms and security alarms. Each glove box is equipped with a heat detection system and the building itself has an automatic sprinkler system. Fire alarm annunciation is provided at the LLL fire station which will provide firefighting assistance to SLL. Airborne radiation and ventilation alarm annunciation occurs at the TPL control room and the security station after working hours. A small facility control computer located in the control room scans the room, glove box and stack tritium monitors, and generates alarms. It also activates the Gas Purification System when preset levels are reached.

The TRL has a "once-through" high flow ventilation system which provides at least 6-10 airchanges per hour in each laboratory. Incoming air is temperature and humidity conditioned and subsequently exhausted through a 30 m stack whose nominal airflow rate is about 1,560 m³/min. As mentioned earlier pressure zoning is used to control contamination movement and the building is maintained at a slightly negative pressure relative to the outside. All floor drains and laboratory sinks terminate in one of two 9.5 m³ hold tanks whose contents are monitored for tritium prior to discharge to the sanitary sewer system.

The building is supplied with 750 kVA of power via an underground distribution system. A 200 kVA emergency generator starts up automatically when primary power fails. Battery backup will eventually be provided to the control room computer along with power from the emergency generator. The ventilation system, GPS, VERS, tritium monitoring system, specific room lights, and some of the glove box equipment are also provided with power from the emergency generator.

Summary of Section 5. Description of Operations

Operations in the Tritium Research Laboratory will depend upon the research programs in effect. Presently, it is expected that these programs will be concerned with the physical and chemical characterization of tritium and its compounds, and the fabrication of tritium compounds for use as engineering components. All operations with tritium gas and metal tritides will be carried out in containers constructed with certified hydrogen compatible materials which in turn will be inside glove boxes, providing double containment. Metal tritide work and storage will be carried out in dry, inert, sealed glove boxes.

It has been projected that the total quantity of tritium in the facility will be approximately 100 grams, but could increase to 300 grams if programmatic activities demand. A computerized tritium accountability program has been developed for record keeping. The movement of tritium, or any other radioactive materials, into or out of the TRL will be controlled by the SLL SSMR.

Tritium processing operations will be carried out in the Tritium Handling System which is housed in 1.2 m x 2.4 m x 2.4 m sealed glove boxes. The Tritium Handling System comprises the assay, low pressure and high pressure recovery stations.

Solid and high level liquid radioactive wastes produced as a result of operations at the TRL will be assayed and appropriately packaged for transfer to LLL's Laboratory Waste Processing Facility at Building 612. Low level liquid wastes will be held until they are assayed and released to the sanitary sewage system. Routine releases of microcurie amounts of tritium gas to the 30 m stack will be made. Estimates of the tritium wastes based on the activities of current programs are:

solid waste for burial,	< 400 Ci/yr
liquid waste for burial,	< 100 Ci/yr
liquid waste to sewer,	< 0.1 Ci/yr
liquid waste for recovery,	< 6×10^5 Ci/yr
gaseous waste for recovery,	< 1×10^5 Ci/yr.

Summary of Section 6. Accident Analysis

Credible accidents that could affect the TRL building and the environment can be divided into those attributable to acts of nature and those caused by human error. Acts of nature include such phenomena as high winds,

tornadoes, flooding, earthquakes and lightning. Human errors may result in fire, explosion, or gaseous tritium release.

Plutonium-238 is used as a calorimetry standard at the TRL, but only in quantities of a few grams. Therefore, nuclear criticality is not a possibility. Low combustible fuel loading, noncombustible material construction, automatic sprinkler protection and compartmentalized construction preclude the possibility of extensive fire involvement. Explosion of a combustible gas after an accidental release into a TRL lab was reviewed and considered credible. However, multiple engineered safety features on the gas service and building ventilation makes this accident very unlikely.

An accidental tritium release could result from human error or from damage by natural phenomena. In any event tritium gas is a much higher risk than stored tritides, because of the strong containers to be used for tritide storage. An analysis of a hypothetical release of tritium oxide was performed to determine the off-site consequences. The total tritium gas inventory (10 grams) of a glove box was assumed to be released up the stack over a 15 minute interval. A maximum whole body dose equivalent of 1 rem would result at the site boundary under the most adverse weather conditions. Using the same accidental release conditions, contamination of the South Bay aqueduct was evaluated. The water concentration of HTO, resulting from both wet and dry deposition, at the nearest downstream water treatment facility was determined to be less than the U.S. DOE Manual Chapter 0524 Concentration Guide values.

The effects on the stack and building from the high winds (60 m/sec) of a tornado was reviewed. Both structures were found to be capable of surviving the tornado loading and a 1.4 kPa pressure differential. Damage from high winds or lightning strikes is uncommon in the Livermore Valley.

Flooding from a 72-hour period, maximum probable precipitation or failure of any of the dams in the area were found to have little or no effect on the TRL building.

An earthquake is the most potentially destructive phenomenon of those considered in this analysis. URS/John A. Blume and Associates investigated the structures and vital systems of the TRL. An evaluation was performed to determine their structural adequacy for the requirements of two standards: the 1976 UBC and the postulated ground motion developed in the geological study of the SLL site.

The analysis of the buildings showed that the equipment room was quite adequate, but the Laboratory Building was deficient for a north-south earthquake because of the low capacity of the gypsum-concrete roof diaphragm system. A remedial scheme recommended by Blume will provide the necessary increase in structural strength to meet the two standards mentioned above. The scheme links the equipment room to the lab building so that the two will work together as one structural system. The lab building was found to be adequate for seismic loads in the east-west direction without further remedial work.

The steel stack was found to be designed with sufficient capacity to meet the requirements of both standards with no further structural reinforcement. This was not the case for the GPSS, GPSR and VERS systems which were not designed for lateral forces. A scheme for bracing the piping and supports in the corridor was developed along with general recommendations for pipe bracing. These bracing schemes provide more than enough strength to meet the seismic criteria.

Bracing of the holding tank supports on the roof and the four decontamination equipment skids in room 115A was also recommended in order for

this equipment to meet the lateral forces of two standards. The exhaust ducting and glove boxes require no additional bracing although flexible connections on the ventilation system ducting and glove box connecting piping were suggested.

The remedial schemes proposed by Blume and Associates are in the process of being implemented.

Summary of Section 7. Environmental Monitoring Program

Environmental monitoring at Sandia is carried out by LLL because of the proximity of the two facilities. The LLL environmental monitoring program analyzes for depleted uranium, fission products, tritium, beryllium, metallic elements and pesticides, which may be released to the environment from operations at SLL. A copy of the preoperational environmental monitoring report, SAND76-8033, is included as Appendix G.

Summary of Section 8. Emergency Plans

A reciprocal emergency assistance agreement between LLL and SLL has been established. This includes firefighting, medical aid and radiological emergency aid such as environmental monitoring and atmospheric release evaluation. A description of the tritium monitoring system alarm functions and the radiological emergency procedures are provided in Chapter 9.

Summary of the Safety Analysis

This report describes the Sandia Laboratory Livermore site, the likelihood and extent of damage from acts of nature or human error, the safety systems incorporated into the TRL and finally the radiological consequences of a

tritium release. Adhering to an as low as reasonably achievable philosophy, gram quantities of tritium in the TRL are doubly contained in controlled-atmosphere glove boxes, which are connected to a gas decontamination system. Releases to the environment shall be minimal and protection of personnel is maximized.

Based upon the analysis in this report, we conclude that the Tritium Research Laboratory can be operated without undue risk to employees, the general public, or the environment.

SECTION 3. DESCRIPTION AND SAFETY ASSESSMENT OF THE SLL SITE

Location

Sandia Laboratories Livermore (SLL) is located about 64 km east of San Francisco. The site occupies 0.65 km² of the north half of Section 13, T3S, R2E, Mount Diablo baseline (known as Murray Township), as shown in the U.S. Geological Survey topographic map "Altamont Quadrangle." It is in the southern Alameda County at the southeast end of the Livermore Valley. The City of Livermore is located 5 km west of the Laboratory. Open agricultural areas surround the laboratory on the east, west, and south sides. The Lawrence Livermore Laboratory of the University of California borders on the north side of the property. Land to the north, east, south and part of the west is zoned industrial, although its present use is agricultural. The remainder of the land to the west is zoned agricultural and is used as pasture. Figures 3-1, 3-2 and 3-3 show the SLL location with respect to adjacent communities.

Population, Distribution and Land Use

The population density is of interest to a distance of some 80 km (50 miles) because of the possibility of airborne tritium hazards emanating from the TRL. The present population within a 80 km radius is approximately 4.3 million. The description of land use to follow is largely concerned with the Livermore-Amador Valley.

The on-site population of SLL, including contractor's employees, is approximately 1,000, depending on time of day and the number away from their normal work areas (on sick leave, vacation, travel, etc.). Adjoining property is agricultural land on all sides except for the LLL facility to the

Figure 3-1 Relationship of SLL to surrounding urban areas and transportation routes.

Figure 3-2 Communities of the Livermore Valley.

Figure 3-3 Immediate environs of SLL. Circle represents 1-mile radius from SLL center. Small circles represent dwellings within one mile.

north across East Avenue. The on-site population at LLL varies between 5,000 and 6,000 persons.

Population Within 16 km (10 Miles)

The nearest urban residential area is 1.2 km from the west perimeter of SLL. The Livermore General Plan adopted in 1959 envisions industrial development to the north and a low density urban population of 9,500 in the 2.6 km² area immediately to the west of LLL and SLL by 1990, while the foothills to the east and south will remain agricultural. Estimated present population by 22.5-degree sectors as a function of direction and distance up to 16 km (10 miles) is shown in Figure 3-4.

Extended Regional Population

The regions to the west of SLL are the most heavily populated with the City of Livermore (47,000) extending 3 to 10 km west and north. Pleasanton (30,000), Dublin (15,000) and San Ramon (15,000) are located 24 km west and north of Livermore. Located over the low ridges 32 km to the west are the densely populated areas of San Francisco, Oakland and San Jose (3,700,000). Other urban concentrations at similar distances to the north are Concord, Walnut Creek and Pittsburg - Antioch, and to the east in the San Joaquin Valley are the cities of Tracy, Stockton and Manteca. The hills forming the Livermore Valley from the north toward Mt. Diablo through the east toward Altamont Pass and through the south toward Mt. Hamilton are very sparsely populated.

Figure 3-5 shows estimated populations by 22.5 - degree sectors with 16 km radius increments to a distance of 80 km from SLL. The distribution was derived from the 1970 census. The total population within 80 km from SLL is approximately 4,300,000. Recent zoning ordinance changes

and a growth limit initiative should tend to reduce change in present population densities in the SLL environs.

Population Projections

Population growth in the Bay Area, along with the rest of the state, has been at a greater rate than for the nation as a whole, at least since 1900. Before the 1970's, the major growth was in the close-in or Bayshore parts of San Francisco, Alameda, Contra Costa, Marin, and San Mateo Counties. But since that time, the increase in number of places to work in new centers and an improved highway system have led to the spread of medium- or low-density residential development (tract homes) to virtually all remaining areas where the costs of development and sales are economically feasible. Efforts by local and regional agencies to limit this growth through control of its rate or through planning for alternate land uses such as "open space" or continue agricultural use have not so far modified this trend in any large sense. But a more controlled and planned growth may modify the growth and distribution of future population. A recent Alameda County zoning ordinance limits the construction of new homes in the unincorporated areas of the eastern part of the county to sites of 0.4 km² (100 acres). There are a number of pre-existing smaller homesteads along Mines and Tesla Roads; here a 0.02 km² (5-acre) limitation applies. This would tend to reduce change in the population in these areas as long as they do not become part of an incorporated city. Figure 3-6 indicates the growth of the City of Livermore since 1876, projected to the year 2000.

The most rapid growth in the Livermore-Amador Valley has been in residential dwellings, mostly single family type, but with some two-story apartment houses. At present, light industrial development is occurring in the Pleasanton-Rublin areas to the west, but such development is at a virtual

Figure 3-6 Population of the City of Livermore, 1876 to 2000

standstill in the Livermore area. The local rate of growth has been reduced since 1975 due to limited capacities of water, sewage, or school services.

Table 3-1 gives the 1970 U.S. census populations of counties lying all or partly within the 80 km (50 mi) radius of SLL, with projections for every decade to the year 2000. These projections were published by the Population Research Unit, California Department of Finance, and are known as Series D-100 which represent a set of assumptions in the middle of the range of possible choices.

Land Use -- The rural areas of the Livermore Valley are occupied by vineyards, orchards, irrigated pastures, seed crops (flowers), many small farms (poultry and rabbits), and larger tracts devoted to grains and hay. The hilly terrain surrounding the valley is used for cattle and sheep pasture. Dairying is not intensive in the Livermore Valley, but is prominent in the San Joaquin Valley to the east.

There is a large complex of gravel quarries just east of Pleasanton, most of which have rather large ponds at their bottoms. Numerous mines in the surrounding hills are no longer active, but there are several producing oil wells northeast of SLL on Patterson Pass Road.

The California Aqueduct and its facilities are important in the area. A branch, the South Bay Aqueduct, carries water destined for the San Jose area around the east and south margins of the valley, passing very close to the southeast corner of LLL, and 420 m east of SLL. At this point the aqueduct is not covered. The Del Valle and San Antonio Reservoirs to the south and southwest tie into this aqueduct as reserve storage and watershed contributors.

Table 3-1. Population Projection for Counties Near SLL to the Year 2000

County	Area		1970 Census			1980 ^a	1990 ^a	2000 ^a
	km ²	(mi ²)	% Urban	Population	% Change			
Alameda	1,898	(733)	99.0	1,074,400	6.5	1,143,800	1,251,200	1,358,100
Contra Costa	1,901	(734)	93.6	558,100	17.0	652,800	780,900	903,300
Marin	1,347	(520)	92.4	207,500	12.4	233,200	265,400	293,400
Merced	5,133	(1,982)	50.0	105,500	19.7	126,300	151,400	173,100
Napa	1,963	(758)	58.0	79,700	27.5	101,600	126,600	151,600
Sacramento	2,546	(983)	95.1	637,700	18.2	753,600	884,900	996,300
San Francisco	117	(45)	100.0	714,300	- 7.4	661,100	653,700	656,600
San Joaquin	3,649	(1,409)	76.9	292,200	13.0	330,200	375,000	418,300
San Mateo	1,176	(454)	98.2	557,400	6.4	593,100	637,500	664,500
Santa Clara	3,372	(1,302)	97.5	1,074,200	25.0	1,342,800	1,614,300	1,804,900
Santa Cruz	1,137	(439)	75.2	124,100	42.8	177,200	227,800	227,100
Solano	2,141	(827)	93.0	173,600	14.3	198,400	249,400	329,200
Sonoma	4,090	(1,579)	58.7	205,200	46.4	300,500	395,400	477,900
Stanislaus	1,295	(500)	70.1	195,300	20.5	235,400	278,300	314,200
TOTALS	31,765	(12,265)	82.5	5,999,200	14.2	6,850,000	7,891,800	8,818,500

^aThese projections were published by the Population Research Unit, California Department of Finance, January 10, 1974. They are based on Series D-100 Projection Rates.

Transportation Routes -- The major artery through the Livermore Valley is Interstate 580, which feeds traffic from the Bay Area to the Central Valley of California. With its connection to Interstate 5, it forms the major route between the Bay Area and Los Angeles. The average daily vehicle flow is 30,500.* The interchanges at Vasco Road and Greenville Road about 3.2 km north of SLL serve as the major routes from most points other than Livermore to SLL. Interstate 680 connects the San Jose Area with Interstate 80 at Cordelia, passing through Pleasanton and Dublin at the west end of the valley.

The Livermore area is served by main lines of the Southern Pacific and Western Pacific Railroads. These lines pass just north of LLL, but neither LLL nor SLL has spur tracks. Both lines carry freight only, with some 15 trains a day passing through.

The Livermore Municipal Airport 10 km west of the laboratories is the nearest public airport. It has a 1200 m paved runway with clear approach zones and runway lights. LLL operates flight service with an F-27 turboprop transport aircraft to the Nevada Test Site and other locations from this airport. The nearest airports with scheduled airline service are Oakland, San Jose, and Stockton.

Geology and Seismicity

The geology of California and western Nevada has been intensely studied because the region has many heavily populated areas and is very active seismically. Our knowledge of the geology and seismology of Livermore

*California Division of Highways estimate for I-580 at First Street Interchange, Livermore. This is the total traffic count for one year divided by 365. There are, of course, seasonal and daily variations, especially due to the importance of this route to recreational travel.

Valley has benefitted from the many studies. URS/John A. Blume and Associates were contacted to perform a detailed geological/seismological study of the SLL site. A similar study was performed for LLL by Wight in 1974. The report by Wight is included as Appendix A of the report. The results of the Blume investigation including their lineament study, trenching, gravity survey, and magnetic and resistivity surveys are provided in Appendix B. The geology and seismology sections of the Blume report follow.

General Statement

Sandia is located in the southwest part of the Livermore Valley. The valley is a structural depression, elongated in an east-west direction but dominated by northwest-southwest trending geologic structures. To the west, the valley is terminated by the Calaveras fault. On the east, it is bordered by the Carnegie fault. Both are extensive, well-documented right lateral faults bounding the valley. The southern border of the valley is determined by the plunge of structures that rise to the south, with some faulting possibly involved (Figure 3-7).

"The geology of the Tesla quadrangle" (Huey, 1948) covers the area of interest of this report. It indicates a complex history of tectonic activity with repeated episodes of deposition and erosion. This complexity is evident in the abrupt appearance and disappearance of surface and subsurface stratigraphic units, which has led to various and often conflicting geologic interpretations.

Stratigraphy

Franciscan -- The Franciscan is the oldest stratigraphic unit and is the basement rock for this region. It is recognized as a subduction-derived melange, and its very heterogeneous nature has led to its being called a

FIGURE 3-7 GENERALIZED REGIONAL GEOLOGIC MAP

NOTE:
Modified after geologic map of California, San Jose Sheet, California Division of Mines & Geology.

group, formation, tectonic unit, and terrane. Sediments predominate, consisting mainly of greywackes, shales, argillites, and cherts. Also prominent are volcanics and low-grade metamorphics, especially greenstones, serpentine, and greenschists. The Franciscan crops out about 5 km (3 mi) southeast of Sandia. Its surface dips about 20° to the northwest, and it is overlapped by Livermore gravels. Generally, the age is regarded as Jurassic-Cretaceous.

Panoche Formation -- The Panoche Formation is composed of indurated siltstones, silty shales, and dirty lithic feldspathic sandstones, with lesser amounts of conglomerate. Genetically they are regarded as deep-water marine turbidites with an eastern source. The sediments are hard and moderately well indurated as a result of their deep deposition and subsequent burial. The present surface exposure is more than 2.4 km (1-1/2 mi) northeast of Sandia, but deep gas wells have penetrated the Panoche, and data indicate it is present underground about 0.8 km (1/2 mi) to the northeast. The Panoche is upper Cretaceous, 65 to 90 million years old, and depositional contacts with all other formations are unconformable. In the Tesla quadrangle, it is reported to be up to 3050 m thick.

Tesla Formation -- The Tesla Formation consists of friable, mature, quartzose sands, clays, shales, and low-grade coal. The lower part was predominately deposited in brackish water, but the upper part was laid down under marine conditions. These factors indicate that the sediments accumulated in shallow waters during a marine transgression. The low density and lack of induration are probably due to the shallow depth of accumulation and lack of subsequent deep burial. The distance between Sandia and the nearest outcrop is 6.4 km (4 mi); however, a deep well has penetrated Tesla rocks 3.2 km (2 mi) to the northeast, and it is probable that Tesla is present within a mile of Sandia in the subsurface. The Tesla Formation is middle Eocene in

age and is unconformable in its depositional relations with other formations. The formation is up to 600 m thick but is probably not over 520 m thick in the Sandia region.

Cierbo Formation -- The Cierbo Formation consists of friable, conglomeratic, poorly sorted sands, carbonaceous shales, and tuffs with lignite and petrified wood. The sands are superficially similar to those of the Tesla Formation, and the sediments were apparently deposited in a shallow transgressive sea. Lack of induration appears to be related to lack of deep burial. The nearest outcrop is 2.2 km to the northeast, but it is less than 0.8 km northeast in the subsurface. The Cierbo is up to 300 m thick but probably not more than 275 m in the Sandia region. The age is upper Miocene and possibly Mio-Pliocene. All depositional contacts of the Cierbo are unconformable.

Neroly Formation -- The Neroly Formation can be divided into lower and upper parts. The lower part is composed mainly of blue sandstone with andesitic boulder conglomerates and tuffaceous clay-shales. The upper part consists mainly of clays with some soft sands, gravels, and blue sandstone. The Neroly is of transgressive marine origin with a few brackish water deposits. It underlies Sandia and is considered Mio-Pliocene in age. In the Tesla quadrangle, the lower member is up to 200 m thick, and the upper member is up to 600 m thick. Subsurface data indicate the undivided Neroly is up to 550 m thick below Sandia. Depositional contacts are unconformable.

Earlier works have shown an arbitrary stratigraphic division along the trends of the Corral Hollow fault and/or Ramp Thrust. To the east the beds have been called Neroly, and to the west they have been called Orinda. The Neroly and Orinda are actually contemporaneous facies: the Orinda is

essentially a nonmarine deposit with some marine beds, and the Neroly is essentially marine with a few brackish water deposits. Both formations are Mio-Pliocene age (Delmontian Stage of Kleinpell, 1938). Because the type area for the Orinda is in the Berkeley Hills, and because the beds in this area are not known to be nonmarine, the name Neroly seems most appropriate.

Livermore Gravels -- The continental Livermore gravels make up the low hills to the south and east of Sandia. The formation dips beneath recent alluvium of Livermore Valley and overlaps older rocks. It is composed chiefly of Franciscan detritus with rounded clasts mixed with pebbles, sands, silts, and clays in various proportions. Deposition took place on alluvial fans and debris cones, with intermixed deposits ranging from thick debris flows to thin fluvial mud laminae. Bedding ranges from massive to subparallel, with tabular clasts and pebbles showing local imbricate structure. Cut-and-fill structures cause abrupt bed terminations. The gravels are generally low dipping, but they are locally steeply tilted in the ridge south of Sandia. In the vicinity of Sandia, subsurface data indicate the Livermore to be about 360 m thick. Recent studies (Sarna-Wojcicki, 1976) show that a tuff bed near the base of the formation is 4-1/2 million years old. This age agrees with the Plio-Pleistocene estimate of Huey (1948).

Geologic Structure

Folding -- Two folds are relevant to the Sandia site. They are the Livermore syncline, shown on the geologic map (Figure 3-8), and a Franciscan basement nose adjacent to and southwest of the syncline. Both structures are oriented and plunge in a northwesterly direction. The syncline contains Mesozoic, lower and upper Tertiary, and Quaternary beds, while only upper Tertiary and Quaternary beds overlie the Franciscan nose. These structures

Figure 3-8 Geologic map of SLL and area.

have been delineated by drilling data, unpublished oil company geophysical data, and a USGS gravity map (Holden, 1976).

Faulting -- There is a clear relationship between the folding and faulting in the area. The Livermore syncline is bordered by the Carnegie fault on the northeast and the Tesla fault on the southwest. These faults have strong thrust components, southwest on the Carnegie and northeast on the Tesla, reflecting the compression associated with folding. The Franciscan nose is bordered by the Tesla fault on the northeast and the Mocho fault on the southwest. The Mocho fault trends in a northerly direction toward the Tesla fault and is upthrown to the east. Its description is based on oil company subsurface geology and seismic data (Huey, 1972).

Two possible faults are pertinent to Sandia: Tesla and Las Positas. The Tesla fault trends northwest-southeast and is the most strongly documented fault near Sandia. In this area, it is composed of two strands, with Tesla No. 2 the most critical and recently active. Tesla No. 2 has been located by deep drilling, geomorphic and geophysical evidence, and by apparently related surface rupture. Deep drilling and magnetic data define Tesla No. 1, which is apparently inactive.

Tesla No. 2 Fault -- Geologic information shows that Tesla No. 2 dips to the southwest (Figure 3-9) and has lateral and reverse components, with the southwest side up, in the southeast Livermore Valley. Less than a mile southeast of Sandia, Tesla No. 2 was found in Hancock Oil Company's Signal-Hanson No. 41 well. It cuts the well at 720 m and causes a repeat of approximately 120 m of Neroly Formation, demonstrating that there is a reverse component to the fault at this location (Figure 3-9).

Relatively recent movement on Tesla No. 2 is seen in the area midway between Sandia and the Hancock well. On Greenville Road is a small surface

fault in Livermore gravels. This rupture falls on the trend of Tesla No. 2, strikes N37°E, has a vertical dip, and apparently fits the model for an antithetic fault associated with a right-lateral wrench fault. Relatively recent right-lateral wrenching of Tesla No. 2 is also apparent in spurs where Arroyo Seco cuts through the ridge immediately south of Sandia. West-trending spurs, adjacent to and northeast of Arroyo Seco, turn abruptly to the northwest. These features are consistent with drag associated with right-lateral faulting.

On June 21, 1977, an earthquake of magnitude 4.6 occurred in the southeast Livermore area. The epicenter was plotted on the Tesla fault, and seismologic data show both strike and dip components consistent with right-lateral motion and relative dip movement up on the southwest.

The 1972 URS/Blume report presented geomorphic evidence showing that Tesla No. 2 had captured the drainage of Arroyo Seco and directed it to the northwest, through the ridge at the south border of Sandia. This showed relatively recent movement on the fault and indicated the fault to be upon the west. The report also presented evidence that Tesla No. 2 may have displaced soil layers in a Pacific Gas & Electric (PG&E) pipeline trench and was identifiable by discontinuities on gravity profiles.

Approximately 1.6 km northwest of the Sandia site, a reflection seismic line was obtained from Hershey Oil Company. This line shows a reversal of dip across the projected trend of Tesla No. 2 that is consistent with fault data to the southeast.

The Las Positas Fault -- The Las Positas fault was first named by Herd in a USGS open file report (Herd, 1977). Many lines of evidence were cited, but the Las Positas and other faults mapped are based essentially on air photo lineaments. A lineament trending southwest-northeast at the base of the

north slope of the ridge south of Sandia was designated the Las Positas fault. This lineament has been recognized earlier (URS/Blume, 1973), but evidence did not warrant its designation as a fault.

The fault is described by Herd as dip slip, down to the north. A cross section shows Las Positas as a vertical fault with minor displacement, down to the north, of a contact between the Livermore gravels and undivided Greenville and Tassajara Formations. (The Greenville and Tassajara Formations crop out north of Livermore Valley and are roughly equivalent to the Livermore gravels.)

Several types of evidence are presented in the USGS report. They include alluvial stratigraphy, geomorphology, and a postulated groundwater barrier.

Field Evaluation of Faulting, Las Positas Trace -- In January 1978, a survey of the surface geology in the Sandia area of the Livermore Valley was carried out. The purpose of the survey was to review the local geology with special consideration of structure in general and faulting in particular. Emphasis was placed on examination of field evidence cited by Herd (1977) relevant to the reported Las Positas fault.

Previous work has shown several northwest-trending faults southeast of the Sandia area. Along the flanks of the southwest-trending ridge bordering the southern part of the Laboratory area, air photo lineaments were indicated as possible fault traces.

In 1977, an open file report covering the area was released by the USGS. This report, 77-689, showed the photo lineaments as definite faults. Further, it asserted that the easterly trending faults were the dominant structures in the area, a situation virtually unknown in California outside of the Transverse Ranges.

The fault bordering the northwest flank of the ridge was named Las Positas fault zone. The fault described along the southeast side of the ridge was not named.

The new fault evidence is preponderately geomorphic. Only two exposures are described for the Las Positas fault and only one for the fault along the southeast flank of the southwest-trending ridge.

A great deal of the report is based on a stratigraphic breakdown of the Quaternary sediments. This stratigraphy is enlisted as evidence of faulting and sequences of fault movement. Unfortunately, criteria for recognizing and differentiating the stratigraphic units are not presented, making it impossible to evaluate them, or evidence based on them, in the field.

The first area examined was along Greenville Road, between East Avenue on the north, and Tesla Road on the south. Greenville Road transects the southwest-trending ridge to the east of Sandia. Two of the reported fault exposures occur in road cuts along this road. A traverse along the road indicates that the southwest-trending ridge is an apparent anticline. Evidence is not absolute, as the core of the ridge is composed almost entirely of massive silty, clayey sands and sandy, silty clays. However, vertical dips on the north flank progressively flatten in a southerly direction until they dip only 4° to 6° to the north. South of the massive sediments, the bedding dips steeply to the south. Imbricate sedimentary structures in a road cut indicates a north-to-south current flow during some of the Livermore gravel deposition.

An exposure of the Las Positas fault is given in the report at 80 m south of the intersection of East Avenue and Greenville Road, on the east side of the road. It is stated that Neroly sandstone, in a south block, is faulted against colluvium composed of Livermore gravels in a north-facing

scarp. Investigation found the sediments of the south block to be olive-tan to olive-brown clayey sands and sandy clays with beds of very light gray to whitish marl. The sediments are soft and unconsolidated, appear to be fluvial and/or lacustrine, and not Meroly. At the north end of the road cut, there is a change to reddish soil. The nature of the contact is not clear, but it appears to be a disconformity or unconformity. There is no overt evidence of faulting. An old road or trail cut into the northwest-facing slope may have been confused for a fault scarp.

The southern, unnamed fault is reported as crossing Greenville road approximately 0.5 km north of the Tesla Road intersection. This exposure is clear cut. A vertical, northwest-facing scarp strikes N37°E into the east side of a cut (N65°E in the report). Because the fault is entirely within Livermore gravels, and because of a small slide immediately adjacent to the scarp, it is not possible to determine the throw. This fault is described elsewhere in this report as a minor antithetic fault associated with a right lateral wrench fault (Tesla No. 2). A small gravity anomaly on this feature indicates that near-surface displacement has been downward on the north side.

The only other fault exposure reported in the area is located in the south bank of Arroyo Seco, near the northwest edge of the southwest-trending ridge. Here a small fault is exposed, dipping 87°NW. It cuts sands and gravelly sands presumed to be part of the Livermore gravels. The throw appears to be up on the northwest, making this a high-angle reverse fault. This is diametrically opposite to the type of fault and direction of throw shown on the report map. It is significant that the fault does not cut the overlying alluvium. A poor exposure at the base of the bank appears to be a small drag fold. It is located about 3 m north of the shear and is:

concordant with the direction of throw. About 120 m north of the fault zone, a gravel with imbricate structure occurs in alluvium. The indicated direction of flow is slightly west of south, directly opposite the present creek.

Other fault locations shown on the map accompanying the USGS report were visited. Evidence of faulting, slope changes, and diffuse contacts of dissimilar lithologies are not persuasive. The variations of slopes may well be scarps, but it is most probable they were caused by erosion or ground failure. The contacts appear to be erosional disconformities or unconformities.

The fault mapping of the Sandia area in USGS open file report 77-689 (USGS, 1977) is too positive. The field evidence is much too weak to support it. Faulting does exist in the area, as shown at two locations, but the magnitude cannot be ascertained by the field evidence. Further, accurate dating of fault movement is not possible in the field as the two proved fault exposures are both confined to the Livermore gravels, limiting the most recent movement dating to Plio-Pleistocene. At this time, with the data available, it would seem best to continue to regard the location of the possible fault as postulated, based on the two known fault locations and the photo lineaments.

Findings of the various investigative techniques used to examine the Las Positas trace are briefly summarized in Table 3-2.

Seismic History

The coastal portion of central California is one of the most seismically active regions of the United States. Recorded seismic history goes back to 1800. The important earthquakes that have been documented since that time begin with observations recorded by Spanish missionaries. Some crude instrumentation was introduced into the area in the late 1800s at Chabot Observatory

Table 3-2. Summary of Previous Las Positas Fault Evidence

Las Positas Trace	Lineations	Trenching	Deep Drilling	Gravity	Magnetics	Resistivity	Seismicity
	+	+	0	-	-	0	-

Key:

- + Positive correlation but not conclusive.
- 0 Evidence weighs neither for nor against.
- Evidence against presence of fault but not conclusive.

and Mt. Hamilton; however, before the 1906 San Francisco earthquake, the sensitivity and location of these seismographs were of little value in locating the smaller earthquakes in the area. Instrumentation for accurately recording and measuring large earthquakes has been available since the early 1930s. Sufficient instrumental coverage for locating and measuring small earthquakes has been available since the early 1940s and continues to be improved up to the present time.

Earthquake epicenters for the coastal central California area are plotted on a map (Figure 3-10) showing the major active faults in the area. It is important to remember that many of the older earthquake locations are based on, or influenced by, historical personal accounts. Population density influenced the epicenter locations toward the centers of population, thus making many of the estimated epicenter locations inexact.

Seismic History Related to Active Faulting -- The historic earthquake record indicates that the San Andreas fault was the probable source of destructive earthquakes in June 1838; October 8, 1865; April 24, 1890; April 13, 1906; and, most recently, March 22, 1957. The April 18, 1906, earthquake, perhaps the most thoroughly studied seismic event until the recent 1971 San Fernando earthquake, had a Richter magnitude of 8.25. Visible surface faulting extended for more than 320 km from San Juan Bautista on the south to Point Arena on the north, where the fault enters the ocean. Surface faulting was noted at Shelter Cove, 120 km north of Point Arena along what is probably an extension of the San Andreas fault. A total surface rupture in excess of 430 km could therefore have resulted from this earthquake. Maximum horizontal movement was 7 m in the vicinity of Olema, some 42 km northwest of San Francisco. North of the Golden Gate, the horizontal movement was accompanied by 1 m of vertical displacement, and as much as 2 m

of vertical displacement took place at Shelter Cove further to the north. Both the horizontal and vertical movement decreased in magnitude to the south toward San Juan Bautista. Damage from this earthquake has been estimated at between \$350 million and \$1 billion. About 700 persons were killed. Most of the loss was due to fires in San Francisco. This earthquake resulted in an estimated intensity of between VII and VIII in the Livermore Valley. However, few structures existed at the time and the intensity estimates are probably inexact.

Destructive earthquakes occurred on the Hayward fault on June 10, 1836, and October 21, 1868. Approximately 64 km of surface rupture between Mission San Jose and San Pablo accompanied the 1836 earthquake. Surface rupture along a 32 km length accompanied the 1868 earthquake between Warm Springs and San Leandro. Right-lateral movement accompanied both earthquakes, with 1 m of offset associated with the 1868 earthquake and an unknown amount associated with the 1836 earthquake. No reliable estimates are available on the dollar value of damage from the earthquake; however, almost every building was destroyed or damaged along the areas of surface rupture, and approximately 30 deaths were attributed to the 1868 earthquake. Both of these earthquakes are estimated to have had a magnitude of somewhere between 7 and 7.5.

Destructive earthquakes on the Calaveras fault have not been well documented, if indeed any at all have occurred. The Calaveras fault has been considered active for many years because of small earthquakes that are locally felt in the Livermore Valley-Amador Valley area. Possible destructive earthquakes associated with the Calaveras fault occurred on July 3, 1861, and appear to have been most severe in the San Ramon Valley, which is situated on the mapped zone of the fault traces. One of these events is reported to have caused damage in the Amador and Livermore valleys, but no

damage is reported from other nearby locations such as Hayward, San Leandro, or Mission San Jose. Epicentral intensity for this earthquake has been estimated at VIII and possibly might have been as high as IX. Ground surface displacement is reported to have occurred. The magnitude for this earthquake could be as low as 6 because of the apparent local area of damage or as high as 7.5 if the most conservative interpretation is placed on the sketchy observations of this event.

Another large shock that might have been associated with the Calaveras fault occurred on March 30, 1898. Damage was greatest at Mare Island, which, if this is assumed to be the approximate position of the epicenter, could be on the northward projection of the Calaveras fault across the Carquinez Straits.

Closer to Sandia in the Livermore Valley area are several epicenters of microearthquakes. Historically, there have been no earthquakes larger than 4.6 magnitude recorded in the Livermore Valley area, and most of these microearthquakes are less than magnitude 3.5. Although nothing indicates that these small events have occurred on faults, they tend to substantiate conclusions based on other evidence that some of the faults near Sandia are active.

For engineering purposes, the following table summarizes the recommended design earthquakes to be considered for the Sandia site. The location of a possible earthquake on the Tesla fault is based primarily on geologic evidence and is discussed elsewhere in this report.

<u>Zone</u>	<u>Minimum Epicentral Distance</u>		<u>Magnitude</u>
	<u>(mi)</u>	<u>(km)</u>	
Tesla fault	2	3	5.7
San Andreas fault	35	56	8.3
Hayward fault	17	27	7.5
Calaveras fault	10	16	7.5

Livermore Valley Seismicity

Earthquake Relocation -- The seismicity of the Livermore Valley was reviewed to select specific earthquakes of interest to redetermine the hypocentral parameters. Almost 40 events were located from the time period 1940 to 1977, which are listed in Table 3-3. The method of relocation employed the master event technique. The June 1977 ($M_L = 4.6$) earthquake was selected as the master event to determine seismographic station time and adjustments to be applied to the data from the University of California, Berkeley, network. Unfortunately, two earlier stations, Fresno and Palo Alto, had been discontinued. The remaining stations, Berkeley and Mt. Hamilton (Lick), had time adjustments of ≥ 0.1 sec. Thus, this relocation method proved unsatisfactory due to the incomplete station adjustments and was not applied to the data set. The earthquake relocations were determined from the raw data obtained from the University of California, Berkeley, and USGS (NCER) data files. Particular seismograms were reread for the 1943 sequence. The hypocenters were determined by a least-squares program by Bolt and Toro (1963). Both P and S wave phases were used. The velocity model of Byerly for central California was adopted. This model is:

Table 3-3. Hypocentral Parameters of Seismic Events in the Livermore Valley, 1943 to 1977

Event Number	Date	hr min sec	Lat(N)	Long(W)	Depth (km)	M _L
1	03/29/1943	11 45 45.6	37° 38.6'	121° 49.7'	R(5.0)	4.2
2	03/30/1943	23 06 08.6	37° 41.1'	121° 48.8'	R(5.0)	3.6
3	04/15/1943	15 23 02.6	37° 40.4'	121° 45.9'	R(5.0)	4.0
4	04/15/1943	15 31 01.4	37° 42.2'	121° 42.3'	R(5.0)	4.2
5	04/21/1943	23 39 42.9	37° 40.4'	121° 43.5'	R(5.0)	4.2
6	04/26/1943	11 53 59.3	37° 39.1'	121° 47.5'	R(5.0)	4.1
7	05/29/1943	17 04 08.0	37° 36.8'	121° 50.0'	P(5.0)	3.7
8	05/02/1946	01 26 12.0	37° 41.0'	121° 35.7'	P(5.0)	4.6
9	05/02/1946	02 11 36.6	37° 40.7'	121° 36.1'	R(5.0)	3.7
10	08/29/1949	01 56 01.1	37° 39.8'	121° 30.8'	P(5.0)	3.4
11	10/07/1956	02 38 17.2	37° 52.7'	121° 43.9'	R(5.0)	3.6
12	10/31/1958	00 26 14.6	37° 26.8'	121° 48.0'	P(5.0)	4.2
13	03/07/1962	17 52 49.5	37° 30.3'	121° 47.7'	P(5.0)	2.9
14	03/17/1962	21 38 44.4	37° 50.6'	121° 50.7'	R(5.0)	4.1
15	05/30/1963	19 57 51.9	37° 39.8'	121° 48.2'	R(5.0)	3.4
16	01/12/1964	07 48 13.7	37° 39.3'	121° 39.6'	P(5.0)	2.6
17	06/25/1965	01 01 02.0	37° 39.7'	121° 41.8'	R(5.0)	3.4
18A	06/28/1965	11 15 11.5	37° 33.2'	121° 38.9'	R(7.0)	3.6
19	07/30/1965	18 13 30.8	37° 38.6'	121° 53.1'	R(7.0)	2.9
20	08/19/1965	11 04 05.7	37° 39.3'	121° 41.4'	R(7.0)	2.5
21	02/10/1966	14 19 47.3	37° 49.3'	121° 45.3'	R(2.7)	3.3
22	02/10/1966	14 21 08.5	37° 48.1'	121° 47.3'	R(2.0)	3.9
23	07/17/1966	02 33 25.9	37° 39.9'	121° 36.1'	R(7.3)	3.6
24	07/19/1966	12 57 41.4	37° 38.8'	121° 37.4'	R(5.2)	3.3
25	08/29/1966	17 30 11.8	37° 48.3'	121° 59.8'	R(7.0)	3.0
26	09/29/1966	17 32 43.0	37° 48.1'	121° 58.9'	R(5.0)	2.6
27	03/11/1968	23 18 36.0	37° 26.9'	121° 33.6'	R(6.8)	3.2
28B	12/29/1969	19 31 11.4	37° 46.1'	121° 42.8'	R(7.0)	3.8
29	01/05/1970	17 12 12.4	37° 31.3'	121° 50.3'	R(6.7)	3.3
30	01/06/1970	08 34 55.8	37° 32.6'	121° 51.2'	R(7.0)	2.8
31	02/28/1970	02 05 00.2	37° 47.9'	121° 57.7'	R(2.0)	2.9
32	08/06/1971	09 38 39.9	37° 45.5'	121° 48.6'	R(5.0)	2.7
33	05/30/1972	02 54 46.4	37° 33.6'	121° 48.2'	R(5.0)	2.6
34	06/29/1972	05 05 54.0	37° 53.5'	121° 39.7'	R(4.7)	2.5
35	10/07/1973	17 45 12.3	37° 33.8'	121° 51.3'	R(5.4)	2.7
36C	08/31/1976	12 29 28.8	37° 37.9'	121° 40.4'	R(6.9)	3.3
37D	06/21/1977	02 43 06.9	37° 38.2'	121° 39.6'	R(9.8)	4.6
38	06/28/1977	12 46 40.4	37° 38.5'	121° 40.3'	P(9.2)	3.2

Depth (km)		
0	$V_p = 5.6 \text{ km/sec}$	$V_s = 3.3 \text{ km/sec}$
12	$V_p = 6.6 \text{ km/sec}$	$V_s = 3.8 \text{ km/sec}$
30	$V_p = 7.8 \text{ km/sec}$	$V_s = 4.5 \text{ km/sec}$

The relocated epicenters are shown in Figure 3-11 and listed in Table 3-3. The magnitude range is from 2.5 to 4.9. The accuracy of the epicenters varies from approximately ± 5 km for 1940 to 1968 and ± 3 km for 1969 to 1977. Also, the depth control parameters are poorly determined for the earlier events.

The results for an earthquake of a magnitude equal to or greater than 4 are:

1. The 1943 sequence, which included five events of magnitude between 4.0 and 4.2, shows an east-west alignment in the central Livermore Valley region.
2. The 1946 event, with a magnitude of 4.6, appears to have been associated with the northwest-striking Greenville fault.
3. The 1958 earthquake, with a magnitude of 4.2, is associated with the Calaveras fault.
4. The 1977 event, with a magnitude of 4.6, is located along the northern section of the Tesla fault system.
5. The additional earthquakes are generally associated with the Calaveras fault and the various faults to the north and south of the Livermore Valley.

FIGURE 3-11 SEISMICITY OF THE LIVERMORE VALLEY AREA, 1943 TO 1977,
SHOWING FAULT PLANE SOLUTIONS

Fault Plane Solutions -- The fault plane solutions were determined for a few selected events. The method used a linear velocity gradient technique to approximate the Ryerly velocity model. The first motions of the P waves are plotted on an equal-area, lower hemisphere projection. The individual solutions are shown in Figures 3-12a through 3-12d. The focal mechanisms have been plotted in Figure 3-11. The results indicate mainly strike-slip faulting with a northeast-southwest compressional stress system. Unfortunately, the earlier events have fewer first motion data, and the focal mechanism interpretation is more ambiguous. The June 1977 event clearly indicates a reverse motion on the northwest-striking Tesla fault system. The dip angle of this selected fault plane solution is 56°NE (Figure 3-12d); however, examination of the figure indicates that, although the dip is most likely northeast, its value is not well constrained and could be more nearly vertical.

Surface geologic mapping shows the Tesla fault to be dipping southwest. However, the 1977 event occurred at an estimated focal depth of 9.7 km, and the possibility exists that the dip angle associated with this reverse thrust fault may well be a function of depth, in which case there is not necessarily a conflict between the two interpretations.

Probabilistic Assessment of the Exposure to Strong Motion

In order to describe the seismic exposure of the Sandia site, a probabilistic calculation was conducted to estimate the rate of being exceeded as a function of peak horizontal ground acceleration at the site. Two basic sets of information are required for such a calculation. The first is a description of earthquakes in space, time, and magnitude. The second set of information consists of an empirical relation expressing the dependence of peak ground acceleration on earthquake magnitude and distance to the earthquake

04/28/65
M = 3.6

LAT = 37° 12' N
LONG = 121° 18' W
DEPTH = 7.6 km

FIGURE 3-12a FAULT PLANE SOLUTION FOR MAGNITUDE 3.6 EVENT 4/28/65

12/28/69
M = 3.8

LAT = 37° 44' N
LONG = 121° 42' W
DEPTH = 7.2 km

FIGURE 3-12b FAULT PLANE SOLUTION FOR MAGNITUDE 3.8 EVENT 12/28/69

08/31/76
M = 3.3

LAT = 37° 17' N
LONG = 121° 40.4' W
DEPTH = 7.5 km

FIGURE 3-12c FAULT PLANE SOLUTION FOR MAGNITUDE 3.3 EVENT 8/31/76

08/21/77
M = 4.6

LAT = 37° 38' N
LONG = 121° 35.6' W
DEPTH = 9.8 km

FIGURE 3-12d FAULT PLANE SOLUTION FOR MAGNITUDE 4.6 EVENT 8/21/77

rupture. If the Las Positas fault were to be substantiated by future studies as a structure capable of generating moderate earthquakes, it would not have any significant effect on the results of this statistical analysis.

The seismicity data used in the calculation are summarized in Table 3-4. The main constraint used in constructing the seismicity model was the historic record of large earthquakes that have occurred within about 100 km of the site since the 1830s. Large earthquakes (magnitude 6 or more) have occurred in this region at the rate of approximately one per decade. The seismicity of the region has been documented extensively by Townley and Allen (1938), Tocher (1958), and Bolt and Miller (1975). The major part of the regional seismic activity that could produce strong motion at the site is concentrated along well-recognized active faults of the San Andreas fault system. Although large earthquakes (magnitude 6 or more) in northern California usually occur along recognized active faults, events of small and moderate magnitude (magnitude 5 or less) are distributed more diffusely and cannot always be clearly associated with mapped active faults: this applies to the seismicity of the Livermore Valley region as registered over the past century. Presumably, the apparently diffuse seismicity is concentrated along numerous minor active faults in a manner that is not presently determined.

In the calculation, the seismicity of the Livermore Valley region was represented schematically by two seismic sources: an area source and a line source representing a minor active fault whose trace passes within close range of the site. For all of the seismic sources, it was assumed that earthquake occurrence is randomly distributed in space and time.

In Table 3-4, parameters A and R are coefficients in the recurrence relation

$$\log N = A - RM$$

Table 3-4. Seismicity Model

Earthquake Source	Recurrence Parameters		Maximum Magnitude	Shortest Distance To Site (km)	Radius (km)
	A	R			
San Andreas Fault	3.65	0.8	8-1/4	55	--
Hayward Fault	4.33	1.0	7-1/2	30	--
Calaveras Fault	4.15	1.0	7-1/2	20	--
Antioch Fault	3.55	1.0	6-1/2	20	--
Concord Fault	3.55	1.0	6-1/2	30	--
Livermore Valley Area Source	3.30	1.0	5-3/4	--	20
Possible Nearby Active Fault	2.40	1.0	5-3/4	0.1	--

where N is the number of events per year of magnitude M or greater. The aggregate B value for all sources combined is approximately 0.9. For the San Andreas fault, the value given for A applies to a 500 km segment rather than the entire length of the fault.

The relation between peak ground acceleration and earthquake magnitude and distance that was employed in the calculation was based on the work of Gutenberg and Richter (1956). The Gutenberg-Richter relation was amended for small distances in accordance with recent observations indicating that peak ground accelerations in the near field depend less strongly on magnitude than in the far field (see Hanks and Johnson, 1976). Locally, relatively high peak accelerations may be experienced during earthquakes of moderate size. Peak ground acceleration was treated in the calculation as a log-normally distributed quantity, with a geometric standard deviation of approximately two.

The results of the calculation are illustrated in Figure 3-13, which shows the probability of being exceeded in any period of 30 years versus peak horizontal ground acceleration at the site. The calculation indicates that the local seismic activity in the Livermore Valley region accounts for roughly one half of the overall rate of occurrence of strong ground motion. For peak ground accelerations of a few percent of the gravitational acceleration, this conclusion is supported (although not confirmed) by the accelerograph data recorded in the Livermore Valley since mid-1943. Most of the accelerograms to date have been recorded during local earthquakes, and, in particular, aftershocks of the 1943 Livermore earthquake sequence and the Livermore earthquake of June 22, 1977 (USGS, 1977). However, the Livermore accelerograph record is too brief to afford a meaningful check of this calculation.

FIGURE 3-13 PEAK HORIZONTAL GROUND ACCELERATION, PROBABILITY OF EXCEEDANCE, SANDIA TRITIUM BUILDING

From Figure 3-13 we find that, at the median-plus-one-standard-deviation level of confidence (84.2%), the most severe acceleration experienced at the site in any 30-year interval should not exceed 0.27g. At the median-plus-two-standard-deviation level of confidence (97.7%), the largest acceleration in 30 years should not exceed about 0.5g. The probabilities of exceedance of these two levels are 15.8% and 2.3%, and are usually characterized as "small" and "negligible," respectively.

Finite probabilities of large accelerations ($>0.5g$) in this calculation reflect the assumption that peak acceleration is a lognormally distributed quantity. Because the actual distribution is not well determined, it is difficult to attach great confidence to the estimated probabilities of large accelerations. Thus, it is not appropriate to use this calculation to estimate the maximum potential ground acceleration.

Assessment of the Maximum Potential Ground Motion Amplitude

Evaluation Based on Earthquake Source Theory and Observational Data --

As noted above, a probabilistic calculation is not informative as to the maximum potential ground motion. A deterministic approach to this question is also problematical, first because the Livermore Valley seismicity is not well understood, and second because not enough is known about earthquake sources in general, and about elastic wave propagation in crustal geologic formations in particular, to permit strictly quantitative calculations of strong ground motion. The following assessment of the maximum potential ground motion at the site is based on available strong ground motion observations, and where these are lacking (in the near field of major earthquakes), on some results of earthquake source theory.

According to the seismicity model given in Table 3-4, events of magnitude up to 5-3/4 may occur within close range of the site. Large earthquakes

(magnitude 6 or more) are confined to major active faults that pass within 20 km of the site. Major events of magnitude 7 to 7-1/2 may occur on the Calaveras and Hayward faults, which pass within about 20 km and 30 km, respectively. Earthquake magnitudes given in Table 3-4 refer to the Richter magnitude scale, which was developed to compare the sizes of earthquakes in California. For this scale, magnitude is determined from the logarithm of the maximum response of standard torsion displacement seismographs (natural period of 0.8 sec; 0.8% critical damping), which record an earthquake at epicentral distances within 600 km. Definition of the size of an earthquake in terms of the local Richter magnitude scale is not directly descriptive of the maximum ground accelerations to be expected within close range of the event.

While far-field ground displacement scales logarithmically with magnitude (by definition of the magnitude scale), high-frequency ground acceleration in the near field does not appear to scale in the same way. For example, Hanks and Johnson (1976) reported acceleration to be "essentially independent of magnitude" in the magnitude range from 4.5 to 7.1 for a set of accelerograph data recorded at source-site distances within 10 km. The data set used in this study, consisting of 40 accelerograms obtained from events of magnitude between 3.2 and 7.1, is biased toward unusually large accelerations for the smaller-magnitude events. A more complete set of accelerograph data might indicate more magnitude dependence of near-field acceleration than indicated by this study, but it does appear that the magnitude dependence is rather weak.

The results of recent studies in which the dislocation theory of earthquake sources is adopted suggest an explanation for the apparent weak dependence of near-field acceleration on magnitude. It is found that magnitude is closely related to the seismic moment, which is given as the product of the

rupture surface area, the average dislocation amplitude, and the rigidity of the medium wherein elastic strain energy is stored prior to seismic release. Kanamori and Anderson (1975) analyzed the source parameters of 41 large shallow-focus earthquakes and found that the static stress drop, which is proportional to the ratio of the average dislocation to the rupture dimension, is practically independent of seismic moment. Kanamori and Anderson found that the static stress drop depends more on the tectonic environment than on the seismic moment, and gave average figures of 30 bars for interplate earthquakes occurring along, or parallel to, major plate boundaries, and 100 bars for intraplate earthquakes (1 bar = 15 psi). The 1952 Kern County and 1971 San Fernando earthquakes were classified in the latter category, while earthquakes of the San Andreas fault, and parallel or subparallel faults such as the Hayward and Calaveras, fall in the first category.

If it is presumed that the dynamic stresses that determine near-field acceleration amplitudes during faulting are proportional to the static stress drop, then the weak dependence of near-field acceleration on magnitude can be seen as a reflection of the moment (or, equivalently, magnitude) independence of static stress drop. This model is undoubtedly a simplification of reality: for example, the Earth's crust is not a homogeneous elastic medium, and actual rupture surfaces may have considerable geometric complexity, so dynamic stresses may vary considerably along the length of a rupture. The similarity of static stress drops for events differing vastly in moment suggests that the same physical processes are involved in small and large earthquake ruptures.

Three pertinent conclusions can be drawn from the foregoing considerations. First, moderate earthquakes occurring in the Livermore Valley may

produce locally severe ground accelerations, although accelerations recorded during such events in the Livermore Valley since instruments were first installed in 1943 have not exceeded 0.1g. Second, although no accelerograph data have been recorded to date within 20 or 30 km of earthquakes as large as the magnitude 7-1/2 events postulated for the Hayward and Calaveras faults, it is most probable that peak ground accelerations would not differ appreciably from those observed for events one magnitude unit smaller in the same distance range. Third, the appropriate accelerograph data to consider in assessing the maximum potential ground acceleration at the site are data recorded in the near field of earthquakes of the San Andreas fault and associated sub-parallel subsidiary faults. Data for three such events are listed in Table 3-5. Our best estimates of the largest accelerations that would occur at the site due to the earthquake sources listed in Table 3-4 are 0.5g (horizontal) and 0.3g (vertical).

Evaluation Based on Fault Characteristics and Observational Data -- An alternative procedure for estimating maximum potential earthquake motions at a site based on capability of the causative fault is in use for evaluation of nuclear power plant sites and is also used in general engineering practice.

In this method, the fault capable of producing the greatest motion at the site is determined by placing the maximum potential earthquake for the fault on the fault at its nearest point to the site. The resulting ground motions at the site are then calculated as a function of magnitude and distance (site properties are sometimes also taken into account). In this case, site properties are average and are not given special consideration. The basic step in this procedure is to assign a maximum potential earthquake to each fault of interest. This can be done by referring to the historic earthquake record or by estimating the earthquake magnitude based on total

Table 3-5. Near-Field Accelerograph Data for
Strike-Slip Earthquakes of the San Andreas Fault System

Event	Date	Magnitude	Recording Station	Closest Distance to Fault (km)	Peak Ground Acceleration (cm/sec ²)		
					Horizontal	Horizontal	Vertical
Long Beach	3/10/33	6.3	Long Beach	5	193	156	280
Imperial Valley	5/18/40	7.1	El Centro	10.8	342	210	206
Parkfield	6/28/66	6.6	Cholame-Shandon 2	0.1	480	---	202
Parkfield	6/28/66	5.6	Cholame-Shandon 5	5.5	425		117
Parkfield	6/28/66	5.6	Cholame-Shandon 8	9.6	270	233	78
Parkfield	6/28/66	5.6	Temblor	10.6	341	264	130

length of the fault, length of surface rupture, or other factors such as amount of displacement for the event if that should be known from geologic studies of past earthquakes on the fault. Such analysis has been carried out for a nearby facility (URS/Blume, 1972). Our current findings tend to substantiate our earlier evaluation, which placed major emphasis on capability of the Tesla fault. The following discussion has been adapted, with minor modifications, from the 1972 URS/Blume evaluation.

Most of the known faults near Sandia and the Tritium Building are limited in their total length and are therefore not potential locations for the maximum event; one fault is not considered because it is inactive. The lesser faults are Strand No. 1 of the Tesla (inactive), Strand No. 3 of the Tesla, the Corral Hollow fault, the Ramp Thrust fault, and the Noutherty fault.

The two larger faults, which will govern for considerations of vibratory motion, are the Tesla, passing northeast of the site, and the Carnegie fault, also passing northeast. A third fault, called the Greenville, ends in the hills east of the Carnegie fault and extends northwestward from there. Huey (1948) states that the Greenville fault does not join the Carnegie and that its possible connection with other faults to the northwest is very doubtful. He estimates displacement on the Greenville to be about 30 to 100 m in the vertical direction. The horizontal component is unknown but is probably not large. Therefore, it is concluded that the fault is not a major structure. The Carnegie fault is about 26 km long from a point at its junction with the Tesla fault to an estimated point extending 6.5 km across the alluvium of Livermore Valley. Its surface trace is about 2.4 km from the Tritium Building.

The Tesla fault is the largest fault with the nearest location to Sandia, and evidence of its recent activity is more conclusive than in the case of the other faults. The Tesla fault strikes S80°E and continues to the south-east a distance of 18 km from Sandia, where it intersects a major fault trending N45°W. This is considered to be the southeasterly end of the Tesla fault because it is highly unlikely that two faults such as these intersecting at an angle of 35° would act as one fault in case of surface rupture or fault displacement. The northwesterly limit of the Tesla fault is not known but appears to be well beyond the area that was investigated as part of this study. A conservative estimate for the northwesterly extent of the Tesla fault is 8 km across Livermore Valley beyond Sandia. The total length of the Tesla fault is therefore estimated to be approximately 26 km.

The reported Las Positas fault passes very close to the Tritium Building, as does the Tesla fault, and its total length is about 16 km. If the Las Positas fault were to be substantiated by future studies as a structure capable of generating moderate earthquakes, the maximum credible earthquake based on this length and the resulting ground motion at the site would be less than is estimated for the Tesla fault.

In order to estimate the probable magnitude of an earthquake that might occur on the Tesla fault, it is necessary to estimate the length of a surface rupture that could occur on such a fault. The distance over which the Tesla fault has controlled the course of Arroyo Seco Creek is about 0.5 km. This might be considered indicative of the length of surface rupture for a single displacement. It would be unreasonable to presume that surface rupture might take place along the entire length of the fault simultaneously. A surface rupture length of 9.6 km is considered to be a conservative estimate because it equals more than one-third of the total fault length. Data

published by Bonilla (1967), relating length of surface rupture on the main fault to earthquake magnitude, show that an earthquake magnitude of 5.7 would be a conservative estimate for a 10 km length of surface rupture on a reverse fault.

This event of magnitude 5.7 is selected as the maximum potential earthquake. It is located on the Tesla fault at its nearest point to the Tritium Building. Allowing for an 80° south dip on the Tesla fault and a focal depth of 8 km for the earthquake, the epicentral distance would be about 3.2 km from the Tritium Building. Because this is a very close earthquake, it is necessary to estimate the peak ground acceleration by comparison with available records of peak acceleration at very small distances from the epicenter. A publication by Boore and Page (1972) reviews data relating to accelerations near faults that have moved during moderate-sized earthquakes.

For an earthquake magnitude of 5.7 and epicentral distance of 3.2 km, a conservative estimate of peak ground acceleration based on the data of Boore and Page is 0.5g, a value that is in good agreement with other methods of analysis described above.

Meteorology

General Climate

The Livermore Valley is flat and roughly bowl-shaped, about 21 km long and 6 to 11 km wide, and is surrounded by hills that are 300 to 600 m higher. The general area has a "Mediterranean scrub woodland" climate that is characterized by mild, rainy winters (about 38 cm of rain from October through April) and warm, dry summers. Sunshine is abundant throughout the year since the winter rains are of a showery nature. Snow is very rare. Winter storms are a result of migratory low-pressure systems that

become detached from the semipermanent Aleutian Low and move over or north of the area. Following the passage of the migratory low, skies typically clear as the Eastern Pacific High moves inland. Occasionally, under these conditions, strong northerly surface winds with gusts up to 100 km/h are observed for a day or two. The summer is consistently warm and dry. A sea breeze typically develops during the afternoon when modified ocean air moves through the passes to the west; and although the effect upon maximum temperatures is slight, the breeze persists into the early evening and brings cool nighttime temperatures. The strength of this sea breeze rarely exceeds 48 km/h in Livermore. The spring and autumn seasons are typical transitional periods.

Severe Weather

The Livermore Valley rarely experiences severe weather. The greatest recorded rainfall in one day was about 9 cm. Thunderstorms occur less than 5 days per year and are not intense; hail occurs even less frequently. Strong winds with gusts to about 100 km/h occur a few times each fall and winter, usually following the passage of a low-pressure system. Damage from such winds is rare. Dust devils occur at times on warm summer afternoons. They are limited in extent and usually pass unnoticed.

Air Pollution Potential

Because of its location, surrounded by hills, the Livermore Valley has more days of high photochemical smog levels (oxidant) than most of the other air pollution sampling stations in the San Francisco Bay Area. Such smog is generated from automobile emissions; it is estimated that about one-half of the ambient Livermore smog is imported into the valley from upwind metropolitan areas.

Local Meteorology

Station Summary -- Tables 3-6 and 3-7 are taken from the National Weather Service (NWS) compilation for Livermore and are based on data from 1931 to 1960.

Temperatures are moderate during the winter and high during the summer. The average annual temperature is 59°F (15°C) and extremes as high as 115°F (46°C) are sometimes reported in the Livermore area. Maximum temperatures of 90°F (32°C) or higher occur as many as 65 days per year. Freezing temperatures occur about 55 days each year with extreme lows being 20°F (-7°C).

Rain falls mainly in the winter with little or no rainfall during the summer. Rainfall in an average year is 15 inches (380 mm), with most of it falling from October through April.

Wind Direction and Speed -- Winds have not been measured at NWS's climatological substation in Livermore. Wind observations were taken at LLL for several years by instruments mounted atop a telephone pole. No maintenance records nor calibration reports of these instruments are available. Furthermore, trees have gradually grown up around the pole during the past 10 years. Consequently, these measurements are not deemed reliable for obtaining a representative wind summary. In 1971, an instrumented 30 m mast was installed in an open area of LLL. Using data from it, an annual wind rose has been derived as shown in Figure 3-14.

Atmospheric Stability -- The wind records mentioned above have been used to estimate Pasquill-Gifford stability categories*. In the dry season, D and F stabilities are of nearly equal prominence (about 70 percent combined frequency); during the wet season, E stability is observed nearly 40 percent of the time.

*A = Extremely unstable conditions, R = Moderately unstable conditions, C = Slightly unstable conditions, D = Neutral conditions, E = Slightly stable conditions, F = Moderately stable conditions.

Table 3-6. Climatological Temperature Summary for Livermore (1931-1960 Normals)

Elevation 166 m (545 ft), Latitude 37° 39'N, Longitude 121° 47'W
 Wind: Calm 24%, W 19%, SW 16%, NW 7%, NE 12%

		No. Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Highest	(°F)	30	75	77	81	93	103	110	112	112	115	102	90	79	115
Mean Daily Maximum	(°F)	30	56.4	60.0	64.3	70.5	76.4	82.7	89.6	88.4	87.1	78.0	67.1	58.2	73.2
Mean Daily	(°F)	30	46.1	49.0	52.4	59.9	61.9	67.0	71.7	70.8	69.5	62.6	53.4	47.5	59.1
Mean Daily Minimum	(°F)	30	35.8	38.0	40.5	43.3	47.4	51.2	53.8	52.9	51.8	47.2	39.7	36.8	44.9
Lowest	(°F)	30	19	23	25	30	32	40	41	41	35	29	25	20	19
Degree Days	(°F)	30	586	448	391	246	133	33	0	0	12	90	348	543	2830
Number Days Above (90°F)		19	0	0	0	+	3	8	17	14	12	4	+	0	58
Number Days Below (32°F)		19	15	9	4	+	+	0	0	0	0	+	4	23	55

+ = More than 0 but less than 1

- = Trace

Table 3-7. Climatological Precipitation Summary for Livermore (1931-1960 Normals)

(Elevation 545 ft, Latitude 37° 39'N, Longitude 121° 47'W
 Wind: Calm 24%, W 19%, SW 16%, NW 7%, NE 12%)

	No. Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Greatest Monthly (in.)	30	8.13	6.76	5.07	3.74	2.74	0.59	0.24	0.16	1.88	1.84	5.95	10.15	10.1
Mean Monthly (in.)	30	3.01	2.67	1.94	1.13	0.49	0.10	0.01	0.02	0.12	0.59	1.46	2.86	1.2
Greatest Daily (in.)	30	3.45	1.44	2.00	1.80	0.70	0.40	0.16	0.15	1.53	0.84	3.05	3.26	3.4
No. Days (0.01-0.10 in.)	30	11	10	9	5	3	+	+	+	1	3	6	10	58
No. Days 0.10 in. or more	7	7	6	4	4	2	+	0	0	+	1	2	5	31
No. Days 0.05 in. or more	10	2	2	1	1	+	0	0	0	+	+	1	3	10
Snowfall	30	2.5 0.1	T	T	0	0	0	0	0	0	0	T	T	2.5 0.1

+ = More than 0 but less than 1

T = Trace

Figure 3-14 Annual windrose for SLL. Length of line is % frequency; 4.4% calm.

Humidity and Fog -- Long-term records of humidity and fog are not available in the Livermore Valley.

Data summarized by the NWS indicate that heavy fog (visibility less than 0.4 km) occurs on some 27 days per year. The monthly frequency is rather uniform at 2 or 3 days per month, except for 4 days in January and 1 day in March. Ground fogs are more prevalent in late fall and early winter. High fog (coastal fog that is lifted in passing over the western hills) is prevalent on many spring and summer mornings but rarely reaches the ground in the vicinity of the SLL site.

Severe Wind Assessment

No tornados have been observed in the immediate Livermore area although at least four tornadic storms have been reported in the San Francisco Bay Area. This lack of occurrence in the Livermore area is due in part to the surrounding terrain. The area in the vicinity of Livermore, particularly to the southwest or northwest, is relatively hilly and such roughness is not conducive to the development and propagation of tornado events.

The tornado criteria for California were developed by Meteorology Research, Inc. and were taken from UCRL 13533.

On the basis of the established criteria, maximum wind speeds are estimated to be 60 m/s (135 mph). These speeds consist of a 10-m/s (25-mph) translational component and 50-m/s (110-mph) rotational component. The estimated atmospheric pressure change to the tornado is 1.4 kPa (0.2 psi). The tornado criteria were based on a recurrence interval of 10^{-6} /yr. Since the terrain in the Livermore area is not the type that supports tornados, this estimate is believed to be conservative.

Surface Water Hydrology

There are four water systems considered as having a potential hydrological effect on the SLL site. These are: 1) treated water, 2) storm water, 3) the South Bay Aqueduct, and 4) the Del Valle Reservoir.

The Zone 7 water treatment plant, which provides water for a portion of the City of Livermore, is located northeast of SLL. The 0.68 m (27 in) pipeline from the treatment plant crosses the northern boundary of the Lawrence Livermore Laboratory to the north of SLL and runs parallel to the Arroyo Las Positas on its way to Livermore. The Hetch Hetchy Aqueduct, which provides treated water for the City of San Francisco, is located approximately 11 km (7 mi) southwest of the Laboratory. SLL and LLL receive all of their treated water from this source. Water is pumped from the aqueduct to reinforced concrete holding tanks located on the southern end of the SLL site that have a total storage capacity of 4750 m^3 (1.25×10^6 gal) each. Water from the storage tanks then flows down through the SLL site approximately 60 m from the TRL.

Figure 3-3 shows the location of the site, plus the topography and local natural drainage channels. An intermittent stream called the Arroyo Seco crosses the SLL site. Many of the arroyos and creeks in the Livermore Valley area are dry most of the year and have only minimal flow in them from October to April, the area's rainy season. SLL storm water is channeled through storm sewers and open ditches designed to accommodate a 10-year flow. Storm water is directed via the Arroyo Seco northwest to the nearby Arroyo Las Positas.

The South Bay Aqueduct transfers water from Byron, California, to Santa Clara County through a system of pipelines and aqueducts. The aqueduct is an open channel as it traverses the eastern edge of Livermore Valley just

southeast of the LLL and SLL sites. Demand for this water includes local domestic users plus users in surrounding counties.

Del Valle Reservoir is located about 11 km to the southwest. This $9.5 \times 10^7 \text{ m}^3$ reservoir provides water conservation, flood control, and supply to surrounding counties. It is at a slightly lower elevation than SLL and well outside the site drainage basin.

To postulate effects at the site requires an assumption of reservoir waters ponding in the west end of Livermore Valley and backfilling to the Laboratory site. The circumstances required would be seismically-induced dam failure and closure of the valley by seismically-induced landslide. The amount of water to accomplish this is not available from the source reservoir. A further discussion of flooding is included in Section 6 of this document.

Ground Water Hydrology

The eastern Livermore Valley, which includes the SLL and LLL sites, is underlain by water bearing strata, mostly of alluvial origin. Faults have a marked effect on the movement of ground water and divide the Livermore Valley ground water basin into subbasins. Ground water recharge occurs in uplands east and southeast of the SLL site. The flow of this ground water is inferred to be to the northwest, beneath SLL and LLL, in two fault-defined subbasins. Some of the ground water flowing beneath SLL and LLL is discharged by seepage at the surface about 5 km to the northwest. The remaining ground water moves an undetermined distance west of the discharge site. It is not known if this ground water is ultimately contained in the eastern Livermore Valley or if it flows west into other ground water subbasins of the Livermore Valley. Hydraulic potential mapping and other studies would be needed to resolve this question.

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Section 4

FACILITY DESCRIPTION

Introduction

The Tritium Research Laboratory was designed as a research facility to be used for a diverse range of experiments using gram amounts of tritium in various forms. The basic building was completed in the summer of 1975, but testing with small quantities of tritium did not start until November of 1976. Testing of the gas purification system and monitoring systems was completed early in 1978 with full operational status achieved by late 1978.

Special Construction

Because of the nature of the work, the TRL has the following special construction features:

- Ventilation flow is from clean areas toward areas of increasing contamination potential.
- The radioactive materials area is separated from the rest of the building.
- Air is not recirculated, but exhausted through the 30-m (100 ft.) stack.
- The room air and exhaust air are continuously sampled and monitored for tritium contamination.
- Extensive radiation detection and alarms are provided.
- Emergency power is provided to ensure continuous operation of critical systems such as ventilation and alarm systems.
- Double containment of gram quantities of tritium in glove boxes connected to a decontamination system.

Containment and Radiation Exposure Philosophy

The Tritium Research Laboratory was the first major tritium research facility to depart from common practice of employing high velocity air hoods exhausted to the environment for the protection of personnel and containment of tritium. Glove boxes with secondary containment, gas cleanup systems and extensive radiation monitoring instrumentation, as described in this section, were designed for the purpose of reducing tritium releases and personnel exposure to as low as reasonably achievable (ALARA). The ALARA philosophy was the primary concern throughout the design of the TRL.

Keeping personnel internal tritium exposure to a minimum is accomplished by design concepts which assure maximum containment of significant quantities of tritium. The ventilation system design also provides worker safety. A discussion of the bioassay program that was established to evaluate internal exposures is presented in the next section. Radiation shielding is not a concern of the TRL, since the low energy beta emissions do not constitute an external radiation hazard.

Tritium Research Laboratory Building Description (Bldg. 968)

The Tritium Research Laboratory Building 968 (Fig. 4-1) is a single story structure 24 m wide and 55 m long, with a detached equipment room of approximately 111 m² for heating, cooling, and other plant services. Eave height is nominally 5.5 m. Gross area is 1450 m², with a net area of approximately 1000 m², providing a use efficiency of about 75%.

Construction Materials

The laboratory building floor is a reinforced concrete slab on grade. Exterior walls are tilt-up concrete panels connected by poured in place

concrete columns, all sitting on spread footings. The walls are smooth on the interior and have an architectural treatment on the exterior. Approximately 15 door openings and 15 m² of office windows are provided on the exterior walls; doors are hollow metal type and windows are security type. Interior columns, girders, and roof framing are conventional steel construction. The roof is a Class I insulated non-combustible type made of reinforced gypsum-concrete 7.6 cm thick. There are approximately 40 roof penetrations for ventilation system duct work. A metal canopy over concrete slab at grade has been installed along one side of the building for gas bottle protection, receiving, staging and services.

Interior partitions are full height of gypsum board on steel studs. Hollow metal doors are used throughout. Suspended acoustical ceilings at a height of 4 meters are installed throughout except for suspended gypsum board ceilings in Room 126 and rest rooms. Laboratory floors are covered with resilient tile. Rest room floors and wall wainscot are finished with ceramic tile. The office exterior walls are insulated. Other finishes consist of utilitarian painted surfaces.

Relative Hazard Zoning and Access Control

The facility is divided into two zones of differing relative hazard.

They are the office area and radioactive materials area.

- a. The office area, where no work with radioactive materials is allowed, is the area west of the double doors of the main hallway. This includes the office, restrooms, Health Physics office, control room and the west hallway, i.e., the shaded area in Figure 4-2.
- b. The radioactive materials area is that part of the building east of the double doors of the main hallway and includes the east corridor and all of the laboratories.

Figure 4-1 TRL building layout.

Figure 4-2 TRL floor plan of radioactive materials area (unshaded).

Entry to the radioactive materials area does not normally require protective clothing. However, entry into glove boxes that are tritium contaminated or the suspended plastic curtain area (HVAH) of Room 115A requires special protective clothing unless it is determined by the Health Physics representative that these areas are safe for unprotected entry.

Personnel Access

Building 968 is not operated as a security exclusion area. However, to minimize the potential exposure of Sandia personnel to tritium, it is desirable to allow access only to those persons having a need to be in the building. This will be accomplished by a badge exchange system, when modifications to the west corridor are completed. Until that time access to the building will be controlled by a sign in/sign out procedure. Access to each room containing tritium is controlled by a push button combination lock on the door. The door combination is provided only to those individuals on an access list for that particular room. Personnel not on an access list who desire entry to a room containing tritium must have the approval of either the person in charge of the room or the TRL operations supervisor or his alternate.

Personnel Limitations

- a. The number of persons present in a high hazard area at any one time shall be limited to the minimum required to perform operations safely.
- b. Potentially hazardous work will not be performed unless two qualified persons are present.

Ventilation

The TRL ventilation system is a temperature and humidity conditioned, once through, high flow system providing at least 6-10 room air changes per

hour. The building is maintained at a slightly negative pressure with respect to the outside atmosphere and uses a pressure zoning system to ensure that the air flow is from the non-radioactive part of the facility through the experimental laboratories and then to the stack. To maintain the correct pressure differentials, and therefore, the correct air flow, the doors between the hallway and the individual rooms are kept closed at all times when not in use. Use of the outside doors from the individual rooms requires prior approval of the operating staff except during an emergency evacuation.

The building ventilation is provided by a system of exhaust fans, supply fan, heating and cooling coils, ductwork, and a system of manual and automatic dampers necessary to direct air flow through the building and maintain designed building pressure differentials. The ventilation and temperature controls are pneumatic, utilizing the 100 psig compressed air system reduced to 20 psig as the air source. To minimize contamination, the volume between the roof and ceiling is used as a plenum for incoming ventilation air. All air supplied to the laboratory spaces is exhausted continuously through the high velocity air hoods and/or through ceiling return air grilles connected to an exhaust duct system consisting of a central exhaust duct, exhaust fan and 30 m (100 ft) steel exhaust stack (see Figure 4-3). The total air flow is approximately $1560 \text{ m}^3/\text{min}$ (55,000 SCFM). An installed stand-by exhaust fan is provided, with automatic switch-over, to ensure continuous air flow through the building. The exhaust fan is powered by the emergency power generator described below in the event of commercial power failure. The ventilation system is shown in block form in Figure 4-4. The pneumatic control system is shown schematically in Figure 4-5. The compressed air is supplied by two water cooled, non-lubricated, electric motor driven,

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SECTION

Figure 4-3 TRL room ventilation system.

continuous duty rated, industrial type compressors with a capacity of 3 m³/min (100 SCFM) each. The compressor controls are arranged such that one machine may be selected as the lead machine with the second as automatic stand-by in case of failure of the first. The second machine will also start in case air demand exceeds 3 m³/min (100 SCFM). The lead compressor is automatically powered from the stand-by diesel generator in case of commercial power failure.

An absorption type water chiller (220 ton capacity) operating in conjunction with an open type cooling tower provides chilled water for cooling coils in the building air supply fan inlet. The air supply is also provided with hot water coils for tempering the air during the heating season. Final air temperature control in each laboratory space is maintained by individual room thermostats controlling hot water reheat coils located in the supply duct work to each room. Hot water for all heating coils is provided from a steam to water heat exchanger. An electrically driven water chiller (60 ton capacity) is provided for small process cooling loads during the heating season.

Ventilation system failures are primarily associated with systems controls and loss of compressed air. Failure of either of the redundant main exhaust fans does not interrupt building ventilation.

Service Utilities

Utility services include (1) 20 cm water line totaling 100 m, extended from an existing 35 cm main approximately 45 m from the building for fire protection and domestic water, (2) sanitary sewer lines totaling 200 m extended to an existing 15 cm main, (3) an underground steam and condensate piping system extended approximately 520 m from existing mains, (4) an

- Supply fan — Continuous operation and off on elect. power failure
- Exhaust fans — One fan on-line at any given time
- 2nd fan arranged for auto. start-up in case of air flow failure thru on-line fan
 - On-line fan elect. power supplied auto. from stand-by emergency generator in case of commercial power failure

Figure 4-4 TRL Ventilation System

Figure 4-5 TRL Ventilation System

outdoor unit substation of approximately 750 kVA capacity for building electrical power, (5) approximately 400 m of power and communication duct banks extended from existing facilities, and (6) approximately 500 m of site perimeter lighting connected to an existing system.

Site improvements include approximately 7,800 m² of clearing, cut and fill, and grading; 2,760 m² of asphaltic concrete paving; 335 m of 7.4 m chain link fencing; 12 m of drainage culvert, and miscellaneous drainage structures.

A utility piping header system is provided throughout the length of the building central corridor with valved connections extended into the laboratories. Branch piping services for equipment will be extended as equipment is installed. The utilities include hot and cold water, chilled water, plant air, and inert gases.

Two underfloor drainage systems have been installed. The main system collects liquid effluent from the floor drains, sinks and restroom showers. This waste is collected in two underground 9.5 m³ holding tanks. The effluent collected in the holding tanks is monitored for tritium contamination and its disposition determined by the Health Physics representative. Solid or semi-solid waste is not disposed of through any of the drains in the facility. Liquid waste such as lubricants, solvents, etc., are collected and disposed of by the Health Physics representative. The second system, which includes the toilets and urinals, drains into the sanitary sewer.

Building lighting is accomplished with fluorescent fixtures to provide 30 m candles illumination. A minimum number of duplex receptacles have been installed in exterior walls and partitions. Clock outlets, exit signs, and battery-operated emergency lighting are placed throughout the building.

Public address speakers, evacuation switches and bells, fire alarm transmitters, and telephone outlets are also included. Branch distribution power systems and outlets for equipment will be installed as equipment is placed.

The attached equipment room houses water chillers, heat exchangers, steam pressure reducing station, pumps, air compressors, motor control center and switchboard. The area is ventilated, but not heated or cooled.

Emergency Power

In the event of a commercial power failure, a 200 kVA diesel generator located in the TRL equipment room will automatically start up to provide emergency power. Start-up and switch-over time is 6 to 10 seconds. A 3.3 m³ fuel storage tank is located at the site and provides about 48 hours of operation. The following equipment is supplied power by the generator:

1. exhaust fans
2. air compressor
3. small water chiller supplying GPS
4. cooling tower needed for chiller and air compressor
5. one chilled water pump
6. one tower water pump
7. one process (GPS) water pump
8. emergency lights in the equipment room
9. an emergency power panel (designated "EPA" located in the TRL hallway which supplies all the critical monitory and control systems including:
 - a. tritium monitoring system
 - b. computer

- c. gas purification system and control
- d. vacuum effluent recovery system and control

Fire Protection

Building 968 consists of a single story Type I construction, concrete reinforced tilt-up walls, with concrete floor. The partitions are of 1.6 cm thick gypsum board on metal studs and the roof is poured gypsum concrete on fiber board, covered with felt paper, tar and gravel. The occupancy consists of offices and low fire hazard labs.

The building is furnished with automatic sprinkler protection for ordinary hazard, with automatic alarms connected to the Lawrence Livermore Laboratory fire department directly across the street and to SLL's own Security Headquarters. Three manual fire alarm boxes and adequate fire extinguishers are provided. This building also has a formal well trained fire team consisting of a fire captain, a fire extinguisher, and a fire evacuation squad, who are coordinated to work closely with the LLL Fire Department.

The design of this building and subsequent modifications have been carefully coordinated to limit the presence of combustible construction. The building is separated from all other buildings on all four sides by open space and streets; there is no external fire exposure hazard.

Containment Systems

Sealed Glove Boxes

Box Description

All experimentation is secondarily contained in 1.2 x 2.4 x 2.4-m sealed glove boxes as depicted in Figure 4-6. The boxes are of welded construction

of 2.0-mm-thick Type 304 stainless steel. Each box is equipped with 34 glove ports, 14 safety glass viewing windows and one 0.3-m-dia by 0.5 m-long air lock passthrough. The box contains both 0.8 x 0.8-m and 1.1 x 1.1-m removable panels, one on each end for installation of large items. The windows, glove ports, and access doors are gasket sealed.

Both regular utility and emergency electrical power are provided within the box. Feedthrough provision is made for instrumentation and inert gas pressure connections. A cooling system is provided to remove the heat load generated by the experimental apparatus within the box.

Each box can be connected on demand to the two central decontamination systems. The boxes are also connected to, but manually valved off from, the building ventilation system. Both humidity and tritium concentration control are achieved by the connection of the boxes to the gas purification system. The moisture concentration can be reduced to the parts per million level by circulating the box atmosphere through the GPS dryers. A backup to the pressure control system on the glove box is provided by a bubbler system which is set to relieve the glove box pressure when the differential with respect to the room exceeds ± 1.5 kPa. Major glove box performance criteria are summarized in Table 4-1.

TABLE 4-1
SEALED GLOVE BOX PERFORMANCE CRITERIA

Volume	7.25 m ³ (1.2 x 2.4 x 2.4 m)
Atmosphere	Nitrogen, Argon, Air
Pressure Limits	
Operating	-0.25 to -1.0 kPa relative to the laboratory
Maximum	+1.5 kPa relative to the laboratory
Humidity	Down to 1 ppm water
Cooling Load	3 kilojoule s ⁻¹
Electrical Power	5 kilojoule s ⁻¹
Leak Rate	<1 x 10 ⁻⁹ m ³ (STP)s ⁻¹ He at 1.0 kPa differential

Box Operation

The glove boxes are operated in a stagnant mode with dry nitrogen maintained at a pressure of -0.25 to -1.0 kPa with respect to the room by the box pressure control system. Capability also exists to operate the box with an argon or air atmosphere if desired.

The box pressure differential is achieved by the use of two Dwyer Photohelic controllers. One of the units operates a valve to either the laboratory vacuum manifold or a makeup source. The second unit protects the system by isolating the box from vacuum pumps and pressure sources in the event the normal pressure limits are exceeded. The pressure control system may be operated by a remote foot switch or by push buttons on the control panel.

The glove box is normally valved off from the gas purification system, and the box tritium monitor continuously measures the tritium concentration

EXHAUST FROM GAS
PURIFICATION SYSTEM

EXHAUST FROM BOX TO VACUUM
EFFLUENT RECOVERY SYSTEM

EXHAUST FROM
BOX TO GAS
PURIFICATION SYSTEM

SEALED
GLOVE
BOX

Figure 4-6

of the glove box atmosphere. In the event the tritium concentration exceeds a set level, the tritium monitor provides a signal for the facility control computer to send a command to start the gas purification system and reduce the tritium concentration to the parts per billion level.

When conditions permit, the glove box may be operated as a high velocity air hood by opening either of the large end panels and manually opening a valve to the building ventilation exhaust system.

Pressure Alarm

The pressure alarm system also has two modes of operation, enable and disable. When the pressure alarm is in the enable mode the alarm will occur if the pressure exceeds the alarm set points. The pressure alarm causes several events to occur which are designed to protect the glove box. A list of these events is as follows:

1. Solenoid valves close to isolate the glove box from vacuum pumps and pressure sources.
2. The pressure control system switches to the manual mode.
3. An audible buzzer sounds in the glove box and the control room.
4. A visual alarm lamp lights in the control room and on the glove box.

After an alarm occurs the pressure must be brought back between the alarm set points before the alarm is reset. The alarm is reset by pushing a reset button on the glove box control panel.

Fire Alarm

Each glove box is equipped with a normally open, thermally actuated switch (Fenwal, Detecta-Fire sensor) which acts as a fire detector. The units are set to close when the gas temperature is a maximum of 60°C or when the rate of rise exceeds 5°C/min. The detector is connected to a fire

alarm box in the control room which relays the alarm to the LLL Fire Department. When the switch closes the following events occur:

1. Audible alarms sound at the glove box, control room, and at the LLL Fire Department.
2. Visual alarms occur in the control room and at the glove box.

Vacuum Pumps

Each glove box is equipped with two vacuum pumps. One pump is used to pump down the passthrough port while the second is used to evacuate the glove ports. Solenoid valves are installed in the inlet lines of each pump to isolate them from the glove box in the event of a pressure alarm. User ports are provided on the glove port vacuum pump so the experimenter may use them as required.

Note that one pump could serve to do both jobs. However, the probability of back diffusing T_2 into the gloves is considered to be of sufficient likelihood as to dictate the use of two pumps.

Vacuum Gages

The glove boxes are equipped with vacuum gages connected to measure the glove port manifold vacuum and the passthrough port vacuum. The vacuum gage readout is mounted in the control housing. Slave units which display the vacuum gage readings are also mounted on the opposite side of the glove box for convenience.

Power Distribution

AC power for the experimenters use is provided on the inside and outside of the glove box. The power is divided into two panels at each location, an emergency power supported panel and a non-emergency power supported panel.

Each panel section includes four each 120 V AC plugs, one each 208V, 3-phase plug and one each 208 V, 1-phase plug. The building power distribution system was sized to provide an average of 5 kW to each glove box. The glove boxes have been wired to provide up to 15 kW of power if required.

Monitoring

The tritium concentration of the glove box gases is continuously measured and displayed by a monitor mounted in the control housing. The tritium monitor reading and alarms are also displayed on a console display unit in the control room. The glove boxes are connected through a manifold system to a second tritium monitor which can be used to back up or cross check a reading in the event there is reason to question the glove box monitor reading. The console display units are interfaced to the building control computer.

Auxiliary Valve Controls

The glove box will likely be damaged if exposed to a differential pressure greater than approximately 14 inches H₂O. The pressure alarm system has been designed to protect the system from external pressure sources by isolating the glove box from these pressure sources if the alarm limits are exceeded. Three auxiliary connectors are provided on each box for the experimenter. These auxiliary connections will be used to operate normally open or normally closed 120 V AC solenoid valves. The valves will be automatically opened or closed by the pressure control system when a pressure alarm occurs. They will be used by the experimenter to isolate vacuum pumps or external pressure sources which potentially exceed the glove box structural strength.

Bubbler System

In addition to the standard pressure control and alarm system the glove box is further protected from implosion or explosion by a bubbler system. The bubbler is set to relieve the glove box pressure when the differential exceeds ± 6 inches H_2O . Glove box gases are vented to the stack, or air is introduced into the box by means of this system. The bubbler will protect the glove box from structural failure in the event of a failure in the pressure control and alarm system.

Glove Ports

As noted, the glove box is equipped with 34 glove ports. Each port is equipped with a cover and a pump down valve. When not in use the covers are to be installed and the valve positioned to pump down the gloves. In the event of a glove rupture the port vacuum pump would attempt to pump down the glove box. To protect against this situation a solenoid-operated valve is installed in the pump inlet line. This solenoid valve is closed by the pressure alarm system to isolate the box from the vacuum pump. The number of glove ports used at any one time will be minimized to prevent unnecessary releases of tritium into the room atmosphere.

Permeation of tritium through the gloves into the room has also been considered. The maximum quantity of tritium planned for experimental use in a glove box at any one time is 10 grams. It is conceivable that additional quantities of tritium will be stored in a box; however, stored material will be adequately protected so that the maximum tritium released into a box will not exceed 10 grams. The specific activity of tritium is about 10,000 Ci/gram. The internal volume of a glove box is 7.25 m^3 .

As an example, consider a 6 gram accidental discharge into a 7.25 m³ box, resulting in a tritium concentration in the box of 8.3×10^3 Ci/m³.

The tritium in a 6 gram spill is assumed to exchange with water forming HTO; the subsequent diffusion through the rubber gloves is thus by the HTO molecules. With the Gas Purification System in operation, the concentration, C, of HTO in the glove box decreases according to the functional relationship $C(t) = C_0 \exp [-(Ft/V)]$, where

$$F = 3.4 \times 10^2 \text{ m}^3/\text{h} \text{ (flow rate of GPS)}$$

$$V = 7.25 \text{ m}^3 \text{ (glove box volume)}$$

$$t = \text{time in hours}$$

Pertinent quantities are defined below:

$$C_0 = 6/7.25 = 0.827 \text{ gm/m}^3 \text{ of } T_2 = 40/7.25 = 3.52 \text{ gm/m}^3 \text{ of HTO,}$$

$$h = 30 \text{ mils} = 0.762 \text{ mm (glove thickness),}$$

$$A = 1.5 \times 10^3 \text{ cm}^2 \text{ (glove surface area),}$$

$$T = 22^\circ\text{C} = 295^\circ\text{K (temperature),}$$

$$S = 150 \frac{\text{cm}^3(\text{HTO})}{\text{cm}^3(\text{rubber})} \text{ (the solubility),}$$

$$D = 5 \times 10^{-8} \frac{\text{cm}^2(\text{rubber})}{\text{sec}} \text{ (the diffusivity), and}$$

$$R_0 = 82.0562 \frac{\text{atm cm}^3(\text{HTO})}{\text{mole}(\text{HTO})^\circ\text{K}} \text{ (the ideal gas constant).}$$

The quantity $Q(t)$ diffusing into the room after t hours as HTO is

$$Q = - \frac{2\pi^2 D^2 A}{h^3} \sum_{n=1}^{\infty} (-1)^n n^2 \int_0^t \left(\frac{\exp(-\pi^2 D^2 w)}{h^2} \right) \frac{w}{\phi(\lambda)} \left(\frac{\exp(-\pi^2 D^2 \lambda)}{h^2} \right) d\lambda dw \quad (4.1)$$

where

$$D' = n^2 D / h^2$$

$$\phi(\lambda) = C(t = \lambda) S R_O T;$$

after doing the integrations we get

$$Q(t) = \frac{2 \text{ DAC}_0 \text{ SR}_0 T}{h} \sum_{n=1}^{\infty} (-1)^n \frac{1 - \exp(-\pi^2 D' t) - (\pi^2 D' V / F) [1 - \exp(-Ft/V)]}{\pi^2 D' - F/V} \quad (4.2)$$

The total amount diffusing into the room is found by letting $t \rightarrow \infty$ (about 30 hours in this problem):

$$\begin{aligned} Q(\infty) &= \frac{DA C_0 S R_0 T V}{hF} \\ &= 6.8 \times 10^{-5} \text{ gm HTO} \\ &\text{or } 1.0 \times 10^{-5} \text{ gm of tritium} \end{aligned} \quad (4.3)$$

After 3 hours, 4-1/2 hours, 6-3/4 hours, and 9-1/2 hours, about 25%, 50%, 75% and 90% respectively of the tritium that will escape from the box (at $t = \infty$) has permeated into the room.

Passthrough Port

The passthrough port is used for moving material in and out of the glove box. A vacuum pump, dry nitrogen and associated valves are installed on the glove box to provide pumpdown and backfill of the passthrough. Two small hand valves have also been installed so that a portable tritium monitor can be connected to monitor the passthrough port contamination. If the

interior door is accidentally left open during a pump down or backfill operation the glove box could be over-pressurized. To prevent this, solenoid operated isolation valves are installed in the dry nitrogen line and the vacuum pump inlet. These valves close to isolate the glove box when the pressure alarm limits are exceeded.

Cleanup

Tritium released into the glove box, either in an accident or because of slow background buildup, can be removed by circulating the contents of the glove box through the Gas Purification System (GPS). The TRL control computer regulates cleanup of the glove boxes based upon the tritium monitor readings. The sequence of events that will occur during a cleanup operation are as follows:

1. High background buildup or accidental release of tritium into the glove box occurs.
2. Control computer reads increased tritium concentration through the console display interface.
3. Control computer sends alert cleanup alarm to control room and to the glove box in question.
4. Audible and visual alert cleanup alarms occur in the control room and the glove box.
5. Approximately 30 seconds after the GPS cleanup alert signal occurs, the glove box valves will open and the gases will be circulated through the GPS for cleanup. During the 30 sec delay period the experimenter should cover all glove ports. When the GPS valves open, the normal glove box pressure control system is disabled and the pressure is controlled by the GPS.

6. When the tritium concentration has been reduced to a safe operating level the valves to the GPS will close and the system will return to the normal mode of operation.

The cleanup system may also be used to backfill the glove box with dry nitrogen or argon if an inert atmosphere is required for glove box operations.

High Velocity Air Hood Mode

Occasionally it may be necessary to move large items of hardware in or out of the glove box. After the box has been exposed to tritium some outgassing of the glove box surfaces is expected even after cleanup by the GPS. When it becomes necessary to remove the large end door for access to the interior, the system may be operated as a high velocity air hood. A 30 cm duct connects each glove box to the building stack. Normally the duct is sealed by a cap on the inside of the glove box. The process of placing the glove box into the hood mode will be approximately as follows:

1. Decontaminate with the GPS in the recirculation mode.
2. Switch the GPS to stack mode to flush the glove box with clean air.
3. Open the glove box stack duct and the passthrough port to flush the glove box with room air.
4. Open the large glove box access door.

Between each phase of this operation the tritium concentration is monitored to ensure that the next phase is safe to enter.

High Velocity Air Hoods

Large "fume-type" hoods are used to house those activities and equipment in which the potential for tritium release is negligible because of low

quantities, subatmospheric pressure operation, or very high quality and proven apparatus (e.g., PC containers). These hoods are connected directly to the central duct of the exhaust/stack system. A minimum face velocity of 45 m/min (150 LFM) is used in these hoods with 60 m/min (200 LFM) or greater typical. High velocity air hoods (HVAH) are used to house the mass spectrometer located in room 122, and for sample preparation in various rooms. Specially designed hoods are used during the decontamination systems testing. Local exhaust ventilation is used in the machine shop when required.

Tritium Research Laboratory Decontamination Systems

Two central decontamination systems are being employed in the TRL. The first of these systems, called the Gas Purification System (GPS), is used to remove tritium, tritiated water and tritiated hydrocarbons from the sealed glove box atmosphere in the event of either a significant accidental release or a slow buildup of background contamination. The second system, called the Vacuum Effluent Recovery System (VERS), is used to remove tritium, tritiated water and tritiated hydrocarbons from the glove box pressure control system and the gases exhausted from all of the vacuum pumps in the laboratory before venting this gas to the stack. Both systems are connected to manifolds that run throughout the laboratory.

Gas Purification System (GPS)

GPS Description

The Gas Purification System (GPS), Figure 4-7, decontaminates the glove box atmosphere in the event of either an accidental release or a slow buildup of background concentration. The GPS, conceptually illustrated in Figure 4-8, consists of the following major elements:

1. A closed loop manifold with glove box bypass capability extending throughout the laboratory.
2. A blower section for circulating the box atmosphere through the system.
3. A catalyst section for conversion of the hydrogen isotopes to water.
4. A dryer section which performs three functions:
 - a. collect the oxidized hydrogen isotopes;
 - b. regenerates the dryers for continued usage and collects the tritiated water for subsequent safe disposal.
 - c. dehumidifies glove boxes as required.
5. A control and diagnostics system for providing both remote and local control and for assessment of the operational status. This system includes tritium and humidity sensors for assessment of system efficiency.

Redundant prime function components, i.e., blowers, heaters and catalyst and dryer beds are provided for reliability. A dryer regeneration system provides for removal of water from a loaded dryer while the GPS is operating with the use of the other two dryers. Entry and exit nozzles allow safe removal and replacement of both catalyst and sieve material while the system remains operational by the use of a redundant flow path.

Major system performance criteria are summarized in Table 4-2. Acceptance testing at the manufacturer's plant and pre-operational testing at Sandia Laboratories have verified the capability of the GPS to meet all of the criteria in Table 4-2.

Catalyst performance tests using a prototype reactor were run with tritium. Reduction factors of approximately 10^5 from inlet concentrations of approximately 1 ppm were measured during these tests.

Figure 4-7 Gas Purification System Conceptual Diagram

Figure 4-8 - Gas Purification System Schematic

TABLE 4-2
GAS PERFORMANCE CRITERIA

Processing Capacity	0.06 - 0.12 m ³ s ⁻¹ nitrogen, argon and air
Catalytic Reactor	
Operating Temperature	338°K - 750°K
Standby Temperature	293°K - 750°K
Catalyst	Engelhard Minerals & Chemicals No. A-16648
Tritium Concentration Reduction Factor	1000 per pass for concentrations from 20,000 ppm to 1 ppm at operating temperatures >367°K
Molecular Sieve Dryer	
Capacity	37 moles of water while maintaining less than 1 ppm water at exit
Regeneration Time	6 hours
Regeneration Temperature	589°K
Molecular Sieve	Type 4A
Startup Operating Time	30 s
Glove Box Pressure Control	-0.25 to -1.0 kPa relative to the laboratory
System Leak Rate	1 x 10 ⁻¹⁰ m ³ (STP)/s maximum helium at 98 kPa differential

GPS Operation

Upon receipt of a signal from the glove box tritium monitor, the laboratory control computer selects the flow path for the glove box and signals the GPS

to start. The GPS operates the valves to program the selected flow path. Standby heaters maintain the catalyst at approximately 750°K to ensure catalytic conversion of trace hydrocarbons at startup. Two modes of operation, recirculation and stacking, are possible.

Recirculation Mode: The recirculation mode is the normal method of operation of the GPS. In this mode the glove box gases are pumped from the box through the GPS and returned to the box. The operation of the system will be approximately as follows:

The control computer reads the tritium monitors periodically, sorts those associated with glove boxes into amplitude order and checks the readings to determine whether a glove box cleanup is required. If cleanup of a box is required, the control computer connects the box to a control interface and sends a GPS alert signal to the glove box. The control program selects the flow path for the glove box and signals the GPS to start up in the selected flow path. The GPS operates the valves to program the selected flow path. The GPS starts recirculating the gas in the manifold through the bypass valve. The GPS pressure control system adjusts the pressure of the manifold between the limits of -0.25 to -1.0 kPa relative to the laboratory. The pressure control is necessary to prevent damage to the glove box when the box valves are opened. At the end of 30 seconds the pressure in the manifold is within limits and the flow established at $0.08 \text{ m}^3 \text{ s}^{-1}$.

The valves connecting the box to the GPS manifold are opened and the bypass valve closed. The GPS control system then introduces air into the manifold at approximately $3.4 \text{ m}^3/\text{h}$ for a period of 2 minutes. An equal volume of gas is vented from the manifold (to the VERS) so that

pressure control is maintained. This air is introduced to ensure that an adequate amount of oxygen is available in the gas stream to oxidize the tritium.

The flow of gas through the GPS is as follows: The gas leaves the box through the remotely actuated valve and travels down the intake manifold and through the blower. Downstream of the blower, the gas is heated by the combination of preheater and heater in order to maintain the 750°K catalyst temperature. Tests with methane show that this gas temperature is sufficiently high to crack hydrocarbons contained in the gas stream. The gas then enters the catalytic reactor where the tritium is oxidized to tritiated water.

The tritiated water/gas stream is then cooled to 294°K and passes into the first molecular sieve dryer. The dryer section is capable of removing moisture from the gas stream to the 1 ppm level or less. Water in excess of 1 ppm is adsorbed onto the molecular sieve. The gas stream exits the first dryer at no more than 1 ppm tritiated water concentration, and 1000 ppm H₂O is added to it before it enters the second dryer. Exiting the second dryer the moisture content of the gas stream will again be 1 ppm; however, only 1/1000 of this, or 1 ppb, will be tritiated water. The gas stream exiting the second dryer enters the exhaust manifold and is returned to the glove box. The returned gas mixes with the gas in the glove box and dilutes its concentration. Assuming exponential dilution and perfect mixing of the gases, an estimate of the cleanup rate of the system can be made. The glove box heat exchanger blower can be used to aid mixing of the recirculating gas during cleanup. The equations describing the concentration of the glove box at any time is as follows:

$$C(t) = [C(I) - C(F)] \exp(-t/\tau) + C(F)$$

$C(t)$ = glove box concentration at any time t , min.

$C(I)$ = initial glove box concentration,

$C(F)$ = final glove box concentration,

$$\tau = \text{system time constant} = \frac{7.25}{4.7} = 1.54 \text{ min (assuming a } 4.7 \text{ m}^3/\text{min system flow rate).}$$

The final box concentration is set by the effluent concentration of the GPS and will be 1 ppb tritium or less. Using the system time constant of 1.54 minutes and assuming $C(I) \gg$ GPS exit concentration, the concentration of the glove box is reduced by a factor of 10 every 2.3 time constants or each 3.55 minutes of operation. Allowing for a 0.5 minute startup time, a concentration of 1000 ppm will be reduced to 1 ppm in $3 \times 3.55 + 0.5 = 11.15$ minutes.

When the control computer determines that the glove box tritium concentration has been reduced to a safe operating level the bypass valve is opened, the glove box valves are closed, and the GPS is shut down.

In the event that a tritium release should occur in another glove box while the GPS is operating, the control computer will automatically program the GPS to clean up the glove box which has the highest tritium concentration.

Stacking Mode: The GPS operation in the stacking mode is similar to that in the recirculation mode, with the exception that the glove box atmosphere is not recirculated but stacked after passing through the GPS.

This is accomplished by drawing clean box atmosphere gas into the manifold ahead of the glove box and venting the GPS effluent to the ventilation exhaust. This mode of operation may be used to backfill the glove box with dry nitrogen or argon when an inert atmosphere is required. It can also be used to drive the glove box concentration below 1 ppb when it is necessary to clean up a box for reentry.

Dryer Regeneration

The tritiated water collected in the dryer will be removed and held in a trap until regeneration. The tritiated water collected in the trap will be transferred to a DOT/DUE-approved sieve vessel and shipping container for later recovery or disposal. The sieve vessel and shipping container planned for this use have been designed by Monsanto Research Corporation, Mound Laboratory.

Control System

The GPS control system has been designed to provide versatility in the selection of the flow paths and modes of operation. A request from the control computer to the GPS to operate includes the flow path number. The GPS then starts operating in the flow path and mode defined by the switches in the selected flow path number.

A primary and secondary flow path number will be selected for each glove box in the laboratory. If cleanup of the glove box is required, the control computer will start the GPS in the primary flow path. If a component failure occurs in the primary flow path which causes the GPS to shut down, the control computer will restart the GPS in the secondary flow path. The control system has been designed to operate unattended on a 24-hour basis.

The GPS can be operated manually by Tritium Research Laboratory personnel to perform routine testing and for dehumidification of glove boxes. The

manual mode will also be used when computer or interface maintenance is required.

Vacuum Effluent Recovery System (VERS)

VERS Description

The VERS, Figure 4-9, is used to decontaminate the exhaust gases from the laboratory vacuum systems before venting these gases to the stack. The VERS is a system similar to the GPS and uses the same precious metal catalyst.

The VERS, as conceptually illustrated in Figure 4-10, consists of the following major elements:

1. A vacuum manifold extending throughout the facility for connection to all sources of tritiated effluent.
2. An effluent separation section to divide effluent into two contamination level categories; one for venting up the stack and one for decontamination.
3. A holding section consisting of two 5.7 m³ tanks for effluent collection.
4. A decontamination section consisting of a catalytic reactor for conversion of hydrogen isotopes to water and molecular sieve beds for collection of the tritiated water.
5. A control and diagnostics section for providing both automatic and manual operation and for assessment of the operational status. This system includes tritium and humidity sensors for assessment of effluent contamination and system efficiency.

The catalytic reactor will be maintained at an elevated temperature standby condition to assure combustion of tritiated hydrocarbons and readiness to begin processing upon receipt of a start signal.

Figure 4-9 Vacuum Effluent Recovery System Conceptual Diagram

Figure 4-10 - Vacuum Effluent Recovery System Schematic

Major system performance criteria are summarized in Table 4-3. Acceptance testing using hydrogen at the manufacturer's plant has verified the capability of the system to meet all of the criteria in Table 4-3. Prototype reactor tests using tritium are described below. Modifications were made to expand the processing capacity to $17 \text{ m}^3/\text{hr}$, increase the standby and operating temperatures to 750° and 811°K respectively, and use the GPS dryers for tritiated water collection.

TABLE 4-3
VERS PERFORMANCE CRITERIA

Processing Capacity	$2.5 - 17 \text{ m}^3/\text{h}$
Holding Capacity	11.4 m^3 at 93 kPa
Catalytic Reactor	
Operating Temperature	811°K
Standby Temperature	750°K
Catalyst	Engelhard Minerals & Chemicals No. A-16648
Tritium Concentration Reduction Factor	1000 per pass for concentration from 20,000 ppm to 1 ppm
Molecular Sieve Dryer	Will use GPS dryers
Molecular Sieve	Type 4A
System Operating Pressure	0.13 to 103 kPa
System Leak Rate	$1 \times 10^{-10} \text{ m}^3 \text{ (STP) s}^{-1}$ maximum helium at 98 kPa differential

VERS Operation

The laboratory vacuum manifold will be maintained at an average pressure of approximately 3.3 kPa. The effluent exhausted to the manifold is pumped

into a 0.3 m³ tank, where its contamination level is monitored. To minimize VERS operating time, the effluent of the 0.3 m³ tank is divided into two levels of tritium concentration which are collected in separate 5.7 m³ holding tanks. The lower concentration will be selected such that effluent can be vented directly to the stack while the effluent with the higher tritium concentration will be decontaminated before stacking.

Effluent is collected until the holding tank pressure reaches 93 kPa. The decision to stack the holding tank contents will be made by control room personnel and will be initiated manually. The decision to process the holding tank contents through the decontamination section will be automatically made by the VERS control system. The tritium monitor at the exit of the decontamination system will, depending upon the tritium concentration, generate a signal to either recirculate the effluent through the VERS or direct it to the stack.

When a holding tank is to be processed through the decontamination section, the VERS control system will alert the control room by means of an alarm light and begin circulation of the hold tank contents through the decontamination system. When the hold tank pressure is reduced below 1.3 kPa, the system will shut down.

The VERS has the capability for being operated in a continuous stacking and processing mode. However, the decision to use this mode will not be made until a later time as a result of operation experience.

GPS and VERS Maintenance

Both the GPS and VERS are located in Room 115A in a high velocity air hood to provide personnel protection from any tritium leakage from the equipment. The philosophy that is proposed for achieving safe maintenance of

Figure 4-11 Typical Isolation Valve/Purge Port Arrangement

the various GPS components and subsystems is isolation and vacuum purging prior to breaking the system flow boundaries. This will be achieved by pairs of isolation valves and a purge port on either side of the components or subsystems requiring maintenance (see Figure 4-11). For component removal the isolation valves will be closed and the volume between the isolation valves will be alternately evacuated and backfilled until the tritium concentration is reduced to a safe level for removal to a glove box for maintenance. For maintenance in place, the isolation valves will be closed and the component purged until the tritium concentration is reduced to a safe level. In both cases, a temporary high velocity air tent will be set up over the component requiring maintenance/removal and the maintenance/removal operation will be performed by personnel wearing bubble suits.

The decontamination systems, particularly the GPS, have been modified to provide the capability for isolation and purging of all components and subsystems such as automatic valves, catalyst sections, etc., that may require routine maintenance. Special maintenance equipment has been designed and fabricated for replacement of such items as heater elements, catalyst and molecular sieves.

Potentially the most hazardous maintenance operation will be that of transferring the regenerated dryer water from the equipment manufacturer's trap to a container to be used for transportation to another site for recovery or disposal. A Mound Laboratory designed sieve vessel and shipping container, designated AL-M1-CONF. 5, is planned for this usage. The equipment for this transfer has been designed and used successfully to transfer the dryer water.

Decontamination System Testing

The decontamination systems in the TRL were given two series of performance tests. The first series was with hydrogen and methane to provide confidence

that the catalytic reactors in both systems were operating properly before tritium was introduced. These tests were also to determine the appropriate catalyst operating temperature.

The second test series was with tritium and tritiated methane to determine that the systems were capable of achieving the design requirement of a single-pass concentration reduction factor (ratio of inlet to exhaust concentration) of 1000 per pass for inlet concentrations of 1 part per million. Sensitivity limitations of gas chromatography required that this confirmation be made with tritium as the test gas. Tests were run with methane and tritiated methane because tritiated hydrocarbons are expected to be present in both systems, particularly in the VERS.

Results of the tests with hydrogen, methane, tritium, and tritiated methane performed on the TRL decontamination systems in order to determine their ability to meet design specification are summarized as follows:

1. The hydrogen and methane tests show that to achieve concentration reduction factors greater than 1000 per pass, the catalyst must be operated at temperatures in excess of 365K and 750K for hydrogen and methane respectively.
2. Tritium and tritiated methane tests on the Vacuum Effluent Recovery System have established lower bounds on single-pass concentration reduction factors over a range of inlet tritium concentrations from 0.18 Ci m⁻³ to 132 Ci m⁻³.
3. Tritium tests of the Gas Purification System have established single-pass concentration reduction factors over a range of inlet tritium concentrations from 0.14 Ci m⁻³ to 115 Ci m⁻³.

The test program to date has demonstrated that both the Gas Purification System and Vacuum Effluent Recovery System perform 10-1000 times better than

required by specifications and that tritium removal systems can be designed to achieve concentration reduction factors much in excess of 1000 per pass at inlet concentrations of 1 part per million or less for tritium and for tritiated methane.

Monitoring and Alarm Systems

This is a discussion of the alarm systems and set points to be used during initial testing and start-up phases of the TRL. This discussion is not intended to set policy but rather to establish a basis for selecting appropriate alarm points. Actual settings in use on a particular system at a given time will be determined by Health Physics and TRL operational personnel based on this discussion. As operational experience is gained, appropriate adjustments may be made.

DOE Regulations

A review of DOE regulations is appropriate at the outset. Manual Chapter 0524 defines standards for radiation protection and also describes the "as low as reasonably achievable" (ALARA) philosophy. The appropriate radiation protection standard for employees exposed to tritium in the TRL is 5 Rem per year or 3 Rem per quarter. This exposure would be the internal whole body exposure. Exposure to population groups in uncontrolled areas is limited to 0.5 Rem per year. In the interest of the ALARA philosophy, every effort will be made to limit employee exposure to levels far below these maximum numbers. As a guide for determining exposure, 100 mrem/week is equivalent to 5 Rem/yr.

Based on these exposure limits, DOE MC 0524 lists concentration guides for radioactive isotopes in air and water. For example, air concentration

guides (CG's) for HTO are: in a controlled area: $5 \mu\text{Ci}/\text{m}^3$; in an uncontrolled area (off site): $0.2 \mu\text{Ci}/\text{m}^3$. Although the primary use of tritium at the TRL is as a gas, the CG for the oxide will be used unless the concentration is known to be HT.

Alarm Philosophy

A discussion of alarm philosophy is appropriate at this point. High level alarms on a monitoring system will announce situations requiring immediate, rapid, and complete evacuation to prevent serious injury. In this event, all personnel will immediately cease operations in a glove box, seal the glove ports, and evacuate the lab. When the actual level is established, reentry can be accomplished (with or without bubble suits) at the discretion of Health Physics. Situations may arise where high exposure levels are encountered, and accepted, in order to secure a leak in as short a time as possible.

Low level alarms will notify experimenting personnel that the level is higher than normal, but evacuation is not necessary. Low level alarms cause termination of glove box work in an orderly fashion until the cause of the elevated level is determined. Ports will be sealed and checked for leaks, etc. A problem should be corrected in a time scale of 1 hour. Personnel exposure at this level will exceed weekly dose limits in a matter of hours.

Retatec tritium monitors do not distinguish between the molecular and oxide forms of airborne tritium (HT/HTO), and therefore some assumptions must be made during initial phases of operation. The CG_a (concentration guide for airborne contaminants) for T₂ is $2000 \mu\text{Ci}/\text{m}^3$ and for T₂O is $5 \mu\text{Ci}/\text{m}^3$. Therefore, the oxide form is by far the most biologically hazardous. The HT/HTO ratio will not be known initially and no uptake experience in the

TRL is available. There is much experience on this subject at LLL, LASL, LL, and SRP which indicates that when working with the gaseous form, the oxidation rate is very low (on the order of 1% per hour) even at high humidity levels. Therefore, during initial phases of operation, the assumption is made that the tritium is in the oxide form and a CG_a of $5 \mu\text{Ci}/\text{m}^3$ will be used. This is consistent with the other laboratories' philosophy. When measurements of the HT/HTO ratio are completed and if bioassay experience so indicates, the alarm settings can be relaxed if necessary.

In summary, alarm settings are set at the CG_a for HTO and it is assumed that the contamination is oxide until otherwise determined. Based on the CG_a for HTO, the following permissible working time versus air concentration tradeoff can be made:

<u>Concentration</u>	<u>Exposure Time</u>
5 $\mu\text{Ci}/\text{m}^3$	40 hours
10	20
25	8
50	4
100	2
200	1
500	24 minutes

Note that these levels are for normal working conditions and not for emergency conditions.

Summary of TRL Alarm Systems

I. Radiation Alarms (Local, Remote, Control Room)

A. Room Air

- 1) Low
- 2) High

B. Glove Box

- 1) Low

2) High

C. Stack

1) Low

2) Intermediate 1

3) Intermediate 2

4) High

Also Available

5) Totalizer

a) Low

b) High

II. Building Fire Alarm

III. Glove Box Fire Alarm

IV. Security Alarm

V. Evacuation Alarm

A. Manually Activated

B. Computer Generated

1) Stack Alarm and High Room air Level

VI. Control Room/Guard Headquarters - Computer Generated

A. Operational

1) GPS System

2) VERS System

3) Other Facility Functional

B. Hazard

1) Ventilation System

2) Building Power

3) Control System

4) Low Level Radiation Alarm

- 1) Low Level Stack
- 2) More than one lab air concentration low alarm
- 3) High Room Air Alarm

D. Emergency

- 1) High Level Stack

Betatec tritium monitors are the ionization chamber type used in conjunction with a sensitive electrometer. These auto-ranging instruments have both low and high, visual and audible alarm functions. The low alarm function is a yellow panel light and audible alarm with a fundamental frequency of 450-500 Hz. The high alarm has a red panel light and modulates the fundamental frequency of 4-5 Hz. Sound pressure level of the alarms is at least 10 db above ambient. Alarms are enunciated in the room on the readout unit, in the hall adjacent to the door to the lab, and in the control room.

Low Level 50 $\mu\text{Ci}/\text{m}^3$
(HTO CG_a (HTO) reached in 4 hours)

High Level 500 $\mu\text{Ci}/\text{m}^3$
(HTO CG_a (HTO) reached in 24 minutes)

This is high enough to indicate a definite problem which must be dealt with expeditiously. Since operations are discontinued immediately, the level can be expected to drop rapidly and a 15 minute exposure at this level could result in a dose of about 1.6 mrem.

In considering a GPS/HVAC system failure mode, the following analyses were made. If the GPS and HVAC were both inoperative, and two glove ports were left open, a level of 7.5 Ci/m^3 in a glove box could result in a room air concentration of $25 \text{ } \mu\text{Ci/m}^3$ within two hours. If the GPS was inoperative, and the HVAC was operating normally, the glove box level required for a room air concentration of $25 \text{ } \mu\text{Ci/m}^3$ within two hours would be 13.5 Ci/m^3 , again, with the glove ports open. Normally, the glove ports would be closed during this emergency condition. In this case the glove box concentrations required in the above examples would be 16.5 Ci/m^3 and 100 Ci/m^3 .

The length of time personnel can operate through gloves is dependent on the glove box concentration. A "routine" GPS cleanup of a glove box at 100 ppb (0.26 Ci/m^3) will result in a maximum expected level in the room of $2 \text{ } \mu\text{Ci/m}^3$.

High Alarm

Although a long way from dangerous to life, this alarm condition is sufficiently high to indicate a problem. Assuming a rapid evacuation can be effected in 1.5 minutes (1.6 mrem), a reasonable shutdown period of 24 minutes could result in 100 mrem. This concentration is readily detected in the stack, which will act as backup for the room air monitor. A continuous concentration of $500 \text{ } \mu\text{Ci/m}^3$ in the room would result in a stack level of between 20 and $60 \text{ } \mu\text{Ci/m}^3$, depending on the particular laboratory.

Radiation Alarms: Glove Box

Glove box alarms, to reiterate, enunciate hazard conditions rather than cleanup status. On this basis, the alarm set points will be initially set at:

1 Ci/m^3 for the low level,
(2 $\text{ } \mu\text{Ci/m}^3$ in the room air);

100 Ci/m³ for the high level,
(200 uCi/m³ in the room air).

Thus, with personnel working in the box for several hours a day, no uptake is expected at the low alarm set point. The alarm will indicate the need for an orderly adjustment to procedures to reduce concentrations. At a box concentration of 100 Ci/m³, an uptake in some individuals may occur if they remain in the gloves for some time. Although this condition is still not extremely hazardous, it does represent a potential major malfunction of the primary container or the decontamination system. For a continuous source, operations and Health Physics personnel will be notified of high glove box levels long before these alarm conditions are reached and mandatory glove box cleanup will have occurred. Present plans call for optional or off-hours cleanup at 0.1 ppm and mandatory cleanup at 1 ppm. The low alarm was selected to provide backup capability for glove box cleanup set points. Should a failure occur in the non-redundant cleanup command system, a low box alarm would signal a malfunction. Again, these set points are a function of GPS/experiment parameters and may be adjusted from time to time.

Action to be taken by experimenters operating in glove boxes follows:

Low Alarm: Locate the source of the leak and rectify in the time frame of 15 minutes. If this cannot be achieved, the experiment will be terminated in an orderly fashion. Room air concentrations will be a factor on the action sequence.

High Alarm: All gloved operations will be terminated in a matter of minutes and the glove ports sealed. If not already initiated, this alarm requires mandatory cleanup.

Radiation Alarms: Stack

The stack monitoring system is capable of detecting an instantaneous or continuous release on a real time basis, and distinguishing between HT and HTD on an integrated basis. The real time system consists of a low level monitor, a high level monitor and a totalizer. Alarm settings for these monitors will initially be set as follows:

Low Level Stack,	50 $\mu\text{Ci}/\text{m}^3$;
Intermediate Level 1 (visual only),	500 $\mu\text{Ci}/\text{m}^3$;
Intermediate Level 2 (visual only),	5 mCi/m^3 ;
High Level Stack,	50 mCi/m^3 .

Low Stack Alarm

Potentially, the most hazardous room within the TRL is Room 115A. It has an air flow of 142 $\text{m}^3/\text{min.}$, which is approximately 10% of the total stack effluent. With a "steady state" concentration of 500 $\mu\text{Ci}/\text{m}^3$ in Room 115A, the expected stack effluent concentration will be approximately 50 $\mu\text{Ci}/\text{m}^3$. A steady state level of 500 $\mu\text{Ci}/\text{m}^3$ in any laboratory will result in stack effluent concentrations of between 20 $\mu\text{Ci}/\text{m}^3$ and 60 $\mu\text{Ci}/\text{m}^3$, depending on the particular laboratory. A low level stack alarm set at 50 $\mu\text{Ci}/\text{m}^3$ provides backup room air monitoring for a single lab and will detect smaller concentrations in several labs. Since this alarm enunciates only in the control room during operational hours, a somewhat more frequent alarm rate can be tolerated during startup phases and will provide needed data.

Intermediate alarms indicate increasing levels of hazard and provide optimum levels of warning to operations personnel. These alarms give visual indication only--the audible alarm being silenced to provide distinction between low and high stack alarms.

High Stack Alarm

A high stack alarm indicates a serious condition in the TRL. Other tritium facilities which operate in the high volume hood mode may have large releases from the hoods to the stack and still maintain low room air concentrations.

In the TRL, the stack level usually reflects the room air concentration. (Other sources of high stack concentrations include VERS, GPS, and glove boxes operating in the "stack" mode. Operation in these modes will be known before the release occurs and although the high stack alarm may be triggered, the condition is not necessarily hazardous.)

50 mCi/m³ in the stack indicates a level in the room of approximately 500 mCi/m³, depending on which room or rooms are the source. Assuming the worst case, all HT0, 0.5 Ci/m³ would result in a 1 rem exposure in about 1 minute.

Totalizer Alarm

Three possible schools of thought can be applied to the totalizer alarm settings. First, the alarm points can be extensions of existing alarm points on the low and high level stack monitors. Second, the totalizer can be used to back up existing alarm points directly. Third, the totalizer can be used to "announce" a "given event" within a pre-selected time. In reality, these all turn out to be extensions of the real time stack monitors.

A concentration in the stack at the low alarm position will result in a 0.8 Ci release in 15 minutes integration time. A high alarm level results in 800 Ci. The maximum alarm setting on the totalizer is 900 Ci. Since the stack alarms will provide adequate warning, and in order to limit the number of alarms, the audible totalizer alarms will be silenced during

startup phases at the TRL. If justified, these alarms can be used at a later date, perhaps in conjunction with a rate of rise alarm.

Evacuation Alarm

Selection of a meaningful evacuation alarm must be concerned with the safety of individuals within the TRL, employees working in contiguous facilities as well as compliance with DOE Manual Chapters 0502 and 0524. Addressing the subject of DOE compliance first, immediate notification is required when a release occurs, which if averaged over a period of 24 hours, exceeds 5000 times the off-site CG of $0.2 \mu\text{Ci}/\text{m}^3$ (HTO).

$$(5000)(2 \times 10^{-7} \frac{\text{Ci}}{\text{m}^3}) = 1 \frac{\text{mCi}}{\text{m}^3}$$

or at a stack flow of 10^6 m^3 per day

$$(1 \times 10^{-3} \frac{\text{Ci}}{\text{m}^3})(10^6 \text{ m}^3) = 1000 \text{ Ci at the stack.}$$

Diffusion estimates indicate maximum ground level concentration during stable meteorological conditions at about the site boundary (200 m) with a dilution factor of about 50.

$$(50)(5000)(2 \times 10^{-7} \frac{\text{Ci}}{\text{m}^3})(10^6 \text{ m}^3) = 50,000 \text{ Ci}$$

Thus, a 5 gram release would require immediate notification to DOE. The concentration associated with this level is also the stack high alarm point:

$$(50)(5000)(2 \times 10^{-7} \frac{\text{Ci}}{\text{m}^3}) = 50 \frac{\text{mCi}}{\text{m}^3}$$

However, the high level stack alarm can be triggered by an instantaneous release of on the order of 10 curies in a lab. This condition may be

encountered when the GPS or VERS are run in the "stack" mode--not a basis for evacuation.

If the stack high alarm reflects room air concentration, this level will in a very short time result in an exposure requiring immediate notification to DOE or an injurious exposure level in 30 minutes (again assuming 40). Thus a reasonable evacuation alarm approach is to set a 50 mCi/m^3 level on either stack monitor and a room air concentration level of 500 mCi/m^3 .

Summary of Radiation Alarm Settings

In the above discussion, a relationship between the various alarm set points has been developed. Although conservative from the standpoint of any other tritium facility in the DOE complex, the adoption of these alarm levels will provide:

- 1) Optimum backup capability throughout the entire monitoring system.
- 2) Maximum response time to distinguish between routine, semi-routine, and non-routine occurrence.
- 3) Maximum radiation protection safeguards for all personnel inside and outside the TRL.

Pollution Control

General

Tritium represents the primary pollution concern. The main emphasis in radiotoxic pollution control in the TRL is in prevention of a release. This is accomplished by severe construction requirements as required by Sandia Laboratories Operating Instruction OI 6476-L-8330-1 and the quality assurance program (Appendix E), operation in sealed glove boxes with decontamination systems, double and triple containment, and comprehensive

administrative controls such as personnel indoctrination, safe operating procedures, safe work permits, and pressure system certification.

Operations in the TRL will involve tritium in the gaseous, liquid, and solid-compound form. Estimates of the quantities of tritium wastes produced as a result of current research programs are provided in Section 5 of this report. As previously stated, the primary emphasis is on containment. Small releases from operations in high velocity air hoods and these due to normal operations as well as larger unplanned releases are controlled as follows.

Gaseous Pollutant Controls: The TRL building ventilation and pressure zoning controls were designed to dilute and exhaust gaseous pollutants quickly from the laboratories and minimize exposure to operational and experimenting personnel. Inadvertant gaseous tritium releases to the glove boxes will be contained and then collected by the GPS. Contaminated vacuum effluents and any other gaseous tritium wastes generated during operations at the TRL shall be processed through the decontamination systems or returned to another facility, such as Mound Laboratory, for recovery.

Liquid Pollutant Controls: All floor drains and laboratory sinks (sanitary drains excluded) terminate in one of the 9.5 m³ hold tanks. The effluent in the hold tank is monitored for tritium content before release to the sanitary sewer. Tritiated oil and mercury wastes associated with vacuum pumps in the facility are collected in specially designed collection apparatus and shipped to waste disposal as described in the Waste Management Site Plan (Appendix F).

Solid Pollutant Controls: Solid tritium compound wastes are collected in sealed containers, sealed in metal drums, and shipped to waste disposal. More severe controls and contamination monitoring practices are carried out in areas where solid compounds are used.

Effluent Monitoring: Contamination in effluent streams is kept as low as reasonably achievable commensurate with the latest accepted technology. Sandia Management is firmly committed to reducing total quantities of effluents released to the environment. All effluent streams are monitored and recorded to assure accurate measurements of all releases under normal and unusual conditions. The monitoring systems have been described previously.

Other Controls

Quality Assurance: Responsibility and authority for development, implementation and management of the QA program is clearly defined in Sandia Laboratories directives, policies, procedures and instructions. The QA program for the TRL is described in Appendix E.

Certified Hardware: Certified valves, fittings, tubing, etc. are maintained by Stores at SLL designated for use in the TPL. Noncertified materials and construction practices are allowed only under the provisions of OI 6476-L-8330-1 or with approval of the Safety Review Committee.

Facility Safety Review: A review of basic philosophies and construction practices has been and is being carried out by an independent SLL Committee to ensure safe operation of the facility (A separate "Safety Review Committee" reviews all experiments to be conducted in the facility.) This group is made up of materials, stress, electronics, experimenter, and health physics specialists. Several potential problem areas have been corrected as a result of this review.

DOE Contractor Reviews: Representatives from LLL, SRP, LASL, and ML have met twice at SLL to review the facility -- first during design phase and again during preoperational phase. The exchanges were very useful in furthering the safe operation of the facility.

Provision for Future Expansion

The corner and corridor column footings at the east and west ends of the Laboratory building and corner column footing at the east end of the equipment room have been sized to accept future columns of the same size and load capacity as the columns provided in this building. The walls and footings at the east and west end of the buildings have been designed to accept future contributory loads equivalent to that provided. Provision has also been made for saw cutting and removal of a 1.8 m x 2.1 m high opening at the center of each wall panel. The structural framing at the east wall of the equipment room has been designed for future removal of wall panels and doors.

Section 5

DESCRIPTION OF OPERATIONS

Introduction

The Tritium Research Laboratory was designed as a research facility to be used for a diverse range of experimentation using gram quantities of tritium in various forms. No operations involving fissile materials are anticipated at this time and the use of these materials are limited to calorimetric heat standards. Since the use of gram amounts of tritium poses a potential radiological problem, operations within the facility are governed by a Safe Operating Procedure (SOP#709) and various supplemental SOP's. Each major experiment is covered by an SOP and all other systems in the facility are covered by operating procedures which do not require SLL management approval.

Since programmatic requirements change, there is a continuous need to modify or move existing equipment or to obtain additional equipment. The present description of the various operations in the facility reflect present thinking and may be modified or deleted as required by programmatic change.

Quantities of tritium to be processed and stored.

Amounts of tritium varying from curies to grams will be received, stored, and processed in the facility. The tritium standard gases used in the mass spectrometer vary from curies to tens and hundreds of curies with a total inventory of somewhat less than 1 gram. The amount used in testing the VERS and GPS typically varied from 1 to 750 Ci. Uranium storage beds are received from other facilities loaded with a tritium inventory of one to three grams in solid form. Typical receipts of gaseous tritium will be 12 grams.

The total tritium inventory in the facility when fully operational is anticipated to be approximately 100 grams. Programmatic changes may require this amount to be increased to 300 grams or more.

Material Flow

With the exception of small sealed sources, movement of all radioactive material in and out of the TRL is controlled by the SLL SSMR. The TRL is designated as a material balance area and the operations staff is responsible for inventory control and record keeping. The accountability procedures are included as Appendix C.

Operations at the TRL

Operations in the TRL vary according to programmatic requirements, but in general are oriented toward the major goal areas of:

- specifically compounded and fabricated tritium compounds for use as engineering components;
- research with tritium and its compounds to study their physical and chemical behavior.

These goals are discussed in brief detail in this section.

Control Room (Room 116)

During working hours the TRL control room provides operations with a complete, overall view of the condition of the facility. A PDP 11/40 control computer gathers and stores data from various monitoring functions, provides automatic control of the GPS and actuates alarms. In addition to the computer, the control console for the GPS and VERS, and the remote readout modules of all the tritium monitors (stack, room and glove box) are located in the control room. Finally, the Tritium Handling System

control console is housed in the control room. The control room is manned at all times during normal operation. Audio/visual alarms immediately notify operational staff of changes or hazardous conditions in the facility.

Analysis and Assay Laboratory (Room 122)

Calorimetry and mass spectrometry measurements are made in this lab. Sealed samples will be assayed with a Sandia Laboratory fabricated calorimeter, which is housed in a glove box. The mass spectrometer, a high vacuum system with a low pressure sampling manifold, is enclosed in a high velocity air hood. Samples received from experimenters, or the Tritium Handling System, will be analyzed only after the sample containers are thoroughly monitored for tritium off-gassing. The total tritium in the system standards amounts to about 0.6 grams with the largest amount in a container being about 1.3 grams.

Tritide Laboratory (Room 122)

Metal tritide studies in special inert gas glove boxes are expected to be made during FY 1979. Modified connections to the GPS and VERS and a unique waste handling capability will be provided for this work.

Permeation Laboratory (Room 125)

Room 125 is used for tritium permeation research experimentation. This program includes studies of the effects of diffusion trapping and clustering (bubble formation) of helium and tritium in metals and alloys. These activities require two sealed glove boxes--one for storage and transfer, and another for containment of the experimental apparatus. Approximately one gram of tritium is stored on a uranium bed and small amounts of the tritium are then transferred to the experimental apparatus by means of interconnecting, doubly contained pipe. This system was in operation at LLL for three years prior to being reestablished in the TRL in 1977. This system was also reviewed by the SLL Safety Review Committee and approved for operation at pressures below 100 psig.

Tritide Characterization (Room 119)

This program will synthesize tritium compounds and study the long term storage effects on these substances. The tritiding apparatus shall be housed in a glove box and only high reliability storage containers will be employed. Mass spectrometry analysis of the samples will be made on a regular basis. Several grams of tritium will be kept on hand for this program. Raman scattering studies will also be conducted.

Microscopy Laboratory (Room 121)

Room 121 has been designated as a microscopy lab in which Transmission Electron Microscopy and Autoradiographic techniques are performed.

Materials Characterization (Room 115)

Various analytical techniques, such as scanning electron micrography, x-ray diffractometry, metallography and Auger analysis will be carried out in this lab. Either high velocity air hoods or glove boxes will be used to house the equipment. High pressure tensile testing of tritium charged metal specimens and other hydrogen embrittlement studies are planned for this lab. Only test specimens containing milligrams or less of tritium will be handled in this lab although storage of larger quantities of tritium gas is expected.

Decontamination Systems (Room 115A)

The glove box decontamination systems (GPS and VERS) are described in detail in Section 4. These decontamination systems are positioned in the center of room 115A and surrounded by ceiling-to-floor plastic curtains which control the air flow near the equipment much like a high velocity air hood. Since tritium gas is converted to HTO by these systems, maintenance work or

system leaks represent a potential hazard to operations personnel. Tritium air monitoring is provided both inside and outside the curtain partition.

Tritium Handling System (Room 120)

Tritium handling in the TRL will consist of removing tritium from the container in which it is received (LP-12 or LP-50), filtering it to remove contaminants, mixing it with other hydrogen isotopes if desired, and then transferring it or its prescription into containers for use in experiments in the laboratory.

The processing operation will be carried out in the transfer, loading and unloading stations described below. The system will be housed in sealed 4' x 8' x 8' glove boxes of the type previously described. Interconnections between glove boxes used for the handling system will be in doubly contained copper tubing. It should also be noted that all storage systems, interconnecting piping and valves are to be protected by relief devices. In the event of inadvertent system over-pressure the contents of the system will be transferred to evacuated hold tanks from which they can be returned to the handling system or to one of the two laboratory decontamination systems for recovery.

Prior to pressurization with tritium all piping and container sections will be proof tested at twice working pressure with inert gas and leak tested at working pressure to assure the leakage is less than 1×10^{-9} atm-cm³/sec.

After proof and leak tests the system will be evacuated and back flushed to remove all the test media.

Transfer Station: The transfer station is the receiving, storage, and accountability point for incoming tritium and consists of the equipment necessary to install and connect a tritium container to the system, as well as the valves, regulators, surge tanks, and controls necessary to evacuate the container. The contents of the tritium container will be transferred to a uranium hydride storage container which will be maintained at ambient temperature (vapor pressure is on the order of 10^{-5} torr). From the storage container the gas can be transferred to the loading station.

Loading Station: The loading station serves as the point of delivery for a specified prescription of tritium to the experimenter. Two stations will be used: a low pressure (L.P.) transfer station for supplying material at pressures up to 3.45 MPa (500 psi) and a high pressure (H.P.) station for supplying material at pressures above 3.45 MPa (500 psi).

The low pressure station will consist of a uranium diffuser to strip inert contaminants from the tritium, a double contained Metal Rellow MR601 transfer pump, a PPI diaphragm compressor (specification L-23023) to boost pressure to 3.45 MPa (500 psi), mix and hold tanks for addition of other gases and the piping and valves to transfer the material to the experimenter's container. Interconnecting valves and piping will be provided to permit mass spectrometric analysis and PVT measurements of the prescription for mass determination.

The low pressure station is used to supply the high pressure station which consists of a two-stage PPI gold sealed diaphragm compressor (specification L-23022) with related hardware and piping. Interconnections and instru-

mentation will be provided to permit analysis and mass measurement of the prescription as delivered.

Unloading Station: The unloading station will be the accountability and disposition point for tritium that has been used in an experiment. Disposition of the experiment prescription will be accomplished by the reverse of the loading procedure. Material accountability will be accomplished by calorimetry or a combination of PVT and mass spectrometric analysis. After the accountability has been accomplished, the container will be evacuated into a uranium hydride storage container. The material can then be either reused or discharged into a suitable container for disposition.

Safe Operating Procedures for Experiments

Those practices and safety regulations necessary to prevent injury to personnel, property and the environment are incorporated into documents called Safe Operating Procedures (SOP's). Individual laboratories, experiments or facilities at SLL may be expected to generate SOP's. Generally, SOP's will include Emergency Procedures or Plans, responsible personnel, facility controls, procedures, and safety related requirements. Safe Operating Procedure No. 709 for the TRL is included as Appendix D.

In addition to SOP's, experiment reviews by the SLL Safety Review Committee are held routinely to establish safe practices and guidelines, and investigate potentially hazardous conditions (high pressure chemical toxicity, radiation, explosion, etc.).

Bioassay Program

Weekly or biweekly urine samples are submitted by all TRL operations personnel and experimenters for liquid scintillation counting, although more frequent bioassays are made during hazardous operations. Computer listings

of urine tritium concentrations are kept and assessment of individual biological excretion will be made in the future. Dose equivalent values calculated from internal tritium deposition will be added to radiation exposure histories.

Projected Wastes From TRL Operations

Solid and high level liquid radioactive wastes produced as a result of operations at the TRL will be assayed and appropriately packaged for transfer to LLL's Laboratory Waste Processing Facility at Building 612. Low level liquid wastes are held until they are assayed and released to the sanitary sewage system. Routine releases of small amounts of tritium gas to the 30 meter stack will be made. Estimates of the tritium wastes based on the activities of current programs are:

solid waste for burial, < 400 Ci/yr;
liquid waste for burial, < 100 Ci/yr;
liquid waste to sewer, < 0.1 Ci/yr;
liquid waste for recovery, < 6×10^5 Ci/yr;
gaseous waste for recovery, < 1×10^5 Ci/yr.

Section 6

ACCIDENT ANALYSIS

Introduction

This section presents an analysis of those potential accidents that could affect the Tritium Research Laboratory and SLL personnel, and which may directly or indirectly cause an off-site radiological hazard. Some of the accident situations are presented to illustrate their low probability of occurrence. A risk assessment and scenario was not made for every potential accident; instead the maximum credible radiological consequences, resulting from one of the accidents described below, were analyzed. The accidents are divided into two parts: those considered acts of nature-- such as earthquakes, tornadoes, floods, severe winds and lightning--and those usually caused by human error (fires, explosions and radioactive material releases).

Part II of the URS/John A. Blume and Associates' report, Geological Investigations of the Sandia Laboratories Livermore Site and Structural Investigations of the Tritium Research Facility, is substituted for the earthquake analysis. Considerable structural detail, in addition to the earthquake forces acting on those structures, is included in the Blume report.

Remedial concepts for strengthening the TRL and systems vital for safe operation, and reducing the risk of damage from an earthquake, are recommended in this section. Further strengthening or modifications to the vital systems and the facility, are not required for the other types of accidents.

6.1 STRUCTURAL INVESTIGATIONS OF THE TRITIUM RESEARCH LABORATORY (PART II OF BLUME REPORT)

This section summarizes the results of the structural investigation of the Tritium Research Laboratory, Building 968, at the Sandia Laboratories' Livermore site, including the steel stack and those components and systems within the facility that are important to its safe operation.

The components and systems included in this investigation are:

1. piping and supports for the gas purification system supply and return (GPSS and GPSR) systems, and the vacuum effluent recovery system (VERS);
2. roof holding tank supports and connecting piping;
3. glove boxes and connecting piping;
4. exhaust duct system;
5. decontamination equipment supports (skids) and connecting piping.

The general objective of the work reported here was to determine the ability of the existing structures and systems to withstand the seismic forces predicted from the geological investigations contained in Section 3 and Appendix B this report. In addition, Building 968 and the stack were analyzed for compliance with the lateral force provisions of the 1976 Uniform Building

Code (URC). A remedial concept or scheme for strengthening the structures and systems was developed. The structures and systems were then analyzed in their condition as modified according to the remedial scheme.

Each structure or system was investigated with methods that included mathematical modeling and computer analysis, as well as conventional hand calculations. In each analysis, the strength or capacity was calculated and compared with the expected demand of the postulated ground motion and the URC.

6.2. SEISMIC CONSIDERATIONS AND STRUCTURAL EVALUATION CRITERIA

6.2.1 Seismic Considerations

The Tritium Research Laboratory was evaluated for compliance with the 1976 UBC. Concurrently, geologic and seismicity investigations were performed to determine the seismic exposure of the site. From these investigations, probability curves were developed that indicate the probability of exceeding any level of ground motion up to the maximum credible level for a given period of time. Parametric structural evaluations were then performed by dynamic analysis of a mathematical structural model of the facility. These analyses were performed for a level of ground motion with a reasonable probability of being exceeded. The maximum ground acceleration of 0.275g selected for these analyses represents a 84% probability of not being exceeded in 30 years or 75% in 50 years. The spectral shape selected for the analyses was that developed by URS/Blume from a study of 33 earthquake records. The structures were analyzed for the mean or median spectrum. A comparison of structural responses of the existing structures to the 1976 UBC and the spectra for the postulated ground motion is given in a following section.

Chapter 0531 of the DOE manual covering the safety of nonreactor nuclear facilities (which would include a tritium facility) refers to application of DOE Appendix 6301 for structural design. Appendix 6301 is part of the DOE Facilities General Design Criteria. Part 1, C covers the Basic Structural Design. It states that earthquake loading criteria shall be in accordance

with the URC. Appendix 6301 also states that "facilities, such as those for radioactive material processing and storage, may require application of a dynamic analysis in determining structural requirements for earthquake loading." This requirement which is similar to that in UBC Section 2312(i), means that, for "irregular or unusual" structures, the force distribution to the resisting element should be established by dynamic analysis performed for the base shear required by the code. The 1976 URC earthquake requirements constitute the appropriate seismic criteria for this facility and compliance with the 1976 UBC would satisfy the requirements of DOE Appendix 6301. However, the loads applied via dynamic analysis for site-specific criteria are greater than those derived from the URC. The site-specific criteria used with the dynamic analysis are considered to be a more realistic appraisal of the seismic exposure and structural response. This results in a more conservative approach than would be provided by URC.

6.2.2 Structural Evaluation Criteria

Each structural system was evaluated in its existing condition and in its modified conditions according to the remedial concepts developed in Section 6.5.4 to determine its capacity with respect to the dynamic analysis and to the 1976 UBC seismic forces. Two evaluation criteria were used. For the UBC analysis, the generally accepted allowable stress values were used in determining structural element capacities. The allowable stress values for the different materials come from the various material codes (see 3 below). For the median spectrum analysis, "ultimate" stress values were used in evaluating structural element capacities and were derived from the various material codes and information from the literature (see 3 below).

Other aspects of the structural evaluation criteria are summarized as follows:

1. Combined Forces: The vertical load forces in general do not stress the lateral-load-resisting-system elements significantly. Therefore, it was not necessary to combine horizontal earthquake forces with vertical loads except for the case of shear walls investigated for overturning. In this case, it was sufficiently conservative to assume that 90% of the dead load acts to resist overturning.

In investigating vertical-load-carrying elements, the calculated vertical dynamic forces were combined with actual dead-load forces (and actual live-load forces where applicable) wherever that would lead to significantly different results.

2. Combined Earthquake Components: The horizontal ground motion was considered applicable in any horizontal direction. The worst-condition direction was chosen for each structural system.

In the building system, because the lateral-load-resisting system is distinct from the vertical-load-resisting system, it was generally not necessary to combine the horizontal and vertical earthquake components. In the other structural systems, the same general approach was taken. Combining the two components would result in significantly different conclusions. The combination method used was the square-root-of-the-sum-of-the-squares (SRSS) procedure.

3. Allowable Stress and Ultimate Stress Criteria: The allowable stress values for the structural steel components of the structures were determined by the specifications of the 1971 American Institute of Steel Construction code. The same values for concrete components were determined by section 8.10 of the American Concrete Institute Code 318-71. The values for gypsum concrete components were determined using the UBC Standard No. 24-12, Part II. Various other papers and manufacturers' reports in the literature were also consulted in evaluating the gypsum concrete. The "ultimate" stresses used here are not the failure stresses, but are values of allowable stresses increased by an appropriate factor. For steel members the ultimate capacity would correspond to the load at yield stress. Ultimate capacities for other materials would have the same approximate relation to their failure load as the ratio of yield to failure stresses for steel.

6.3. BUILDING AND SITE SURVEYS

In the course of the investigations, several surveys of the Tritium Research Facility were conducted to familiarize the personnel working on the study with the facility, to identify the vital structural systems, to verify structural configurations and details as given on construction drawings, and to obtain information, such as weights and dimensions, not shown on the drawings. Dead load and live load assumptions were verified where possible. In particular, field investigations to determine as-built conditions were necessary in the study of the laboratory building precast wall construction. Also, surveys of the skid support structure were required because the as-built conditions do not necessarily conform to the construction drawings. A survey of nonvital systems was also made to determine where a failure of these systems could damage those systems that are important. Additional surveys were required to determine the feasibility of structural modifications to the systems. The results of these surveys are presented in the sections covering the various structural systems.

6.4. ANALYSIS PROCEDURES

In the first phase of the studies, the buildings and the steel stack were analyzed for their adequacy with respect to the lateral forces prescribed in the 1976 UBC. These structures had been originally designed under the 1970 UBC, which had lower requirements for earthquake forces. This procedure is essentially a static load analysis.

In the next phase, dynamic analyses were done for these structures. The results of these analyses were then used to determine whether strengthening was required. Subsequently, remedial concepts were developed, and the structures were analyzed again.

In the case of the vital systems, especially the piping, no bracing or other lateral-force restraints had been designed for the original construction. For these systems, remedial concepts were developed and then preliminary analyses were made for the modified conditions.

Piping connected to the various systems takes on numerous configurations and was therefore not analyzed individually. Calculations determined allowable unsupported spans for various sizes and types of pipe. Typical support locations were recommended, and typical support details were shown schematically because they are not required to develop large loads.

6.4.1 UBC Analysis

The UBC analysis consisted of a check of seismic forces as prescribed in

Section 2312 of the 1976 UBC. Seismic requirements for buildings are based on the formula

$$V = ZIKCSW \quad (6.1)$$

where V is the total lateral force at the base of the structure that the structure must be capable of resisting (base shear);

Z is the zone factor of seismic risk, which is specified as 1.0 for Livermore;

I is the occupancy importance factor, varying from 1.0 to 1.5 depending on the type of occupancy;

K is the horizontal force factor, specified as 1.33 for buildings with a box system, which the laboratory building has;

C is the coefficient that is a function of the period and therefore the stiffness of the building (stiffer buildings have higher values of C);

S is the coefficient for site-structure resonance. S varies between 1.0 and 1.5 depending on the relationship between the periods of the site and the structure. The product of CS need not be greater than 0.14 and is the value used here. (See further discussion in Section 6.5.3.1); and

W is the dead load of the structure.

For parts of a structure, including equipment -- such as the vital systems included in this report -- a formula similar to the base shear formula is prescribed. The lateral force F_p that the system must be capable of resisting is calculated as follows:

$$F_p = ZIC_p SW_p, \quad (6.2)$$

in which the symbols are the same as for the base shear formula except that the subscript p denotes those values for the part of the structure rather than the whole structure.

The UBC allows the use of stresses one-third greater than allowable values when a structure is subjected to wind or seismic forces.

6.4.2 Dynamic Analysis

Forces under postulated earthquake conditions were estimated using dynamic analysis procedures. Both elastic and inelastic responses were considered in system evaluation, but only computer routines using elastic response were used for analysis. The analyses were conducted for the postulated earthquakes using the response spectrum modal superposition technique. All modes having frequencies less than 33 Hz were included. In systems where hand calculations were appropriate, only the first dominant mode of response was considered.

Properties of each analysis model were selected to approximate closely the mass and stiffness distribution of the actual structural system. All major structural elements that contributed lateral stiffness were considered. Masses were calculated from construction drawings whenever possible. Member stiffness properties of moment of inertia, shear area, and cross-sectional area were determined for the various elements of the structural systems. These properties, along with the appropriate dimensions and elastic moduli, were then used as input stiffness data for the various computer and hand calculations. Values of the modulus of elasticity and shear modulus used in

the analyses are discussed in the individual systems sections as are damping, inelastic response, and ductility considerations.

6.4.3 Computer Programs

Several computer programs (TABS, SAP IV) were used for the analysis. In these analyses and in hand calculations, possible effects of soil-structure interaction were assumed to be negligible. These computer programs are all capable of three-dimensional analysis. However, this capability was not required here because the structures in this study were simple enough to be analyzed as two-dimensional models.

TABS is a computer program developed at the University of California for the linear structural analysis of frame and shear wall buildings subjected to both static loads and earthquake loadings. Each building is modeled by a system of independent frame and shear wall elements interconnected by rigid floor diaphragms. Column bending, axial, and shearing deformations are considered, and beam and girder bending and shearing deformations are also included. Shear panels can be considered with individual frames. Finite column and beam widths can be included.

SAP IV is a finite-element structural analysis program for the static and dynamic response of linear two- or three-dimensional systems. The program is written to analyze structures that are idealized by combinations of structural element types and has been modified and improved by URS/Blume. There is practically no restriction on the number of elements, the number of load cases, and the bandwidth of the equations to be solved. In a dynamic analysis, the options are (1) frequency calculations only, (2) frequency calculations

followed by response history analysis, (3) frequency calculations followed by response spectrum analysis, and (4) response history analysis using step-by-step direct integration.

6.5. LABORATORY BUILDING AND EQUIP .JOM

6.5.1 Description

The laboratory building is a one-story structure with concrete tilt-up wall panels and a poured gypsum concrete roof deck supported on structural steel framing with two lines of steel columns in the interior at the sides of the central corridor, which runs the entire length of the building. Interior height averages 5.5 m to the underside of the roof deck. Exterior columns are concrete, poured in place, and tie the tilt-up panels together. Footings occur only under columns. Wall panels span between and are supported by the column footings. The gypsum roof deck is 7.5 cm thick, reinforced with welded wire fabric and poured on 2.5 cm form boards laid on bulb tees at 60 cm spacing. The roof deck is connected to the walls by 1.6 cm threaded rods screwed into inserts cast into the wall panels. The protruding end of the rod is embedded in the gypsum. The steel roof girders run in the north-south (transverse) direction and at the exterior walls are connected through clip angles to a steel plate anchored to the concrete columns. These lines of girders hold the wall panels together to prevent separation from the roof deck. In the longitudinal direction, the steel beams are similarly anchored but to the wall panels because they do not line up with the concrete columns. The floor is a 15 cm slab on grade and is tied to the walls and columns by reinforcing bars doweled out from the walls and columns.

The equipment room is a much smaller building, 10 by 12 m in plan, but of similar construction. The main difference is in the roof deck, which is a 15 cm concrete slab instead of gypsum. The reason for the heavier roof is

that it supports equipment over most of its area. The main supply and exhaust ducts with their fans, motors, filter banks, sound traps, etc. are supported on concrete curbs on top of the roof. Another difference is in the structural steel columns at each corner, which support the steel roof beams directly. These columns are placed just inside the corner concrete columns. Another pair of steel columns is located at the center of the north and south walls. These two are 10 cm pipe columns and are embedded in the concrete columns. The interior space of the equipment room is clear of columns and has a height of 3.8 m to the slab soffit. The floor of this building is 30 cm lower than the lab building floor. The two buildings are connected by steel beams at the level of the equipment room roof. These beams support a metal deck canopy, which covers the space between the two buildings. This space is designated as the service area. In both buildings the roof deck is the diaphragm and the tilt-up panels are the shear walls for resisting seismic forces.

In the lab building, the construction drawings show that the horizontal wall bars, projecting into the poured column from one side, are wrapped with paper. The bars projecting from the wall on the other side are not wrapped. This was done to prevent concrete bond along one side of each panel to reduce shrinkage and temperature cracking in the wall. The existence and locations of the slip joints were verified by site surveys. Examination of the wall panels indicated that the joints on one side of the columns on the north and south walls have opened up. On the east and west walls, opened joints were also observed, but only on the corridor side of the columns on lines N and E. From this it is reasoned that wrapping on the reinforcing bars occurs only on the small center panel on the east and west walls.

Construction drawings and photographs taken at the time of erection indicate that the horizontal reinforcing in the wall beams, formed into the top of the panels, is not wrapped at the columns. Site surveys, however, have revealed cracks along panel edge lines extending up through the wall beam, indicating that wraps might be present. The drawings show that the laps of these reinforcing bars occur at the columns, are approximately 30 cm long, and are not sufficient to develop the bars in tension, even if unwrapped. Because of this discontinuity of the wall panels, the steel ledger angle at the junction of the roof and wall was designed to act as the diaphragm chord. This angle is spliced by full-penetration welding to obtain the continuity required for chord action.

6.5.2 Analysis of the Buildings

The lab building and the equipment room were designed originally as separate structures. However, as mentioned in Section 6.5.1, the beams connect the roof of the equipment room to the lab building columns at a point 2 m below its roof deck. Any tendency for differential movement between the two buildings in the north-south direction will force the lab building columns to act in bending on a 2 m cantilever. Structural distress is possible if differential movements are large. However, the buildings are analyzed as separate structures, and, where movements are sufficiently large to cause distress, remedial measures, such as modifying the connection to allow slip, were recommended.

6.5.2.1 Lab Building. It is apparent from the shape of the building that the critical direction for earthquake motions is the north-south direction. Earthquake motions in other horizontal directions generate much smaller

stresses. Consequently, the bulk of the study was based on a north-south earthquake. The critical element of this system is the gypsum concrete diaphragm. For the system in its existing condition, the diaphragm experiences stresses exceeding its design capacity at a relatively low level of peak ground acceleration.

6.5.2.2 Equipment Room. Because of its smaller size and its concrete roof diaphragm, the lateral-force-resisting capacity of this building is much higher than that of the lab building. The equipment room, when analyzed as a separate building, is capable of resisting a base shear in the order of 0.7g. No remedial concepts are required except when considering this building as linked with the lab building in the same structural system.

6.5.3 Analysis and Results for Laboratory Building

6.5.3.1 UBC Analysis. A description of the different variables in the 1976 UBC earthquake base shear formula $V = ZIKCSW$ can be found in Section 6.4.1. The building period T is calculated from the code formula $T = 0.5h_n/D = .11$ sec. This yields a value of C larger than the maximum required by the code. Similarly, using geological data collected for Part I of this report, the calculated value of $S = 1.4$. The product of CS , thus calculated, is larger than the maximum value required by the code; therefore, the maximum value of $CS = 0.14$ is used. Other variables of the base shear formula take on the following values: $Z = 1.0$ and $K = 1.33$. The factor I is specified as 1.0 for all buildings except that 1.25 is used for assembly buildings for over 300 persons and 1.5 for essential facilities. Essential facilities are

defined as those "...buildings which must be safe and usable for emergency purposes after an earthquake in order to preserve the health and safety of the general public." The value of $I = 1.0$ is the appropriate value for the TRL.

The calculated value of the base shear becomes

$$V = (1)(1.0)(1.33)(0.14)W = 0.186W.$$

For the calculated value of the dead load $W = 1104$ kips,

$$V = 206 \text{ kips}$$

This value is about 29% higher than the original design base shear of 160 kips; hence, some overstress may be expected. Calculating the forces, or demand, imposed on the various structural elements of the building by the prescribed base shear in the north-south direction and comparing these with the capacity of the elements as constructed produces the results in Table 6.1.

The ratios in the last column of Table 6.1 indicate adequacy or inadequacy of the building as compared with the requirements of the 1976 UBC. Ratios greater than 1 indicate roughly the overstress that occurs for that structural element. Ratios less than 1 show that those elements are stressed at levels below the allowable maximum. As expected, overstress occurs in the diaphragm system. This overstress may not necessarily result in failure because there are factors of safety built into the allowable values. The original design, it should be noted, is adequate for the criteria under which the building was designed, the 1970 UBC.

An area of concern not noted in the table is the canopy connection between the lab building and the equipment room. The difference in displacement of the lab building relative to the equipment room calculated for the 1976 UBC forces is 0.61 cm. This connection would probably experience some overstress, most likely in bending on the lab building column. To avoid this overstress, it would be necessary to modify the beam connection to allow some movement. Other structural elements and stresses not included in the table are generally not as significant as those listed.

6.5.3.2 Dynamic Analysis and Results. For this analysis, the median response spectrum with 5% of critical damping is used. Because the roof deck is relatively thin and composed of gypsum concrete, it is a relatively flexible diaphragm with a fairly large fundamental period. This situation can lead to large amplifications of earthquake motions and forces that are not adequately accounted for in the 1976 UBC. To evaluate these amplifications, it is necessary to determine the dynamic characteristics of the structural system considering the diaphragm deflection. The amplifications are most serious when the earthquake motions are in the north-south direction, where the diaphragm span is 55 m.

The wall beam, as explained in Section 6.5.1, does not contribute to the diaphragm stiffness for motions in the north-south direction. The east and west walls of the lab building are assumed fixed because their stiffnesses are much higher than the diaphragm's stiffness. The gypsum diaphragm acts as a simply supported beam spanning the 55 m between the lab building east and west walls. The mass of the lab building tributary to the roof diaphragm level was assumed to act uniformly along the 55 m length. The building

system in this case is sufficiently simple that hand calculations were adequate to get the dominant, first-mode response. The calculated first-mode period is $T_1 = 0.28$ sec. For the median response spectrum, with 5% of critical damping, a spectral acceleration of 0.60g at the roof results, and the base shear becomes 545 kips. The diaphragm shear is 273 kips, and the diaphragm chord force is 156 kips. Again, for these high forces, some distress would be expected. The results for the important elements are shown in Table 6.2. For this analysis, the demand of the calculated dynamic forces is compared with the "ultimate" capacity of the structural elements. The "ultimate" capacity is comparable to the allowable capacity with a factor of safety applied (see Section 6.2.2).

The ratios in the last column of Table 6.2 indicate the adequacy or inadequacy of the structural elements, based on ultimate strength criteria, as compared with the demand of the median response spectrum. Ratios greater than 1.0 indicate the overstress that occurs for an element and loading condition. Comparing the values in the last column with the corresponding values in Table 6.1, it is seen that the degree of overstress predicted by the median response spectrum is higher than that predicted by the 1976 UBC.

As was noted in the evaluation of the building for the 1976 UBC forces, large displacements of the lab building relative to the equipment room can result in distress in the two lab building columns because of the load delivered by the canopy beam connection between the two buildings. This relative displacement predicted by using the median response spectrum forces is 1.47 cm and is large enough to cause severe distress in the lab building

TABLE 6.1URC ANALYSIS, LABORATORY BUILDING

V = 206 KIPS

Structural Element and Loading Condition	Demand of 1976 URC I = 1.0	Capacity Based on Allowable Stresses	*Demand/Capacity Ratio
Diaphragm shear	1.33 kip/ft	1.26 kip/ft	1.06
Diaphragm chord force	58.9 kips	45.6 kips	1.29
Diaphragm-to-wall connection	1.33 kip/ft	1.48 kip/ft	0.90
Sliding of shear wall	133 kips	168 kips	0.79
Shear wall overturning	2,178 kip-ft	4,090 kip-ft	0.53
Shear on walls	31 psi	69 psi	0.45

*Ratios greater than 1.0 indicate overstress

TABLE 6.2DYNAMIC ANALYSIS, LABORATORY BUILDING

V = 545 KIPS

Structural Element and Loading Condition	Demand of Dynamic Analysis	Capacity "ULTIMATE"	*Demand/Capacity Ratio
Diaphragm shear	3.4 kip/ft	2.5 kip/ft	1.36
Diaphragm chord force	155.7 kips	57 kips	2.73
Diaphragm-to-wall connection	3.4 kip/ft	2.5 kip/ft	1.35
Sliding of shear wall	317 kips	264 kips	1.20
Shear wall overturning	5,770 kip-ft	4,090 kip-ft	1.41
Shear on walls	81 psi	126 psi	0.65

*Ratios greater than 1.0 indicate overstress

column to which the beam between buildings is connected. Modification of the connection is necessary.

Other structural elements not included in Table 6.2 are generally not as important as those that are listed.

6.5.4 Remedial Concept For Laboratory Building

6.5.4.1 General. The results of the analyses of the lab building in the preceding section show that the structure, in its existing condition, is deficient in certain respects when evaluated against the requirements of both the 1976 UBC and a dynamic analysis using the median response spectrum. The gypsum roof deck, acting as a diaphragm to resist seismic forces, is found to have inadequate capacity. In addition, there are problems with sliding and overturning of the shear walls for forces predicted from the dynamic analysis.

A number of remedial concepts that would increase the level of resistance of the building to lateral forces were developed and analyzed. In these remedial measures, the structural system was modified in various ways to determine if there was an increase in the capacity of the structural system to withstand earthquake forces in the north-south direction. The effects of the remedial measures on the building's structural capacity were evaluated using the 1976 UBC and the median response spectrum. In using the UBC, the specified base shear was distributed to the shear walls in the same proportions as obtained from a dynamic analysis of the building. The remedial concept chosen by SLL is described as follows.

6.5.4.2 Description of Remedial Concept

In this scheme, the lab building and the equipment room are linked together and analyzed as a single structural system (see Figure 6-1). This uses the shear walls of the equipment room to help support the lab building. To determine the stiffness of the shear walls, the east and west walls of the lab building and the east and west walls of the equipment room were individually analyzed, using the TABS computer program, to determine their structural stiffness as shear elements. The linkage between the two buildings occurs on the lines of the east and west walls of the equipment room along column lines 4 and 6. In practical terms, a structural steel member connects the end of the lab building roof girders to the equipment room at its roof level. It will be necessary to add splice plates on the top flange of the girders on these two lines to achieve continuity for the members as collectors. A dynamic analysis was then made for a north-south earthquake using the SAP IV computer program. The lab building roof is modeled as a continuous beam on four spring supports, representing two shear walls in the equipment room and two shear walls in the lab building. The geometric and stiffness properties of the elements accurately model the existing structural characteristics, assuming two links are provided. Of particular importance is the modeling of the gypsum roof diaphragm of the lab building so that the deformation of that element is accounted for. Neglecting this characteristic would result in a total base shear that is unrealistically low and shear distribution to the walls that would not be correct. The equipment room roof diaphragm is a 15 cm concrete slab and can be assumed as rigid. The masses used in the SAP IV lumped-mass model are the same as for the existing condition, except that the masses of the east and west walls of the lab building are lumped at the nodes where those spring elements attach to the diaphragm. Also, the mass of the equipment room is

PLAN AT ROOF

Figure 6-1 TRL remedial seismic strengthening scheme.

lumped at the two nodes where the two spring elements representing the equipment room walls attach to the lab building.

6.5.4.3 Results of Analyses and Evaluations. The results of the analyses of the remedial scheme is shown in Table 6-3, which presents the pertinent structural response data when subjected to two different force levels:

1. Median response spectrum
2. 1976 UBC

It is seen in Table 6-3 that the remedial measure has the effect of stiffening the lateral-load-resisting system as indicated by the decreasing periods. This remedial scheme accomplishes this by stiffening existing walls. The result of this stiffening, as indicated in the dynamic analyses, are decreases in the first mode periods and smaller amplification of ground motions. Consistent with these results is the decreased base shear and decreased deflection. The UBC analyses do not reflect the same results because they do not sufficiently account for the dynamic characteristics of the structure. The total base shear is seen to increase because of the increased building weight included in the remedial concept.

Table 6-3 also presents the forces and moments on the most critical elements of the system (last seven columns). Comparable data from the analysis of the building in its existing condition are shown for comparison.

Table 6-4 compares the earthquake demands on critical elements (Table 6-3) with structural capacities of those elements for the remedial scheme. The demand/capacity ratios of these elements are shown. UBC forces are compared to capacities based on allowable stress criteria. Dynamic forces are compared

to capacities based on "ultimate" criteria (see Section 6.2.2). Structural elements not listed in the table are less critical. The ratios for the existing condition case are included for comparison. Demand/capacity ratios greater than 1.0 point out possible problem areas. Adjustments in the stiffness of certain elements and more precise calculations will bring the ratios closer to 1.0.

TABLE 6-3

RESULTS OF ANALYSES OF REMEDIAL CONCEPT

Scheme	Seismic Loading [#]	Period of First Mode in N-S Direction (sec)	Maximum Deflection (in.)	Maximum Base Shear (kips)	Maximum Diaphragm Shear (kips)	Maximum Diaphragm Chord Force (kips)	Shear on Wall Elements Due to N-S Earthquake (kips)				
							Laboratory Building West Wall	Equipment Room West Wall	Equipment Room East Wall	Interior Wall Line B	Laboratory Building East Wall
Existing Laboratory Building	1 2	0.28	0.57 0.24	545 206	273 103	155.7 58.9	273 103	-	-	-	273 103
Building as Modified	1 2	0.346	0.17 0.09	515 272	117 61	49.3 26.0	54 29	190 80	151 100	-	121 63

TABLE 6-4

DEMAND/CAPACITY RATIOS FOR CRITICAL ELEMENTS OF REMEDIAL CONCEPT

Scheme	Seismic Loading [#]	Demand/Capacity Ratio					
		Laboratory Building			Equipment Room		
		Diaphragm Shear	Diaphragm Chord Force	Shear Wall Sliding	Shear Wall Overturning	Shear Wall Sliding	Shear Wall Overturning
Existing Laboratory Building	1 2	1.36 1.06	2.73 1.29	1.20 0.79	1.41 0.53	-	-
Building as Modified	1 2	0.59 0.61	0.87 0.56	0.63 0.55	0.53 0.28	0.99 0.88	1.20 0.63

[#]1 = Median response spectrum (5% of critical damping, peak ground acceleration = 0.275g)

2 = 1976 UBC

6.6. STEEL STACK

6.6.1 Description

The stack is fabricated from 0.63 cm plate, and its diameter varies from 3 m at the base, to 1.4 m at the top. It is connected by 24, 3.65-cm-diameter anchor bolts to a circular reinforced concrete foundation of 6 m diameter. The breach in the stack is a 1.4-m by 2.3-m-high rectangular opening, reinforced by various steel plates. The main exhaust duct is connected at this opening by bolts.

6.6.2 UBC Analysis and Results

A description of the different variables in the 1976 UBC earthquake base shear formula $V = ZIKCSW$ can be found in Section 6.4.1. The exhaust stack stands by itself, not connected to any building except by the relatively flexible sheet metal exhaust duct extending from the equipment room roof. As such, the variables in the force formula take on the following values:

$Z = 1.0$, the same value as for the buildings,

$CS = 0.14$, its maximum value, which will also be used because the values of C and S calculated according to the code will yield larger results,

$K = 2.0$, which actually applies to structures other than buildings. This value is higher than the K for buildings because the stack has less natural damping and generally fewer redundant structural elements than buildings,

$$I = 1.0$$

W = 27 kips, the dead load recalculated using the actual dimensions
Substituting in the code formula the base shear,

$$V = 0.28W = 7.56 \text{ kips}$$

The force distribution over the height of the structure is specified by the code formula:

$$F_x = \frac{(V - F_t) w_x h_x}{\sum w_i h_i} \quad (6.3)$$

In this case, $F_t = \text{zero}$ because the calculated period $T = 0.10 < 0.7 \text{ sec.}$
This force distribution is essentially triangular over the height of the stack, so the resulting moment at the base of the stack (at the top of the concrete foundation) is:

$$M = 7.56 \text{ kips} \times 66.7 \text{ ft.} = 504 \text{ ft.-kips}$$

The stack was originally designed under the 1970 UBC which specified a smaller base shear coefficient. However, a conservative value for the weight and a larger height were used in the original calculations which resulted in values of base shear and overturning moments that are not too much different from the values calculated here for the 1976 UBC. Consequently, a check of the stresses from the new loading shows that the stack is adequate for the 1976 UBC earthquake loads.

Table 6-5 compares the earthquake demand of the 1976 UBC to the structural capacity for the most critical elements or conditions of loading. Allowable capacities are based on allowable stresses with a one-third increase where applicable.

the values in the last column of Table 6-5 indicate that the level of structural stresses and loading conditions is low compared to the maximum allowable values. Because all the values are less than 1, the stack is adequate in all respects for the 1976 UBC load.

Concrete and reinforcing steel stresses in the foundation are not listed, but calculations show that stresses are generally less than one-third of the allowable.

6.3 Dynamic Analysis and Results

The dynamic analysis was performed using the TARS computer program. A model with masses lumped at ten points along the height of the structure was used. The program was run, using the median spectrum (see Section 6.2) for 2% of critical damping, to generate the lateral forces. In the program, the participation of the first five modes was included, and the results (moments, shears, etc.) are the combined effect of all the modes. The SRSS method is used in the combination.

Seismic forces from the dynamic analysis are:

Base shear $V = 9.61$ kips.

Moment at bottom of stack $M = 619$ kip-ft.
(top of foundation)

It should be noted that the above values are larger than the corresponding values from the UBC analysis (Section 6.6.2). Table 6.6 lists values of demand for the dynamic analysis using the median spectrum compared with the "ultimate" value of the structural elements or load conditions.

Because the base shear and overturning from the dynamic analysis using the median spectrum are higher than the corresponding values for the URC, the demands on the former case are also higher. However, the capacities in the above table are calculated on the basis of ultimate strength. Consequently, the demand/capacity ratios for the dynamic analysis and the UBC analysis are in the same order of magnitude.

6.6.4 Remedial Concepts

The results from the analysis in Sections 6.6.2 and 6.6.3 indicate that there would be no remedial work required on the stack and its foundation.

An area that may require remedial work is the connection of the exhaust duct to the stack. If the deflection of the stack at this point is larger than the maximum deflection that the connection can undergo without distress, it would be necessary to modify the connection. See Section 6.7.4 for recommendations concerning this connection.

TABLE 6-5
EXHAUST STACK UBC ANALYSIS

Structural Element and Loading Condition	1976 UBC Demand	Allowable Capacity	*Demand/ Capacity Ratio
Anchor bolt tension	7.7 kips	25.7 kips	0.30
Shell stress, combined compression and flexure	2.1 ksi	12.2 ksi	0.18
Weld on anchor bolt bracket	4.5 ksi	29 ksi	0.16
Moment corresponding to maximum soil pressure	549 kips	2,068 kips	0.27
Sliding of foundation	57 kips	118 kips	0.48
Overturning	549 kip-ft.	2,655 kip-ft.	0.21

*Ratios greater than 1.0 indicate overstress

TABLE 6-6
EXHAUST STACK DYNAMIC ANALYSIS

Structural Element and Loading Condition	Demand of Median Spectrum	Ultimate Capacity	*Demand/ Capacity Ratio
Anchor bolt tension	9.4 kips	32 kips	0.29
Shell stress, combined compression and flexure	2.7 ksi	16.2 ksi	0.17
Weld on anchor bolt bracket	5.5 ksi	36 ksi	0.15
Moment corresponding to maximum soil pressure	676 kips	3,102 kips	0.22
Sliding of foundation	83 kips	208 kips	0.40
Overturning	676 kip-ft.	2,655 kip-ft.	0.25

*Ratios greater than 1.0 indicate overstress

6.7. VITAL SYSTEMS

The important systems included in this report are listed in Section 6.1. Evaluation was made for each system against both the 1976 UBC and the median spectrum with 2% of critical damping. UBC forces for the systems were determined by the formula described in Section 6.4.1:

$$F_p = ZIC_pSW_p. \quad (6.2)$$

Values of $Z = 1.0$ and $I = 1.0$ were used, the same values as in the base shear formula for the building.

$C_p = 0.5$ is the appropriate value for systems necessary for continued operation of essential facilities.

$S = 1.0$ is believed to be sufficient in this situation because the calculated F_p becomes

$$F_p = 1.0 \times 1.0 \times 0.5 \times 1.0W_p = 0.5W_p,$$

which means that seismic forces will be 0.5g. In some instances, this is larger than the calculated dynamic forces for the system in the existing condition.

For dynamic analysis, the same median spectrum as used for the buildings was used, except that 2% of critical damping instead of 5% was used. The procedure

used in the analyses of the systems depended on the structural characteristics of the system or part of the system. These can generally be divided into two groups. The first group includes those items which are inherently stable and are capable, in their existing condition, of resisting fairly high lateral forces with minor modifications. These items include the glove boxes and the exhaust ducts on the roof. The second group includes those items which do not have very substantial lateral bracing. These items are the support systems for all of the piping included in this report, the roof holding tank supports, and the decontamination skids. For the pipe and duct supports and the holding tank supports, lateral bracing apparently was not provided in the original design. The skids are not currently in accordance with the construction drawings, which show some lateral bracing. For the items in the second group, it is not practical to make an analysis in the existing condition. A remedial scheme of lateral bracing was developed, and the system was then analyzed to determine the adequacy of the bracing scheme. Further modifications were generally not considered necessary because the relatively small masses of the systems did not generate high lateral forces.

6.7.1 GPSS, GPSR, and VERS Piping

These piping systems considered together can readily be divided into two separate areas of study. The first is the corridor pipe rack system, including the supporting elements of the pipe rack. In this study, it is necessary to consider all elements supported by the same pipe rack (supply ducts, water pipes, etc.) because they influence the behavior of the rack. The second area of study is the GPSS, GPSR, and VERS piping and supports within the laboratory rooms.

6.7.1.1 Corridor Pipe Rack System. Thorough examination of construction drawings and on-site investigations have shown that, for lateral earthquake motions in any direction, the corridor pipe rack system is essentially unrestrained. A transverse section through the corridor showing the pertinent structural details is shown in Figure 6-2. This figure also shows a recommended bracing scheme. A section taken at one of the intermediate pipe rack supports would be essentially the same except that the connection of the 1.6 cm hanger rods to the roof system is made through a channel clamp rather than a beam clamp. Because the system is laterally unrestrained, it will experience large displacements from lateral forces with associated pounding between the various building elements. Therefore, the effort on this piping and support system focused on developing a bracing scheme that would restrain the pipe rack system and prevent large displacements or distress for the required lateral forces. Thus, the vital piping will not be damaged by a failure of the pipe rack. Also, the vital piping itself was investigated for stresses and displacements, with the recommended bracing on the supporting system. In the dynamic analysis of the system with the assumed bracing, the following were considered:

- Possible amplification of the peak ground accelerations due to the building framing system, which supports the corridor pipe rack system,
- Possible amplification of the peak ground accelerations due to the new bracing system itself and to the pipes,
- Possible overstress in structural elements restraining the pipe rack system (either laterally or vertically).

The recommendation for this area of piping is the bracing scheme shown in Figure 6-2. In addition to the details shown, the following general recommendations should be followed:

At the column lines, all pipes on the unistrut rack, including those that are not designated as part of the vital systems, should be attached to the rack to preclude sliding along the rack and impacting against each other.

The type and size of the existing clamps attaching the 1.6 cm hanger rods to the channel at the roof should be determined by field inspection and checked for the calculated dead plus seismic load of 1.26 kips. If the manufacturers' maximum allowable load for the clamp is inadequate the clamp should be replaced by one that is capable of carrying this load.

The analysis of the developed bracing system indicates that it is capable of resisting forces larger than the demand of either the URC or the median spectrum.

6.7.1.2 Piping and Supports in Laboratory Rooms. As in the case of the corridor pipe rack system, the piping in the laboratory rooms is also essentially laterally unrestrained, with the exception of its connection to the glove boxes and to the piping in the corridor. The GPSS and GPSR piping, upon entering the rooms from the corridor, reduces from 15 cm stainless steel to 10 cm copper. Because there are so many different pipe configurations within the rooms, it was not practicable to define every support detail. Rather, general guidelines are recommended for typical cases. These recommendations take into account the dynamic characteristics of the pipe.

None of the straight runs of pipe within the rooms is very long. But where they occur, the maximum laterally unsupported length for the GPSS and GPSR lines should be limited to 4.6 m. For the VERS lines, this maximum should be

3 m. In addition, where changes in direction occur, bracing should be installed to restrain lateral motion. By the simple expedient of modifying selected existing supports to provide lateral restraint, the system can be brought up to the capacity required by the UBC and the median spectrum. Such a detail is shown in Figure 6-2.

By using the suggested relatively short unsupported lengths, dynamic amplifications due to the pipes themselves will be small. Hence, lateral demand will essentially be limited to the peak acceleration of the roof plus whatever amplification is introduced by the lateral bracing chosen. Amplifications will be small if bracing schemes such as shown in Figure 6-3 are carried out along with other recommendations given here as to their maximum spacing.

6.7.2 Roof Holding Tank Supports

The tank-support system consists of a framework of structural steel members raised about 30 cm off the roof deck. There are three tanks: two 1.85 m diameter tanks, each weighing 800 kg, and a third smaller tank, weighing 270 kg. The contents are gaseous and have negligible weights.

The tanks are supported by steel plate saddles at each end. These plates are attached to steel channels, which are, in turn, supported by wide-flange sections spanning between jack posts. The jack posts are welded to the roof framing system of the lab building. The roof tank support system with the proposed modifications is shown in Figure 6-4.

By inspection, the amplification of the roof-level accelerations (referred to as base accelerations) due to the various elements of the roof tank system is significant for dynamic loads. Earthquake motions in either of the two horizontal directions would contribute significant forces because of amplifications.

A dynamic analysis of this structural system was carried out using hand calculations. This analysis indicates that large amplifications of motion could be expected, particularly for motions in the north-south direction. The resulting forces would cause stresses in the saddle channels and connections that would exceed yield stress at a relatively low level (less than 0.1g) of base acceleration.

A relatively simple scheme of bracing (see Figure 6-4) will eliminate a major part of the amplification and increase the allowable base acceleration from 0.07g to about 0.75g. Even higher capacities are possible by strengthening various connections. This can be easily accomplished by adding connection angles, adding welding, etc. Again, the values of base acceleration refer to the acceleration of the building at the roof level. If capacities are desired in terms of peak ground acceleration, the amplifications due to the lab building system must be accounted for.

6.7.3 Glove Boxes

These structures are rectangular boxes fabricated from sheet metal with various openings on all sides. They are all supported directly on the floor of the lab building. From the vendor's drawings and field surveys, it was seen that it would not be practicable to analyze the glove box with its contents as part of the same structural system. Of more than a dozen glove boxes, each has a different combination and arrangement of equipment. It was also noted that, in most cases, the equipment does not connect to the boxes except at the base plate. The work was then limited to determining the capacity of the box itself, excluding the equipment within. It is assumed, for the purpose of this study, that the interior equipment is adequately

braced so that it will not impact with the sides of the box or introduce significant amplifications of acceleration to the box.

Stiffness and masses of the glove box elements were determined from vendor's drawings and measurements. The glove box was dynamically analyzed using the TABS computer program by treating the box as a frame in both the transverse and longitudinal directions. In both directions, the box was subjected to the median response spectrum and to a static force at the top level of the box to simulate a possible loading from the pipes attached at that level. Although the box was found to be quite stiff, there was some limited amplification of the transverse motions. Nevertheless, the structural elements of the box are stressed only to a low level. Even with the more conservative assumption of a 2-kip load at the top of the box, the stresses are still low. The capacity of the box as limited by allowable stress in the shell is large. Results of the analysis show that accelerations of 1.0g can be resisted without overstress. Thus, the UBC forces of 0.5g, which in this case are larger than the forces from the median spectrum, pose no problem of stress in the box. For resistance to sliding of the box on the floor capacities of over 1.0g can be readily achieved through proper design of the anchorage.

Although deformations of the boxes are not large when the boxes are subjected to lateral forces in the order of 1.0g, the probability of maintaining an airtight condition of the box under this loading is not within the scope of this study.

The only remedial measures that were recommended for the glove boxes (excluding the contents) were installation of flexible couplings on the pipe connections at the top of the boxes and modification of the floor anchorages.

6.7.4 Exhaust Duct System

This system consists of three main parts: (1) the round ducts, varying from 25 cm to 40 cm in diameter, which start from the glove boxes in the laboratories, run through the roof, and tie on to the main rectangular exhaust duct on the roof; (2) the main exhaust duct on the lab building roof, which starts out as a 1 m square section and increases by increments to 30 m by 1.2 m; (3) the continuation of this duct over the canopy of the service area, which connects to the system of sound traps, baffles, and fans on the equipment room roof and then to the steel stack.

In the analysis of this system, hand calculations were used because the configuration of each part is relatively simple. The lateral forces imposed on the system are generated by the displacements and accelerations of the buildings at roof level. The capacities of the various supports on the lab building roof were calculated in terms of the accelerations they are capable of resisting. These capacities should be compared against the accelerations at the roof resulting from earthquake effects on the building as modified according to the remedial scheme.

The supports for the main rectangular duct in its existing condition are capable of resisting a lateral load of 0.9g at the roof level. The limiting factor is the allowable pullout value of the lag screw that connects the duct through a metal strap to the longitudinal wood sleeper under the edge of the duct. Supports for the round duct are typically a two-legged rigid frame, 45 cm high, fabricated from steel angles welded together. In their existing condition, these supports are capable of resisting a lateral load of 2.0g at the roof level.

The portion of the duct system on the equipment room roof was not analyzed because the connection details were not available. In the field, the anchorages were roofed over and not visible except for the support under the fans. This support appears adequate, but the embedded length of the bolts was not known. The supports in this area are not expected to be a problem because the duct and equipment are supported on a concrete curb on top of the 15 cm roof slab. Anchorages of high capacity can be readily achieved by drilling into the concrete.

Comparisons of the capacities of the duct system calculated here against the UBC requirements of 0.5g indicate that the ducts on the lab building roof are adequate. The likelihood is good that the ducts on the equipment room roof will also be adequate because the weights are relatively light. If the median response spectrum for 5% damping and 0.275g peak ground acceleration is applied to the building, the maximum roof acceleration would be 0.63g, and the duct supports will also be adequate. However, it will be necessary to check the relative deflections between the round ducts and main duct to determine whether the connections can withstand the predicted deformation. Another location where differential deflections may be critical is the point where the main exhaust duct enters the stack. A flexible connection was recommended for this location.

6.7.5 Decontamination Equipment Supports (Skids)

Decontamination equipment is found in Room 115-A of the lab building. It is divided into four separate supporting frames commonly referred to as skids. These skids are identified according to the process carried out by the

equipment they support. These are the dryer and regeneration skid, catalytic reactor skid, blower skid, and VERS skid.

The coupling of dynamic motions between the various skids is negligible because there is only a single 10 cm, thin-walled pipe that spans between the skids. Consequently, the work done here investigates each skid, independent of the others. For all the skids, investigations showed that lateral bracing was minimal and that the existing supports mainly resist vertical loading. Hence, the investigation for each skid was aimed at developing lateral bracing systems that would limit the accelerations of the equipment on the skids.

It was assumed that the numerous pieces of equipment and appurtenances are adequately attached to the supporting framework. Only the most massive pieces of equipment, such as blowers, were investigated for adequate anchorage to the supporting framework. The other equipment was not included in the study.

It should be emphasized that the bracing schemes presented here are concepts. Variations in these bracing schemes are also feasible and may be preferable due to possible interferences. The concepts shown here should be adequate for either one of the standards used in the other sections of this report. Regardless of the criteria chosen, however, the bracing configurations described here would not change other than in the details. Because the forces to be resisted by the suggested bracing are small, the concepts shown should be adequate for a 1.0g force level.

6.7.5.1 Dryer and Regeneration Skid. (1) Cross-bracing, as shown in Figures 6-5 and 6-6, should be installed. Where equipment interferes, alternate configurations could be used. Preliminary design work shows that standard unistrut

members (P5500 or smaller) with typical unistrut or welded connections will probably be adequate. However, because of the irregularity of the existing joints, special connections may be required for some of the new bracing members as well as strengthening of existing connections.

(2) All the cross-bracing done under (1) will not be effective unless each piece of equipment is adequately connected to this supporting framework. By jarring the pieces of equipment by hand, an estimate of their anchorages can be determined.

In particular, anchorages should be provided connecting the elements of the blower to the skid so that displacements in any direction are restrained. Anchorages could be simple "keepers" that butt up against the blower base and attach to the skid base. The anchorages should allow for the proper operation of the isolator pads.

(3) Because of the length of the skid and the relatively low allowable base shear on the existing anchors, two additional pairs of anchor bolts should be installed, spaced along the length of the skid. Anchors should be the same as the existing anchors at the skid corners.

6.7.5.2 Catalytic Reactor. (1) The gas-gas and water-gas heat exchangers should be attached to the supporting 25 cm channel sections so that they cannot slide in the longitudinal direction. These channel sections should, in turn, be rigidly attached to the supporting framework. Sketches of this suggested strengthening are shown in Figure 6-8(a), (b), and (c).

ROOF

COLUMN

AIR-CONVECTION OR DUCT TO ROOF BEAMS BACK JOBS

AIR-LOGIST BEAM HUBS

CONT. CONNED TO ONE END

WALL SEE NOTE 1

NEW PNEUMATIC TEST AREA COLUMN THIS SIDE, SEE NOTE 2

NEW BEAMS JAM AS ABOVE

AIR-1001 UNISTRUT

AIR-1001 UNISTRUT

AIR-1001 UNISTRUT EACH HANGER

GAS GAS

VERI

NEW PIPE LAMP ARE GAS PIPES

CONNECT TO ONE END WALL

NOTES

1 ALL ITEMS ARE EXISTING UNLESS NOTED AS NEW
 2 IF EXISTING AIR-1001 UNISTRUTS FALL ON COLUMN
 LINES, NEW LONG AIR-1001 UNISTRUTS

- NOTES:

- 1 MAX SPACING FOR LATERAL BRACING
GSS, GIR PIPING _____ 15'-0"
VRS PIPING _____ 10'-0"
- 2 LOCATE BRACE AT EACH SIDE OF
HORIZONTAL PIPE BENDS

- 2 LOCATE BRACE AT EACH SIDE OF
HORIZONTAL PIPE BENDS

TYPICAL LATERAL BRACING FOR
RE SUPPORTS IN LABORATORY BUILDING

BRACING OF PIPE RACK IN CORRIDOR

SANDIA TRITON RESEARCH FACILITY

FIGURE 4-2

SANDIA TRITIUM RESEARCH FACILITY

FIGURE 63

NOTE :

ALL CONSTRUCTION IS EXISTING
UNLESS NOTED AS NEW

HOLDING TANK SUPPORTS ON ROOF

TOP OF FLOOR SLAB

(b) ELEVATION A-A

ELEVATION B-B SIM. & OPP. HAND

DRYER SKIN

NOTES

1. NEW BRACING IS INDICATED BY HEAVY LINES - ALL OTHER MEMBERS ARE EXISTING

SANDIA TRITIUM RESEARCH FACILITY

FIGURE 6-4

SANDIA TRITIUM RESEARCH FACILITY

FIGURE 6-5

(2) An additional pair of anchorages should be provided midway along the length of the skid, capable of carrying shear and uplift.

(3) Cross-bracing should be provided as seen in Figures 6-7 and 6-8(c). The connections can be welded or bolted, and preliminary studies indicate that standard unistrut members will probably be adequate.

6.7.5.3 Blower Skid. (1) The lateral bracing schemes shown in Figure 6-9 should be installed on the skid.

(2) It is recommended that the piping be more rigidly attached to the bracing frame. An example of this is seen in Figure 6-9(a).

(3) Recommendations for anchoring the blowers on the dryer regenerator skid apply to the blowers on the blower skid as well. See Section 6.7.5.1.

(4) Two new anchors should be installed to attach the skid to the floor slab. The anchor bolts must resist shear and tension.

6.7.5.4 VERS Skid. (1) Lateral bracing as described by Figures 6-10, 6-11, and 6-12 should be installed. It is noted in those figures that alternative bracing schemes may be required. If bracing marked A is used, then bracing marked B, an alternate, is not required (or vice-versa). It is also possible that many existing connections of the supporting framework will need to be strengthened by welding. Preliminary studies indicate that standard unistrut members should be adequate for the new bracing.

Lateral bracing marked C is suggested to restrain the pumps, but any bracing actually used should allow for the proper operation of any vibration mounting of the pumps.

NOTES:

1. DIFFERENT TYPES OF BRACING ARE SHOWN TO MEET VARIOUS EXISTING CONDITIONS. ANY TYPE MAY BE USED AT ANY TRANSVERSE FRAME (AT GRID LINES SHOWN ON PLAN, FIG. 3)
2. TYPE 1 BRACING IS MOST PREFERRED. TYPE 2 IS LEAST PREFERRED.
3. A TOTAL OF FOUR SETS OF TRANSVERSE BRACING ARE REQUIRED.
4. SEE NOTES ON FIG. 1.

TYPICAL TRANSVERSE BRACING, DRYER SKID

NOTES:

1. ALL STRUCTURAL BRACING, NEW & OLD, IS REPEATED ON WEST SIDE OF 6 BUT NOT SHOWN.
2. NEW BRACING IS INDICATED BY HEAVY LINES.
3. OTHER MEMBERS ARE EXISTING.
4. EQUIPMENT & PIPING ARE NOT SHOWN.

SANDIA TRITIUM RESEARCH FACILITY FIGURE 6-6

SANDIA TRITIUM RESEARCH FACILITY FIGURE 6-7

ADDITIONAL ELEVATION SIMILAR

CATALYTIC REACTOR SKID SECTIONS

SEE NOTES ON FIG. 15

EAST ELEVATION SIMILAR

BLOWER SKID BRACING

SANDIA TRITIUM RESEARCH FACILITY FIGURE 6-8

SANDIA TRITIUM RESEARCH FACILITY FIGURE 6-9

(2) It is recommended that the piping on the skid be more rigidly attached to the frames. This may require new horizontal or vertical members secured to the frame or skid base to which the equipment can be attached.

(3) The anchorage of the skid to the floor is not considered adequate to brace against east-west ground motions. It is suggested that two anchors (of the same type as exist on the north and south sides of the skid) be installed on the east and west sides.

6.7.5.5 Connecting Piping. Piping that spans between the various skids is limited to a single 10 cm stainless steel pipe. Stresses on this pipe and its connections will arise from two sources. The first source is the relative displacement of the two skids to which it is attached. The second source is the accelerations of the pipe itself under the postulated earthquake.

If adequate stiffening of skids as suggested is carried out, the relative displacements between skids should be small, and, if the pipe is securely attached at each end to the skids, the forces induced should be small. Accelerations of the pipe itself will not induce large forces at the connections if, again, the pipe is adequately braced. In particular, the pipe might require a few more anchors to the skid to prevent torsion at any of the existing bellows.

6.8 SUMMARY. Several remedial schemes were proposed by URS/John A. Blume for the building and the systems vital to a safe operation. A majority of the modifications were fitted prior to the completion of this report. All of the recommended changes will be finished early in CY1979.

PLAN OF VERS SKID

NOTES:

1. NEW BRACING IS INDICATED BY HEAVY LINE
2. EQUIPMENT & PIPING ARE NOT SHOWN

ALTERNATE TO EXIST. BRACES

VERS SKID BRACING

JANDIA TRITIUM RESEARCH FACILITY FIGURE 6-10 JANDIA TRITIUM RESEARCH FACILITY FIGURE 6-11

JANDIA TRITIUM RESEARCH FACILITY

FIGURE 6-12

SEVERE WIND ANALYSIS OF FACILITY

Postulated Tornado

The TRL was checked to see if it could resist the tornado postulated for the SLL site. The tornado criteria for the Site were developed from a review of the report by Meteorology Research, Inc., to the Lawrence Livermore Laboratory entitled Characteristics of California Tornadoes by T. B. Smith and V. A. Mirabella, January 1972, Rept. UCRL-13533. (This report is included as an Appendix of Rept. UCRL-51801.)

On the basis of the established criteria, maximum wind speeds are estimated to be 60-m/s (135-mph). These speeds consist of a 10-m/s (25-mph) translational component and a 50-m/s (110-mph) rotational component). The recommended atmospheric pressure change associated with the tornado is 1.4 kPa (0.2 psf). The tornado criteria are based on a recurrence interval of 10^{-6} /yr.

Tornado-Induced Wall and Roof Pressures

The original design of the structure, which did not provide for tornado loading or missile impact, did consider wind loading of 0.72 kPa (15 psf) which is increased with height in accordance with U.S.C., 1970. The wind speeds impinging on the walls of the structure results in direct pressures on windward walls and suction on side walls, leeward walls, and the roof. These wind pressures were calculated from wind speeds with the equation⁽⁶⁻³⁾

$$q = \frac{1}{2} \rho V^2 = 0.613 V^2,$$

where ρ = density of air at 15°C and 100 kPa (1.23 kg/m³), (6.4)

V = wind velocity (m/s),

q = resulting wall pressure (Pa).

Thus, a 60-m/sec (135-mph) wind results in a pressure of

$$q = (0.613) (60)^2 = 2.2 \text{ kPa (47 psf)}.$$

The maximum wind pressure was distributed to the walls and roof in accordance with the ANSI recommendations.⁶⁻⁴

On structure,

windward wall: $0.8 q = 1.8 \text{ kPa (37 psf)}$ direct pressure;

side wall: $-0.7 q = 1.6 \text{ kPa (33 psf)}$ suction;

leeward wall: $-0.5 q = 0.95 \text{ kPa (20 psf)}$ suction;

roof: $- .07 q = 1.6 \text{ kPa (33 psf)}$ suction.

On parts of structure,

wall corners: $+2.0 q = 4.4 \text{ kPa (93 psf)}$;

roof eaves: $+2.4 q = 5.3 \text{ kPa (110 psf)}$;

roof corners: $+5.0 q = 11 \text{ kPa (230 psf)}$;

(These pressures are applied to a 4.5-m (15-ft) wide strip for all corners and roof eaves, and to a 4.5-m x 4.5-m (15- x 15-ft) area for roof corners.)

This pressure distribution reflects the latest experimental results obtained from wind-tunnel tests on structures and from observations of building damage due to extreme winds and tornadoes.

The worst-case combination of internal pressure and wind suction on the structure was determined from the variation of pressure and suction proposed by J. D. Stevenson in a report prepared for Nuclear Structural Systems Associates, entitled Engineering and Marketing Guide to Tornado, Missile, Jet Thrust and Pipe Whip Effects in Equipment and Structures.⁶⁻⁵ The variation of pressure with distance from the center of the tornado is shown in Fig. 6-13.

Fig. 6-13 Variation of pressure with distance from center of tornado.

The maximum combination results in a suction of 2.6 kPa (55 psf) on a side wall or roof, and a suction of 2.2 kPa (45 psf) on a leeward wall.

The worst-case, direct pressure on a windward wall, was determined to be 1.8 kPa (37.3 psf).

An effective roof suction of 55 psf is 1.5 times the roof dead load but less than 1/2 the designed safety factor for resistance to uplift. Table 6-7 summarizes these worst-case conditions used for analysis. These values are also shown in Fig. 6-14.

Table 6-7 Tornado-induced pressures.

Conditions	Pressure or suction	
	kPa	(psf)
Direct pressure on windward wall	1.8	(37)
Suction on leeward wall	2.2	(45)
Suction on side wall	2.6	(55)

Since it was estimated that the structure would be subjected to these loads for several seconds, static analyses were conducted.

Results of Tornado-Wind Analysis

Results of the wind pressures and suctions on the walls and roof of the facility are shown in Table 6-8.

Fig. 6-14. Pressure distribution on structure due to tornado wind and atmospheric pressure change.

Table 6-8 Results of tornado-wind analysis.

	(1) Ultimate moment capacity (kip·in/ft)	(2) Wind- induced moment (kip·in/ft)	(3) Factor of safety
Direct wall pressure	(28)	(20)	1.4
Leeward wall suction	(28)	(24)	1.2
Side wall suction	(28)	(30)	0.93

- (1) Ultimate capacity of sections were determined based on ultimate strength design concepts for reinforced concrete.

$$M_u = 0.9 A_s f_y d \text{ for } d < a/2, \quad (6.5)$$

A_s = area of steel,

f_y = yield stress of steel,

d = distance from compression face to centroid of tension steel,

a = $A_s f_y / (0.85 f'_c b)$,

f'_c = concrete compressive strength,

b = width of section.

- (2) Wind moments were computed assuming a simply supported wall or roof span

$$M = \frac{wL^2}{8}.$$

$$(3) \text{ Factor of safety} = \frac{\text{Ultimate moment capacity}}{\text{Wind-induced moment}}. \quad (6.6)$$

These results indicate that all walls and roofs can adequately withstand the loading due to tornadic winds.

Tornado Analysis of Stack

The tornado criteria postulates a 60-m/s (135-mph) wind with a maximum pressure drop of 1.4 kPa (0.2 psf). Since the pressure drop will not significantly affect the cylindrical stack, only the wind is of concern.

Wind Analysis of Stack

The effects of wind-induced oscillations on welded steel chimneys must be considered. One design formula derived to establish the susceptibility to wind-induced oscillations is given by

$$V_C = 5ND, \quad (6.7)$$

where

V_C = critical wind velocity

N = natural frequency, f_n

D = equivalent diameter for a tapered stack

5 is the reciprocal of the Strouhdal number for a cantilevered structure.

The natural frequency equation for a chimney is calculated by the equation⁶⁻⁶

$$f_n = \frac{3.52}{24\pi} \sqrt{\frac{Eg}{2W_s}} \left(\frac{D}{2H^2} \right). \quad (6.8)$$

In this case

$$g = 386 \text{ in/sec}^2,$$

$$E = 2.9 \times 10^7 \text{ lbs/in}^2,$$

$$W_s = \text{unit weight of steel shell} (= 0.283 \text{ lbs/in}^3),$$

$$D = \text{equivalent Diameter} (= 7.66 \text{ ft}),$$

$$H = \text{equivalent Height} (= 79.55 \text{ ft}),$$

The frequency of the stack was determined to be 3.97 Hz and, therefore, the critical wind velocity is 46 m/sec (103 mph). Since this is a relatively

high wind velocity, the possibility of stack failure from wind-induced resonances is considered small.

The wind shear for tornado winds is the product of the projected area of the stack, the wind load and the cylindrical shape factor (0.6).

$$\begin{aligned}V_w &= (0.6)(72 \text{ m}^2)(230 \text{ kg/m}^2) \\&= 9934 \text{ kg.}\end{aligned}$$

It can be shown that the supports will not fail from a distributed load of this size.

Conclusions

Wind load and wind-induced resonances are not expected to affect the TRL exhaust stack adversely.

LIGHTNING ANALYSIS

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

The actual number of lightning flashes per unit area due to thunderstorm activity has been approximated by Sunde 6-7 as $0.1/\text{km}^2$ per thunderstorm day. This can be applied to a calculation of the probability of a lightning strike near the TRL. Assuming that the area of concern is approximately $3.5 \times 10^{-3} \text{ km}^2$ (38,000 ft^2), the recurring interval of a strike in that area becomes

$$\begin{aligned} P &= 5 \text{ storms/yr} \times 1/2 \text{ day/storm} \times 3.5 \times 10^{-3} \text{ km}^2 \times 0.1 \text{ strike/km}^2 \cdot \text{day} \\ &= 9 \times 10^{-4} \text{ strike/yr or 1 strike per 1100 years.} \end{aligned}$$

Magnitude of Strike

The maximum lightning strike considered possible in this area is one yielding a peak stroke current of 160 kA. This is considered conservative since reported minimum-maximum values range from 10 kA to an average maximum of 110 kA.⁶⁻⁸ Stroke currents of up to 160 kA have been measured, but are considered very rare. Hardin and Clayton in the book compiled by Byers, 6-9 state that when lightning strikes transmission lines in average lightning areas where the isoceraunic level equals 30, only one stroke per 160 km (100 mi) of transmission line per year exceeds 92 kA.

Lightning Protection

The cones of protection provided by the 30-m (100-ft) ventilation stack on the north side of the TRL make a direct strike to the building very unlikely. This stack is grounded to the building ground grid system. The roof top blower ventilation duct system connects directly to the stacks and is therefore well grounded through them.

Building power comes in underground to the equipment room from the substation. Phone lines come in underground to the fan-out located in the central corridor.

Considering the low probability of a lightning strike to the building plus the 30 m (100 ft) stack and well protected power system, the potential for lightning damage is negligible.

FLOODING

No streams other than Arroyo Seco would affect the area around SLL, as explained in Section 3. A storm that produced the "probable maximum precipitation" could cause flooding of Arroyo Seco. The overflow of this stream would most likely occur at the point where the stream bed passes through the southwest corner of the LLL site. The elevation here is such that any water overflowing the Arroyo Seco bank would tend to flow down the slope of the terrain, which pitches to the northwest. Sheet flow would follow existing streets as channels, and flow to the north and west. Water depth would be limited to several millimetres, and would flow fairly fast only during the peak of the storm. Since there is about an 23-m (75-ft) drop from south to north across the site, the water would not pond until it met the Western Pacific Railroad embankment, where it could possibly pond before draining to the west into the Arroyo Las Positas stream bed. Therefore, flooding of the TRL is very unlikely.

HUMAN ERROR ACCIDENTS

Nuclear Criticality

The only operation involving fissile material performed at the TRL is calorimetry measurements. The calorimetry measurement thermal standards are plutonium-238, and the total mass is 16 grams.

Any future experiment which might involve fissile material will be permitted only after a careful review of the experiment and explicit approval by Sandia Laboratories Management.

TRITIUM RELEASE

An analysis of the off-site consequences following a release of tritium is included in this section. It was postulated that 10^5 Ci of HTO gas was released over a 15 minute interval following a breach in the primary and secondary containment of a glove box containing 10 grams of HT gas. After consideration of the operations and structures in the TRL, it was predicted that this is the most probable release mode and quantity. The assumptions employed in the analysis are listed as follows.

1. Simultaneous failure of both the primary and secondary containments of two glove boxes is considered incredible.
2. It is unlikely that a release of tritiated water vapor would occur. Most of the material would remain as HT and T₂ gas, which is 400 times less hazardous than HTO.
3. The greatest population density lies west of SLL. Winds from the east, which would maximize the population exposure, typically occurs less than 25% of the time.
4. Pathways of tritium exposure other than submersion are considered less significant although deposition and washout were evaluated for a nearby aqueduct. Agricultural land use is predominantly cattle grazing and vineyards. There are few food crops or dairy cattle in the vicinity of SLL. It is anticipated that adequate time is available after a release to analyze vegetation and water supplies for tritium prior to human consumption.

5. The TRL seismic and wind investigations concluded that the stack and ventilation system would remain intact following naturally occurring phenomena. Therefore, a 30 m high release was assumed.
6. The most adverse meteorological conditions were used to calculate the site boundary and population dose. A meteorological station is to be installed at SLL during FY 1979. Site specific meteorological data will be used to revise these calculations after collection of data for a one year period.

Ground level air concentrations under the plume center were calculated using the following Gaussian plume-diffusion equation (6-10):

$$x = \frac{Q}{\pi \sigma_y \sigma_z + (CA/\pi)u} \exp[-0.5(h^2/\sigma_z^2)] \text{ Ci/m}^3 \quad (6.9)$$

where

x = air concentration, Ci/m^3

Q = source term, Ci/sec

σ_y = horizontal standard deviation, m

σ_z = vertical standard deviation, m

CA = building wake factor, m^2

u = windspeed, m/sec

h = height of plume centerline above ground, m .

Graphs of maximum ground level air concentration and dose resulting from the most conservative meteorological conditions are presented in Figures 6-15, 6-16.

The population dose was calculated from the ground level sector average air concentration given by (6-10):

$$\bar{x} = x \sqrt{2/\pi} \approx 0.8 \sigma_y/x \text{ Ci/m}^3 \quad (6.10)$$

where

$\bar{x}$ = the sector average ground level concentration, Ci/m³,

x = the ground level concentration under the plume, Ci/m³

σ_y = horizontal standard deviation, m

x = distance from release point, m

Estimates of dose equivalent received by individuals located at the point of maximum air concentration and the sector of maximum population were calculated using the following assumptions.

- 1) The breathing rate for standard man is 0.02 m³/min (6-11),
- 2) The biological half-life of HTO is 8.5 days (6-12),
- 3) The critical organ for HTO is body water, which has a mass of 43 kg in standard man (6-12),
- 4) Tritium betas have an average energy of 5.7 keV per decay and a quality factor of one,
- 5) Clothing reduces the absorption rate to 30% of the inhalation rate (6-12),
- 6) The air concentration-to-dose rate conversion factor*
 $f_{\text{conv}} = 37 \text{ mrem-m}^3/\text{Ci-sec.}$

From these assumptions, the total integrated submersion dose to an individual exposed to a uniform air concentration x during the cloud passage (15 min) is given by

$$D = (f_{\text{conv}} \text{ mrem-m}^3/\text{Ci-sec}) (x \text{ Ci/m}^3) (900 \text{ sec}) \text{ mrem}.$$

Submersion dose values were calculated assuming dry season data, since washout tends to lower air concentrations. The integrated dose equivalent as a

*The air concentration-to-dose conversion factor is calculated for an adult male. Using this factor in population man-rem calculations will overestimate the actual population dose due to age-specific factors, which were not taken into account for simplification.

function of distance is provided in Figure 6-17. The maximum offsite dose from a 30 meter release of 10^5 Ci of HTO into a west wind was estimated to be one rem. Estimates of the total population dose from the same release into an east wind were calculated using the population density diagram in Fig. 3-5. The maximum population dose was calculated to be 600 man-rem.

Figure 6-15 Air Concentration as a Function of Distance (Moderately Stable Conditions with a 2 m/sec wind speed).

Figure 6-16 Air Concentration as a Function of Distance (Extremely Unstable Conditions with a 0.5 m/sec wind speed).

Figure 6-17 Total Integrated Dose as a Function of Distance (Source Released During Extremely Unstable Conditions and 0.5 m/sec wind speed; conditions changed to moderately stable with a 2 m/sec wind speed).

South Bay Aqueduct Contamination

Since the South Bay Aqueduct flows near SLL it was necessary to confirm that no appreciable contamination of the drinking water and subsequent human consumption could occur.

Seasonal variations in aqueduct flow rate and depth do occur, but generally the flow rate is 0.5 to 2.0 m/sec and the depth is 2 to 3 m. Two down stream water treatment facilities use water from the aqueduct; the closest facility being about 12,000 m from the point due east of the TRL. The aqueduct is a prismatic concrete channel that follows a path with many bends and through several pipelines prior to reaching the first treatment facility.

Wet and dry deposition of HTO during an accidental 10^5 Ci tritium release from the 30-m stack into a west wind was considered as the mode of contamination. Both types of deposition were assumed to occur simultaneously. The following worst case assumptions were used to calculate the initial water concentrations.

- 1) The aqueduct flow rate $F = 0.5$ m/s and the depth $D = 2$ m.
- 2) The deposition velocity of HTO: $V_d = 0.005$ m/s, 6-13.
- 3) Water flowing through the duct was uniformly exposed to the ground-level-sector average concentration calculated using stability category B with a 0.5 m/s wind speed (2.4×10^{-2} Ci/m³).
- 4) The washout coefficient for HTO with local rain characteristics is $\sim 10^{-4}$ s⁻¹ 6-13.
- 5) The HTO was quickly mixed transversely and vertically after depositing on the water surface.

Dry deposition onto the surface of the aqueduct resulted in initial water concentrations given by

$$C_d = \frac{\bar{x} V_d L}{FD} \quad (6.11)$$

$$C_d = 2.4 \times 10^{-2} \text{ } \mu\text{Ci/ml},$$

where

C_d = water concentration, in Ci/m^3

$\bar{x}$ = Ground-level sector average air conc., Ci/m^3

V_d = dry deposition velocity, m/s

L = aqueduct length across the sector ($L = 200 \text{ m}$)

F = aqueduct flow rate, m^3/s

D = average depth of the duct, in meters.

Wet deposition results in concentrations given by the equation

$$C_w = \frac{(VI)WL}{FD} \text{ Ci/m}^3 \quad (6.12)$$

$$C_w = 2.8 \times 10^{-2} \text{ } \mu\text{Ci/ml}$$

where

VI = the vertical integral upward through the plume, Ci/m^2

W = washout coefficient, sec^{-1} .

The total water concentration reached after the aqueduct water crosses the 22.5° sector (400 sec) will be the sum of both wet and dry deposition. This value was calculated to be $5.2 \times 10^{-2} \text{ } \mu\text{Ci/ml}$. Down-stream water concentrations will be diluted by longitudinal dispersion or mixing. Several methods of estimating liquid effluent transport in nontidal rivers after transient releases are available in the literature (6-14, 6-15). The model used in this analysis was suggested in USNRC Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I."

For a straight, rectangular channel and an instantaneous release of a finite quantity of material from a line source ($x=0$, $y=y_s$), the downstream concentration is given by

$$C = \frac{M}{\sqrt{4\pi k_x t} A} \exp \left\{ \frac{(x-Ut)^2}{4k_x t} - \lambda t \right\} \left[1 + 2 \sum_{n=1}^{\infty} \exp \left(-\frac{n^2 \pi^2 k_y t}{B^2} \right) \cos n\pi \frac{y_s}{B} \cos n\pi \frac{y}{B} \right] \quad (6.13)$$

where A = stream cross-sectional area, in m^2

B = stream width, m

k_y = vertical turbulent transport coefficient, m^2/s

k_x = longitudinal dispersion coefficient, m^2/s

t = time after release, s

U = stream flow velocity, m/s

x = downstream distance, m

λ = radioactive decay constant, s^{-1}

M = Curies released.

As mentioned earlier, vertical and transverse mixing are assumed to be complete at the point of release (east sector), therefore, only longitudinal dispersion is considered. Since the time of exposure (400 sec) is much less than the time to reach the downstream water treatment facility, an instantaneous stream release can be assumed. The power series solution for the transverse diffusion in the first equation was set equal to one. Radioactive decay can be neglected, so the equation can be simplified to:

$$C = \frac{M}{\sqrt{4\pi k_x t} A} \exp \left\{ \frac{(x-Ut)^2}{4k_x t} \right\} \quad (6.14)$$

Then, with the following values assigned to the variables.

$$*M/A = 5.2 \times 10^{-2} \text{ Ci/m}^2$$

$$t = 24,000 \text{ sec}$$

$$**k_x > 6$$

$$x = 12,000 \text{ meters,}$$

the concentration at the water treatment facility was calculated to be $3.0 \times 10^{-4} \text{ } \mu\text{Ci/ml}$ which is below the DOE/C 0524 Concentration Guides.

*The value of M/A was set equal to the initial water concentration times a unit length (1 meter) to obtain a Curie fluence.

**A value for k_x is provided in Reg. Guide 1.113 for stream channels that are straight. The value increases as the number of bends in the channel increases.

EXPLOSIONS

The possibility of various types of explosions, such as gas-phase combustion, solid or liquid chemical reactions was considered. Gas-phase combustion is always a consideration where flammable gases are employed and such reactions may result in overpressures that can cause structural damage. The TRL has included several design and operational safety features to prevent such explosions from occurring. Only through a chain of malfunctions could such an accident take place.

Solid or Liquid Chemical Reactions

Solid explosives are not permitted in the facility except as approved by special Safe Operating Procedures and Management Review. Fire and overpressurization from solid explosives will be minimal when they are confined to the limitations set by this SOP and review. Since flammable liquids are stored in approved containers of relatively small quantities they represent more of a localized fire hazard than an explosion overpressure problem.

Flammable Gases

The TRL is serviced by hydrogen, deuterium and propane (Lab No. 126) gases. All of the high pressure gas cylinders are stored outside of the building and piped into the individual labs using highly reliable certified hydrogen hardware. A description of the gas line system with its engineered safety features is detailed next.

All gas service piping is constructed of 2500 psi rated stainless steel tubing and SS Swagelok connectors. Beginning at the gas cylinders, the gas is released by solenoid valves whose controls are located in each lab. The gas flows through two check valves and a regulator (exterior to the building), which has an interstage relief valve. Next, the gas passes through a Valin

excess flow valve adjusted to stop flow rates greater than 65 cfm and then to a Nupro burst valve. Now, the gas enters the building, passes a third check valve which vents to the roof. Finally, the gas flows through a manually operated solenoid valve and flash arrestor-check valve (in the corridor) and on to the user. The system piping consists of 3/8-inch O.D. and 1/2-inch O.D. stainless steel. The electrically operated solenoid valve has a warning light which indicates an open valve condition.

The primary safeguard to prevent accidentally released gas-buildup in any lab is the ventilation exhaust system described in Section 4. Ventilation rates in those labs handling flammable gases is provided in Table 6-9. As long as the ventilation is operating, the Lower Explosive Limits (LEL) for the gases would not be reached should a full tank of propane or hydrogen gas release into a lab.

In the event that both the main and emergency power supplies to the TRL fail and ventilation is lost, there will still be some ventilation due to the "stack-effect" and the natural breathing of the construction materials. The percentage of the LEL for propane and H_2 was calculated using the following assumptions:

1. The LEL for H_2 is 4% and for propane it is 2%,
2. A full gas cylinder (5.7 m^3) is released to the smallest lab volume, (225 m^3),
3. The ventilation rate of the room is essentially zero,
4. An ignition source is present.

Localized pockets of gas may reach or exceed the LEL for short periods of time. However, since the diffusive rate of hydrogen is high rapid mixing would occur. A resultant mixture of 2.5% gas will be reached. This concentration is just above the LEL for propane and 63% of the LEL for hydrogen.

In view of the redundant safety features of the gas service and the necessary events leading up to a gas-buildup, it can be concluded that an explosion is very unlikely.

Table 6-9
Ventilation Rates for Labs Handling
Flammable Gases at the TRL

<u>Room No.</u>	<u>*Room Volume m³</u>	<u>Ventilation Rate, m³/min</u>	<u>Air Changes Per Hour</u>
115	670	172	15
119	480	130	16
120	960	172	11
121	340	88	15
122	340	78	14
125	410	93	14
126/128	670	195	18
129	470	140	18

FIRE HAZARD ANALYSIS

Factors Related to Fire Hazard

A discussion of the construction materials and ventilation is included in Section 4. In general, the Tritium Research Laboratory is a Class I, noncombustible building. There are a few mobile trailer offices about 15 m from the facility, but no significant external fire hazards. The fuel for the emergency generator is stored in a buried fuel tank outside the foundation line. All flammable liquids are contained in approved storage cans and stored in Flammable Liquid storage lockers. Explosives are not permitted within the TRL except in accordance with SLL SOP 594. As previously mentioned, combustible gases are kept in an outside covered storage area. TRL laboratories have common electrical ovens and provisions for gas flame burners.

The building is equipped with a 100% automatic sprinkler system spaced for a Hazardous Area. Fixed temperature and rate-of-rise type heat detectors are located in each glove box. The fuel combustible loading limit for the building is 49 kg/m^2 (10 lbs/ft²), although normal loading is less than 4.9 kg/m^2 (1 lb/ft²).

Fire Department Response

The TRL fire alarm system responds at the LLL fire station. In the event that assistance from LLL alone is inadequate the facility fire captain or SLL fire protection engineer can request additional assistance. The response sequence and available firefighting equipment is listed in Table 6-10.

The compartmentalized construction and low fuel loading would be expected to result in a fire of short duration and involving a single laboratory. Considering the building design and the automatic sprinkler system, no significant fire-fighting problems are anticipated.

Although an accidental fire is credible for the TRL, no recommendations for further reducing this hazard are proposed. Glove box involvement would be limited to heat damage to the gloves, window glass seals and wiring. The tritium secondary containment would retain its integrity since pressures generated would not be expected to damage the steel containers.

Table 6-10
Fire Department Response Levels

Alarm No.	Organization	Equipment No.	Equipment Description
First Alarm	LLL	F-1	50-1/s (750-gpm) pumper
	LLL	F-3	60-1/s (1000-gpm) pumper/ 15-m (50-ft) elevating platform
	LLL	Command Car	
Second Alarm	Livermore	E-22	50-1/s (750-gpm) pumper
		E-23	60-1/s (1000-gpm pumper)
		C-1	Chief
	Alameda Co.	E-1	
	Ambulance		
Third Alarm	Pleasanton VCSD	E-11	60-1/s (1000-gpm) pumper
		W-1	60-1/s (1000-gpm) tanker
		E-4	60-1/s (1000-gpm) pumper
		E-1	Chief
	LLL	F-71	60-1/s (1000-gpm) pumper
		F-18	10-kW light trailer
		F-7	Pickup
	Alameda Co. Civil Def.	R-1	Heavy-duty rescue
Fourth Alarm	LLL	F-72	50-1/s (750-gpm) pumper
	VA Hospital	E-1	50-1/s (750-gpm) pumper

SUMMARY OF ACCIDENT ANALYSIS

Type of Accident

Consequences

Natural Phenomena

A. EARTHQUAKE
0.275 g ground acceleration,
$*p \leq 0.16$ for 30 yrs	The capacity of the building and vital systems is greater than the demand after building modifications were made.
B. SEVERE WIND
tornado with wind speed =
60 m/s, $p \leq 10^{-6}$ /yr	Wind load and wind induced resonances are not expected to affect the TRL or the stack.
C. LIGHTNING STRIKE
stroke current = 160 kA,
$p \leq 9 \times 10^{-4}$ /yr	The TRL 30 meter, steel stack has sufficient height and grounding system to intercept and ground a strike of this magnitude.
D. FLOODING	There are no large bodies of water in the SLL drainage basin and an extreme rainfall could result in no more than sheet flow on the sloped SLL site.

Human Error

E. NUCLEAR CRITICALITY	Fissile materials are not presently handled in the TRL except for 14 calorimetry standards (≤ 16 grams).
F. FIRE OR EXPLOSION	A localized fire confined to a glove box or lab is possible. It is expected to be of short duration and minimal lab structure involvement.
G. TRITIUM RELEASE
10 grams (10^5 Ci)
(1) Release into lab	Worker dose for a 30 second stay time = 30 rem, and for a 60 minute stay time the dose = 380 rem. (See Appendix J)
(2) Release to stack	Nearest site boundary dose = 1 rem, Population dose = 600 man-rem, South Bay Aqueduct contamination = 3×10^{-4} μ Ci/ml.

*p is the assigned risk or probability of occurrence.

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SECTION 7 - ENVIRONMENTAL MONITORING

Introduction

The Lawrence Livermore Laboratory has agreed to include SLL in their environmental monitoring program, because of the proximity of the two labs. LLL's monitoring program uses complex analytical techniques capable of detecting numerous radionuclides and nonradioactive substances in the environment at below natural background levels. Currently, the radionuclides and substances of concern, because of their potential for escaping to the environment from SLL operations, include depleted uranium, fission products, tritium, beryllium, metallic elements and pesticides.

The LLL sampling program, which is discussed in this section, includes collection of airborne particulates, soil, domestic water, sewer effluent, sewage plant products, vegetation, and milk. Both gross activity and specific radionuclide activities are determined to ensure that releases are below the standards set forth by the USDOE, EPA, State of California and Alameda County. Background radiation is measured at many locations by the use of thermoluminescent dosimeters.

The results of the environmental analyses are presented in the LLL annual Environmental Monitoring Report which is submitted to DOE on an annual basis. A copy of the pre-operational environmental monitoring for the TRL is provided as Appendix G.

Atmospheric Sampling

Air samples are collected at 17 strategically located air sampling stations by continuous air samplers. The sample stations, shown in Figure 7-1

are located within 16 km of SLL. Collecting filters are changed on a weekly basis. Radiochemical analyses for ^{238}U , ^{238}Pu , ^{235}U , and ^{239}Pu in addition to gross beta, alpha and gamma spectral analyses are performed on these filters.

Measurements of airborne tritiated water (HTO) is made by collection of water vapor in silica gel samplers. The water is recovered from the gel by freeze drying and then the HTO is measured by liquid scintillation counting.

Natural gas combustion products from the SLL power plant was considered a possible source of non-radioactive pollutants. Releases were calculated and found to be below applicable Bay Area Pollution Control District guide values.

Water Sampling

The water sampling program is designed to monitor the effectiveness of SLL's pollution control measures and to ascertain that radioactivity is not entering the domestic water supplies of the surrounding communities. Surface drainage from the Livermore Valley flows westward in several arroyos that feed Alameda Creek, a source of water for the city of Fremont. During the rainy season, this drainage is sampled at various locations in the Livermore Valley. A significant portion of the water used by the cities of Livermore and Pleasanton as well as surrounding ranches comes from local wells. The South Bay Aqueduct and Patterson reservoir are open bodies of water used in domestic supplies. These water sources are sampled on a monthly basis for gross alpha, gross beta and tritium determinations.

Sewer Effluent Sampling

SLL's and LLL's sewer effluent is processed by the city of Livermore sewage disposal plant. The effluent is continuously sampled as it is discharged from LLL, and daily analyses for gross beta activities are performed. ^{239}Pu , ^{90}Sr , ^{226}Ra , ^{228}Ra , and mixed iodine analyses are done on a monthly basis. In addition, the effluent is monitored continuously by both a Field Instrument for Detecting Low Energy Radiation (FIDLER) using a 127-mm-diameter (5-inch) by 3-mm-thick (1/8-inch) NaI (Tl) crystal and a 51- x 51-mm (2- x 2-inch) NaI (Tl) crystal. The FIDLER is capable of detecting the low-energy X and gamma rays emitted by the heavy elements, while the higher energy radiations emitted by fission products and neutron activation products are detected by the 51- x 51-mm (2- x 2 in-in.) NaI crystal. When the effluent enters the municipal sewage disposal plant, the liquid and sludge are separated and the sludge passes into one of two digesters where it is broken down by bacterial action. Methane gas is evolved and burned, and the remaining sludge is released to large sludge lagoons and/or drying beds. The dried sludge is used as a soil conditioner. The treated effluent is used for irrigation on the Livermore Golf Course and a nearby farm; the excess is discharged into the Las Positas Arroyo. Samples are collected weekly from the aeration tanks, each digester, and the effluent to the arroyo. All samples undergo gross alpha, gross beta, and tritium determinations, in addition to ^{239}Pu and ^{90}Sr analyses. The results are reported annually to the city, with unusual occurrences being reported immediately.

Soil Sampling

The LLL environmental surveillance program includes a rather extensive soil sampling effort to measure the surface distribution of various radionuclides that have been deposited within the Livermore Valley as a result of global fallout from atmospheric weapons tests or from possible SLL or LLL effluent discharges. Soil samples are analyzed for a variety of radionuclides including plutonium, uranium, americium, and fission products. These samples are collected on a continuing basis, and include samples collected at immediate off-site locations at yearly intervals.

Vegetation and Milk Sampling

Vegetation samples are collected from various locations in the Livermore Valley on a monthly basis, and are subjected to tritium and gamma spectral analyses. Milk samples are collected monthly from the closest dairy, and are condensed and analyzed for tritium and gamma emitters.

Background Radiation Measurements

LLL presently has about 50 fixed stations for measuring the radiation background near SLL and LLL by means of thermoluminescent dosimeters. These dosimeters are read every three months, giving the capability of detecting increases in radiation levels that may be due to SLL or LLL operations.

Nonradioactive Substance Sampling

Routine measurements are made for nonradioactive substances discharged to the sanitary sewer system. Analyses of metallic elements that can be toxic (in high concentrations) to bacteria used for sewage stabilization and sludge digestion is made on a monthly basis. Pesticide monitoring of surface run-off water is performed to evaluate the levels of pesticides used by SLL and LLL that are washed offsite. Each month, half the perimeter particulate filters are composited for each located and analyzed for beryllium.

Figure 7-1 LLL off-site environmental sampling locations.

Figure 7-2 Locations of soil samples collected in the Livermore Valley during 1977.

Figure 7-3 Location of ground water samples in the Livermore Valley during 1977.

Figure 7-4 Location of TLDs in the vicinity of LLL.

SECTION 8 - EMERGENCY PLANS AND PROCEDURES

Introduction

For this report emergency procedures will be limited to tritium releases. Procedures for other emergencies, alerts, or security infractions are included in the following documents:

Sandia Laboratory Emergency Plans,

Safe Operation Procedure No. 709.

The calculated off-site, wholebody dose from a credible accident causing the release of HTO is within the lower range of the proposed Environmental Protection Agency's Protective Action Guides (PAG). Off-site protective actions, such as seek-shelter warnings or evacuation are not addressed in the report. Such efforts on site may be valuable since ground HTO air concentrations could reach $\sim 0.1 \text{ Ci/m}^3$ within a 100 meters of the stack. The maximum wholebody dose to an employee remaining in a plume of this concentration for 15 minutes is estimated to be 3 rem.

Emergency Aid

A reciprocal emergency assistance agreement has been established between LLL and SLL. In the event of a radiological accident at the TRL, LLL will collect off-site environmental air, vegetation and water samples. Assistance from LLL Atmospheric Release Advisory Capability may also be requested. The California Department of Health, Division of Radiological Health has offered to provide additional environmental emergency monitoring if requested.

TRL Radiation Alarm Levels

The TPL radiation alarms of major significance are summarized as follows:

1) Room Air Low	50 $\mu\text{Ci}/\text{m}^3$
2) Room Air High	500 $\mu\text{Ci}/\text{m}^3$
3) Glove Box Low	1 Ci/m^3
4) Glove Box High	100 Ci/m^3
5) Glove Box HVAH Low	100 $\mu\text{Ci}/\text{m}^3$
6) Glove Box HVAH High	500 $\mu\text{Ci}/\text{m}^3$
7) Stack Low	50 $\mu\text{Ci}/\text{m}^3$
8) Stack Intermediate 1	500 $\mu\text{Ci}/\text{m}^3$
9) Stack Intermediate 2	5 mCi/m^3
10) Stack High	50 mCi/m^3
11) Evacuation Alarm	Composite (High Stack and High Room)

Actions taken by TRL personnel at the various alarm levels are described below:

- 1) Room Air Low Alarm: The building Health Physics representative (HPR) will be dispatched to the room in question. Continue working until the HPR advises you to leave the room or if the alarm has cleared.
- 2) Room Air High Alarm: Work is terminated in a safe and orderly fashion. Personnel should exit through the corridor door to await the arrival of the building alarm response team. The response team is to be informed of any known hazards in the room and the activity in progress at the time of the alarm.
- 3) Glove Box Low Alarm: The source of the leak is located and rectified in the time frame of 15 minutes. If this cannot be achieved, the

experiment will be terminated in an orderly fashion. Room air concentrations will be a factor in the action sequence.

- 4) Glove Box High Alarm: All glove operations will be terminated immediately and the glove ports sealed. Room air concentrations will be a factor in the action sequence.
- 5) Stack Low Alarm: This alarm sounds only in the control room and initiates a review by operations personnel of room air levels and system checks to determine the source of the release. Corrective actions will then be taken.
- 6,7) Stack Intermediate Alarms: These indicate increasing levels of hazard and require increased attention by operational personnel.
- 8) Stack High Alarm: This indicates a serious condition in the TRL. If the source is not a release from the GPS or VERS, it is probably an indication of a high room air concentration. This alarm in conjunction with a high room air alarm causes an evacuation alarm to be sounded.
- 9) Evacuation Alarm: This alarm indicates a requirement for immediate evacuation by personnel to the nearest exit. All personnel will assemble at the entry gate to the compound. At this time, a determination will be made of the whereabouts of all personnel known to be in the TRL at the time of the release. Health Physics will direct reentry.
- 10) Particulate Material: An accident involving tritides will require immediate evacuation to the hallway for monitoring by Health

Physics. If the release is accomplished by fire or explosion call 2222. The operator and Health Physics personnel will determine what actions are to be taken.

- 11) Nonoperational/Security Headquarters Alarms; Seven alarm functions are located in Security Headquarters, Bldg. 911.

- 1) Building Fire Alarm - also LLL Fire Department
- 2) Glove Box Fire Alarm - also LLL Fire Department
- 3) Security Alarm
- 4) Computer Generated Alarms
 - a) Operational
 - b) Hazard
 - c) Danger
 - d) Emergency

If any of these alarms are sounded, the appropriate personnel must be notified as listed in Appendix D.

Radiation Emergency Procedures

A tritium release in the TRL, which results in a building evacuation alarm, shall require all or part of the following actions to be taken:

1. During working hours, operations personnel or the health physics representative shall notify Engineering Safety and Environmental Health 8252 and instruct occupants of the building what actions need to be taken.
2. The control room monitor shall inspect the radiation monitoring system in the control room prior to evacuating and note the following data:

Laboratory air concentration

Stack air concentration

Totalizer value

Wind direction/velocity

3. Personnel shall evacuate to a designated location upwind or crosswind from the TRL.
4. If the release is accompanied by or incidental to a fire, explosion or injury, this must be reported by phone to extension 2-2222. Give the following information:

Name

Location

Nature of the Emergency

Estimate of Injuries

5. Health Physics personnel shall proceed to the designated crosswind or upwind assembly area with instrumentation, protective clothing and

respiratory protection from Bldg 916, Room 126. Personnel who evacuated from the building shall try to account for each individual in the TRL at the time of the alarm.

6. Personnel who were in the TRL are monitored as necessary and given instruction for bioassay sample collection.
7. Every reasonable effort shall be made to rescue trapped or injured personnel. Emergency exposure authorizations as established by DOE are given in SOP 709 (Appendix D). First aid should be provided as necessary until help arrives. Contaminated, injured personnel can be removed to the LLL medical facilities.
8. Upon conferring with operations personnel, Health Physics shall coordinate a reentry using appropriate instrumentation and protective clothing. No one shall reenter the TRL without Health Physics approval.
9. The reentry team shall proceed to the TRL control room and check the radiation status of the stack effluent and the affected lab. Operation of the building ventilation system should also be verified.
10. If air concentrations in the laboratory permit, direct surveillance of the affected lab shall be made and remedial action taken if possible.
11. If corrective measures are impossible and a slow, continuous release condition exists, site-wide or downwind seek-shelter and/or site evacuation warnings should be considered. A puff release to a lab room with subsequent rapid clearance from the TRL requires no submersion-dose mitigating, protective actions on site.

12. If a fire or other hazardous condition still exists in the TRL, the reentry team shall immediately notify the fire fighting or assistance team of the building condition.
13. Upon conclusion of the tritium release and cessation of any hazardous condition, a preliminary evaluation of the total tritium release and the extent of damage, if any, shall be made. The decision to request off-site environmental monitoring from LLL or the California Dept. of Health should be made within a four hour period after the accident.

In the event that a radiation accident occurs during non-working hours, security personnel shall notify those individuals on the emergency call list. Security personnel shall not enter the TPL until Health Physics and Operations personnel arrive at which time their assistance may be requested.

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Environmental and Earth
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**A GEOLOGICAL AND SEISMOLOGICAL INVESTIGATION OF
THE LAWRENCE LIVERMORE LABORATORY SITE**

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MS. date: June 3, 1974

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A GEOLOGICAL AND SEISMOLOGICAL INVESTIGATION OF THE LAWRENCE LIVERMORE LABORATORY SITE

Abstract

In response to an AEC request for Safety Analysis Reports for all critical structures on the Lawrence Livermore Laboratory site, we examine the seismic hazard at LLL. We review the geology and seismology of the Livermore Valley and surrounding regions and identify all the active faults in the region based on

seismic history, geomorphology and geodetic data. After carefully estimating the accelerations that the site would experience from maximum magnitude earthquakes on each active fault, we conclude that the Tesla fault has the most potential for doing damage at the LLL site. The response spectrum is derived.

Introduction

The AEC has requested that LLL prepare, in a format consistent with that specified in Ref. 1, safety analyses for certain critical structures.^{*} One part of these analyses deals with the definition of the seismic hazard in terms of the geology and seismology. This report will define the seismic hazard at LLL in a manner consistent with the AEC specifications in Section 2.5 of Ref. 1. This hazard will be defined in terms of a maximum possible earthquake that the site might experience. This maximum possible earthquake will be derived from a current interpretation of the geology and seismology; we will not discuss the probability of such an earthquake occurring.

^{*}Those structures whose integrity is essential to the health and safety of the public.

Two important reports have preceded this. Bernreuter and Tokarz,² on the basis of the geology known at that time, estimated the earthquake hazard at LLL. Subsequently, John A. Blume and Associates,³ performed a comprehensive geological survey of the LLL site area and on this basis discussed the seismic hazard. We will consolidate the information in these two reports and will reinterpret the hazard in terms of the most current theories and data.

Our analysis shows that the seismic hazard at the site is controlled by earthquakes on the nearby Tesla fault. The peak acceleration at the site from a maximum magnitude earthquake on this fault will be taken as 0.5 g. The acceleration response spectrum associated with the waveshape is given in Fig. 1.

We shall begin by reviewing the provincial geology and seismology and their relation to the Livermore Valley. We shall then discuss the geology and structure of the valley, and specifically, the site. We shall discuss the geologic status of nearby faults and shall derive the maximum magnitude earthquake that each of these faults might produce. We shall then examine the response of the site to earthquakes on each of these faults.

Fig. 1. Response spectrum of maximum magnitude earthquake (SSE) on the Tesla fault.

Provincial Geology

The Livermore Valley is physiographically in the California Coast Range Province. Because the origin and nature of the valley and the province are so closely related, we will first review the provincial geology and its history.

The Coast Range Province is a longitudinal geologic area (Fig. 2) easily distinguished from neighboring provinces by its unique structure and tectonics. Topographically, the region is marked by a system of parallel mountain ranges and valleys all trending NNW by SSE. This relief reflects the general state of stress that the province is experiencing, for most active and inactive faults align with this topography (Fig. 3). While many of the faults shown in Fig. 3 are relatively small and are more related to the local geology, there are three faults which have been fundamental in the history of the province: the San

Andreas, the San Nacimiento, and the Coast Range Thrust (which is now represented by the Tesla-Ortigalita and Stoney Creek faults).⁴ These faults delineate two completely different lithologic blocks. The Salinian Block⁵ lies between the San Nacimiento and the San Andreas and is comprised of granitic-metamorphic rocks. The other block lies between the San Andreas and the Coast Range Thrust faults, and is composed of eugeosynclinal Franciscan rocks. The juxtaposition of these two distinct basement rocks has presented structural and chronological problems which have still not been completely resolved.

Many of these problems arise from the complexity of the Franciscan assemblage and its unusual contact with surrounding formations. The assemblage is a melange⁶ of graywacke, siltstone,

shale, chert, limestone, and mafic volcanic rocks that have been so deformed as to resemble a megabreccia.⁷ Yet, abutting the

Franciscans on the east is the contemporaneous miogeosynclinal Great Valley sequence which is ordered and conformable.

Fig. 2. Relief map of California showing the natural provinces (from Ref. 5).

to the assemblage. Most interesting for our purposes is the Diablo Antiform. This anticlinal structure trends

N35°W from Parkfield to at least Clear Lake, a distance of 400 km.⁸ The anti-form is not continuous, but has been broken by erosion and local structural variations. The Livermore Valley is one such structural depression.

GEOLOGIC HISTORY

There are many theories regarding the evolution of the California landscape and, specifically, the Diablo Antiform. Most appealing, and currently most

popular, are those theories which describe the evolution in terms of plate tectonics.^{7, 9-12} These theories differ in detail, but all assume that the Franciscan assemblage formed during Jurassic time in an ocean trench at the American plate margin [Fig. 4(a)]. At this time, most of California was covered by a shallow inland sea. The sediments which collected on this sea floor formed the beginning of the Great Valley sequence. Relatively rapid sea floor spreading,^{7, 10, 11} or the collision of the American

Fig. 4. Northern California Plate Tectonics.

plate with an ancestral Salinian block,¹² thrust the cooler trench material deeper into the mantle, causing it to be pervasively sheared and locally metamorphosed during the late Jurassic (Nevadan Orogeny). By mid-Cretaceous, the spreading rates had slowed and the lighter, highly deformed Franciscan rocks were buoyed to the surface [Fig. 4(b)]. This and subsequent east-west compression from sea floor spreading thrust the Great Valley sequence over the melange of Franciscan rocks [Fig. 4(c)]. Thus emerged the primeval Diablo Antiform and the Coast Range Thrust fault. Localized uplifting of the Franciscan and associated displacement on the Coast Range Thrust fault probably continued at least through Eocene time⁵ while, perhaps episodically, the direction of spreading changed from east-west to northeast-southwest. This latter mode of plate interaction expressed itself in the formation of an ancestral San Andreas fault in the early Tertiary.^{9,13} By Oligocene time, the trench had completely consumed the Farallon plate, and had intersected the eastward-moving Pacific Rise [Fig. 4(d)]. It seems fairly certain that it was this intersection which activated the present San Andreas fault system. The large strike slip displacements of 500 km^{4,7,12} that have occurred on the San Andreas and its ancestor have served to relieve the compressive stresses within the Franciscan and across the Coast Range Thrust, and instead have put the region in a state of shear. This in turn activated strike slip motion on the Coast Thrust fault and its branches.

Uplifting of the Diablo Antiform and surrounding structures continued, some-

times dramatically, during the Miocene and Pliocene times. The inland sea still covered most of the area, although it began to drain by mid-Pliocene due to regional uplifting. By then, thrusting of the Great Valley sequence over the Franciscan formation had been replaced by localized strike slip on new faults that truncated the older Coast Range Thrust fault.

Drainage of the inland sea was completed by late Pliocene. This was followed by a resurgence of regional uplift and folding. This most recent orogeny resulted in the landscape as we know it today.

PROVINCIAL STRUCTURE

As Fig. 3 illustrates, the structure of the Coast Range Province is exceedingly complex. However, for our purposes, the only significant structural features are the Diablo Antiform and the three major provincial fault systems:

- The San Andreas fault
- The Sur-Nacimiento fault
- The Coast Range Thrust and its second generations (the Tesla-Portigalita and the Stony Creek faults)

The Sur-Nacimiento, although important in the geologic history, is presently inactive⁵ and as a geologic hazard need not be considered further. The other fault systems, however, are presently active and represent a potential seismic hazard to the Livermore Valley area. In the next sections we will discuss some of their more important features.

The San Andreas System

The San Andreas fault and its associated branches represent the best known and most spectacular geologic feature in California. The fault extends over 1340 km from near the Mexican border to the Klamath Mountains. Twice in the last 116 years the fault has been the site of major earthquakes; the Fort Tejon earthquake of 1857 in the south, and the San Francisco earthquake of 1906 in the north. In both of these cases, surface faulting occurred for over 320 km along the strike of the fault with offsets measured in many meters. Yet, other parts of the fault respond in quite a different way. For example, the central portion apparently responds to tectonic forces by gradual deformation; creep rates of 1-3 cm/yr have been measured at Hollister.^{14,15} In any case, whether by creep or sudden slip, the total horizontal displacement along the fault has been an impressive 500 km since Jurassic time.⁵

The fault zone topography is classic. Extensive Quaternary activity has developed a rift valley along the entire length of the fault. Within the rift valley, which varies in width between hundreds and thousands of feet, is a zone of brecciated rocks. The fault cannot be traced as a single fault through this zone; surface rupture usually occurs discontinuously across en echelon faults. Frequently, as a result of local stress concentrations, an en echelon fault will branch off from the fault zone to form a subsidiary fault. The tectonic stresses around Hollister are apparently particularly conducive to branching, for in this region several significant branch faults leave the San Andreas. Two of the most

significant branches are the Hayward fault and the Calaveras fault.

Both of these faults are among the longest in the state; they branch from each other and the San Andreas around Hollister, and both disappear beneath alluvial cover in the Sacramento delta region. Both faults have been the site of large earthquakes (Tables 1 and 2), and both are presently readjusting to stress by creeping. Both faults have historical significance, for block faulting between and beside these two faults has given rise to the impressive horst structure of Sunol Ridge and to the depressions of San Francisco Bay and the Livermore Valley.

The Coast Range Thrust

As we emphasized in discussing the history of the province, the Coast Range Thrust was active only between Jurassic and early Tertiary time. At that time the fault was the most significant structural feature in California; the fault length was at least 1000 km, and thrust displacements across the fault were measured in miles.⁵ During and after early Tertiary time the thrust fault surface was warped, folded, and sheared, and consequently developed into a complex en echelon fault system. North of the Sacramento River this system is known as the Stony Creek fault system and south of the Livermore Valley it is known as the Tesla-Ortogonalita fault system.¹⁶ There is no surface expression of the system across the Sacramento Delta region; it is presumably buried under alluvial cover.

In general, both the Tesla-Ortogonalita and the Stony Creek faults are relatively quiescent compared to the San Andreas,

Table 1. Magnitude 4.0 or greater earthquakes on the Hayward Fault.

Date	Magnitude/Intensity	Location
10/21/1868	X	Hayward
12/4/1887	VI	Hayward
7/31/1889	VII	San Leandro
6/11/1903	VIII	Hayward
8/3/1903	VIII	Fremont
7/1/1911	6.6	W. of Mt. Hamilton
10/8/1915	VIII	Piedmont
10/26/1917	VI	W. of Mt. Hamilton
3/8/1937	4.5	Berkeley
12/29/1942	4.3	San Leandro
6/10/1949	4.6	W. of Mt. Hamilton
6/22/1949	4.1	W. of Mt. Hamilton
10/13/1952	4.2	Hayward
12/17/1954	4.5	San Leandro
10/31/1958	4.2	N. W. of Mt. Hamilton

Table 2. Magnitude 4.0 or greater earthquakes on the Calaveras fault.

Date	Magnitude/Intensity	Location
3/31/1898	VIII	Mare Island
7/6/1899	VII	Pleasanton
10/26/1943	4.9	N. W. of Mt. Hamilton
3/9/1949	5.2	S. W. of Mt. Hamilton
3/14/1949	4.4	S. W. of Mt. Hamilton
9/5/1955	5.8	W. of Mt. Hamilton
10/21/1955	5.4	Walnut Creek - Concord
5/31/1958	4.1	Concord

It is possible that only certain segments of the system are still active, but hypocentral data are inadequate to establish this. Seismicity data indicate that the Tesla-Ortigalita system is much more seismic than the Stoney Creek fault. This may be a result of the former's proximity to the San Andreas. Table 3 gives the locations of magnitude 4 and greater earthquakes which have occurred

since 1934 along these faults. These data were the basis for the detailed structure in the California Seismic Risk Map (Fig. 5) southeast of Livermore.¹⁷

The Diablo Antiform

We emphasize again that generally the basement rocks between the San Andreas and the ancient Coast Range thrust are Franciscan, and that the Diablo Antiform

is a broadly folded and eroded topographical high of highly deformed Franciscan rocks which is breached at its middle by the Livermore Valley. The antiform is dissected by many minor faults, some of

which run out into the Livermore Valley. These will be discussed in detail later. The Antiform (particularly that part south of the Livermore Valley) is exceedingly seismic; literally hundreds of magnitude 4

Fig. 5. California seismic risk map (from Ref. 17).

Table 3. Magnitude 4.0 or greater earthquakes occurring along the western edge of the Great Valley since 1934. (Ordered from south to north.)

Date	Magnitude/Intensity	Location
2/25/1947	4.2	N. of Coalinga
10/22/1955	4.2	N. of Coalinga
8/13/1940	4.0	N. of Coalinga
11/30/1943	4.0	N. of Coalinga
11/27/1958	4.3	W. of Ortigalita Peak
4/22/1932	4.0	E. of Ortigalita Peak
9/18/1941	4.0	N. of Ortigalita Peak
12/1/1938	4.5	N. of Ortigalita Peak
5/2/1946	4.6	E. of Livermore
4/15/1943	4.0	Near Livermore
4/15/1943	4.0	Near Livermore
4/15/1943	4.1	Near Livermore
4/21/1943	4.2	Near Livermore
9/10/1965	4.9	Antioch
11/28/1949	4.0	N. W. of Winters

and 5 earthquakes have been located by the University of California Seismic Station at Berkeley within the antiform in the recent years.

In the preceding sections we have tried to summarize the provincial geology and

structure as it relates to the Livermore Valley. We have tried to emphasize that structure local to the Livermore Valley often has regional significance. In the next sections we shall discuss the detailed local structure and geology of the valley.

Livermore Valley Geology

PHYSIOGRAPHY

The Livermore Valley roughly bisects the Diablo Antiform as an east-west synclinal depression (Fig. 6). To the south sits the Diablo Range, the most prominent unit of the antiform. The range extends broken but unbreached over 90 miles south to Panoche Valley. Elevations of the range average 1000 meters, but rise to 1289 meters near Mt. Hamilton. A single mountain, Mount Diablo, and its

foothills dominate the northern horizon. The mountain (elevation 1173 meters) is a piercement of Franciscan rocks that was very recently thrust up through an anticline of Cretaceous rocks.^{18,19} This anticline, an impressive structure by itself, trends SSE from the mountain and intersects the Altamont anticline to the northeast of the valley. These anticlines are the northeastern and eastern boundaries of the valley. The valley opens slightly to the west before intersecting a

north-south trending valley; to the north this valley is known as the San Ramon Valley, and to the south as the Sunol Valley. At the western edge of these valleys is the Calaveras fault, described earlier.

STRATIGRAPHY

A generalized stratigraphic column for the valley is given in Fig. 7. The section was derived by Huey²⁰ for the southeastern corner of the valley, but

Fig. 6. Satellite photo of Livermore Valley.

Fig. 7. Stratigraphic column for Livermore Valley (from Ref. 20).

well logs indicate that it generally represents the stratigraphy elsewhere.²¹

Basement rocks are everywhere the Franciscan assemblage. These rocks are exposed throughout the entire Diablo Range in the south and at Mt. Diablo in the north, but are covered by thousands of feet of alluvium on the valley floor. These are the oldest rocks in the area and, as we discussed earlier, are thought to have their origin as sedimentary deposits in an ancient offshore trench. The bulk of the formation consists of broadly deformed and folded sandstones, shales and cherts; although diabase, pillow basalts, serpentine and peridotite have been intruded locally.

Overlying the Franciscans are various sedimentary layers. Directly overlying the Franciscan is the Panoche formation, a major unit of upper Cretaceous age. It is widely exposed in the Altamont anticline to the northeast of the valley. These rocks, which are well cemented and indurated concretionary sandstones and shales, may have had their source in the ancestral Sierra Nevada.²⁰

The next major unit is the Tesla formation. It is exposed as a narrow band along Tesla Road, and its extension under the valley has been inferred from deep well drilling. The formation was mined at the old town of Tesla for coal, sand and clay until 1940 in a unique, although barely profitable, venture; all three products were used to their fullest extent by using the coal to fire the kilns for production of clay pottery and fine-grained bricks. Many fossils have been found in the formation, which have accurately dated the formation as middle Eocene.

Overlying the Tesla formation is the Cierbo formation, a relatively thin layer of poorly consolidated white buff sands that has proved to be a minor producer of oil. It is poorly exposed and has been delineated mostly by deep well drilling.²⁰ The surface exposures that do exist have been marked and dated by the occurrence of large fossil oysters of upper Miocene age.

Overlying the Cierbo is another upper Miocene unit, the Neroly formation. The Neroly outcrops widely southeast of the Livermore Valley, and the unit has been followed under the valley by deep well drilling. It consists mostly of bluish sandstones, andesitic conglomerates and clays.

Capping the entire sequence is a thick layer of Plio-Pleistocene clays, gravels, and sands known as the Livermore formation. The source for this formation was the Diablo Range.

HYDROLOGY

The hydrology of the Livermore Valley has been the subject of intense investigation since the turn of the century when the city of San Francisco started exporting water from the Pleasanton area. The high extraction rate steadily lowered the water table and precipitated construction of the Hetch Hetchy Aqueduct in 1934 and the South Bay Aqueduct in 1962. Out of concern for water quality, in 1962 local agencies launched a coordinated program of water table management and quality surveillance. Water quality remains a problem, but as a result of injection of large volumes of water, the water table is gradually returning to its turn of the century position.

The water-bearing rocks are in the upper strata of the Livermore formation; deeper strata are so impervious as to be insignificant producers of water. The depth to the present water table is highly variable, and in many cases these variations can be used to delineate fault zones.²²⁻²⁴ Some of this evidence will be discussed later.

GEOLOGIC HISTORY

The Livermore Basin began to form during late Pliocene time by folding and block thrusting between the Calaveras and other faults, on the western boundary, and a complex system of faults in the east.²⁵ Drainage off the surrounding hills deposited Cretaceous and Jurassic debris on the basin floor, which was then swampy and marsh-covered. This deposition

²⁵ We shall discuss these faults in detail in a following section.

marked the beginning of the Livermore series; the shales and sandstones underlying the marsh bed resulted in the Neroly series. At that time drainage from the valley was north through the San Ramon Valley. Judging from detailed stratigraphy of the Livermore formation this drainage was apparently blocked episodically, either as the result of landsliding or block faulting. When the drainage was open thick layers of gravel were deposited, and when blocked, the basin filled and covered the gravels with silts and sands which later consolidated into clay. We can reconstruct at least four such episodes from deep borehole data. By mid-Pleistocene the Sunol Valley had been block-faulted downward, and by late-Pleistocene the basin drainage had been captured in south-flowing Alameda Creek. The drainage became much more efficient as a result of regional uplifting and subsequent erosion and deposition of alluvial fill gave rise to the present landscape.

Site Geology And Structure

In the last section we considered the general aspects of the valley geology. Here we shall discuss the detailed structure and geology of the eastern edge of the valley as it applies to the earthquake hazard at the site.

SITE GEOLOGY

The site is at the eastern edge of the Livermore Valley near the western limb of the Altamont anticline. As Fig. 8 illustrates, the geology in this area is particularly diverse. The oldest rocks

in the area, the Franciscan, outcrop in the Diablo Range south of the site. These are overlain by successively younger strata toward the site. The Altamont anticline to the east is large. Cretaceous and Tertiary, while the site is on Quaternary alluvium.

SITE STRUCTURE

The geology indicates the structural complexity of the area. This is best illustrated with Fig. 9 which delineates most of the known faults in the Bay Area.

Fig. 8. Site geology.

The faults can be conveniently grouped in terms of their proximity to the site; those in the western part of the valley, in the central part and in the eastern part.

In the west is the Calaveras fault; the properties and seismicity of this fault were discussed earlier.

Crossing the center of the valley are the Livermore and the Mocho faults.

Fig. 9. (a) Faults in Bay Area.

Fig. 9. (b) Faults in the Livermore area (from Ref. 3).

Tesla Fault - 2nd Strand

This fault was located by gravimetric anomalies, breaks in seismic refraction arrival times, and observed soil displacements in trenches.³ The latter evidence is most persuasive in showing that the fault is still active. The trace of the fault out under the valley is not known, but it probably parallels the Tesla fault for some distance.

Tesla Fault

This well-defined fault is probably a remnant of the ancient Coast Range Thrust fault, although it may have modified during the upper Miocene.¹⁶ It separates Jurassic Franciscan rocks on the west from Cretaceous rocks on the east and has been located by surface morphology, magnetic anomalies, water table data, and logs from deep oil and gas

20,23,24 It is the northernmost segment of the Tesla-Ortigalita fault system. This system, composed of many faults of varying ages, runs along the eastern flank of the Diablo Range from the Livermore Valley to Panoche Valley.¹⁶ The northernmost extent of the fault is not known, but it certainly crosses the Livermore Valley, and may connect with the Stony Creek Fault north of the Delta region.^{4,5}

Ramp Thrust Fault

Evidence concerning this fault is scanty, but conclusive. Deep well drilling has revealed displacements on this fault, and there is evidence for surface faulting along its trace.³ The fault is certainly active although, as far as can be determined, a minor structure. There is no evidence that this fault extends under the site.³

Corral Hollow Fault

This fault branches from the Tesla fault 16 km southeast of the site. It has been located by infrared imagery, by gravity surveys, magnetic anomalies, deep drilling, and surface morphology.^{3,20} From the nature of the gravity survey, it has been concluded that the fault does not extend to the west beyond Greenville Road. It does not appear to be an active fault.

Doutherty Fault

This is another fault that was located by the comprehensive effort of J. A. Blume and Associates.³ It was located by infrared imagery, gravimetric and magnetic surveys, geodetic and water table data, and seismic refraction experiments.

The gravity data indicate that the block north of the fault is displaced upward relative to the south block. All evidence indicates that the fault is a minor structure which could be significant only in terms of surface faulting.

Carnegie Fault

This fault has been carefully delineated because of its proximity to the Livermore syncline and the oil production. Huey²⁰ mapped it as a high-angle thrust fault on the basis of surface morphology. It was subsequently better mapped by strong magnetic anomalies, deep well drilling and gravimetric anomalies.³ Displacement locally on the fault is in the same sense as on the Doutherty. This may represent sympathetic faulting on the relatively minor Doutherty fault. To the southeast, the fault truncates the Tesla fault where the motion is strike slip. This fault may be responding to the same tectonic stresses as the San Andreas system.¹⁶

Patterson Pass Fault

This fault, which was first recognized by Huey, has many characteristics in common with the Greenville fault. The two faults apparently merge to the northwest, although the Patterson Pass fault appears more like a branch of the Tesla fault.²⁰

Greenville-Riggs Canyon Fault

This fault was considered by Clark¹⁹ and Vickery²⁵ to be a major structural feature of the area. The connection between the Greenville fault on the south and the Riggs Canyon fault on the west flank of Mt. Diablo is not conclusive, but

persuasive. Evidence includes their alignment, the structural continuity, and some water table data. The Greenville component of the fault can easily be traced along the eastern edge of the valley by several slickenside surfaces and gouges, and a sag pond.²¹ The striations on the slickenside surface were horizontal, but the stratigraphy indicates that there is also a vertical component.

Fig. 10. Geologic cross sections through the site. (a) Cross section A-A'; (b) cross section B-B'.

relation of the syncline to surrounding features.

SEISMICITY

There is a great deal of evidence which indicates that the tectonic forces that induced this geologic and structural complexity are still operating on the valley today. We have already discussed the activity on the Calaveras fault; the other faults in the valley are equally seismic, at least in terms of earthquake frequency. Since 1900, over 120 seismic events have been located by the U. C. Seismic Station in the central and eastern reaches of the valley. Most of the events were less than magnitude 3.5, although there have been several magnitude 4.0 to 4.6 events (Table 3). In addition, there was a very large earthquake in the valley on July 4, 1861. Its exact epicenter is very uncertain, but it appeared to be most severe in Livermore (Intensity IX).⁶ This is a very important piece of evidence for it shows that the faults immediately around Livermore could support magnitude 6-7 earthquakes. Even the microearthquake activity provides interesting evidence, for it shows that the entire valley is readjusting to tectonic stresses. Geodetic level data^{3,26} has shown that the readjustment is lowering the valley floor and uplifting the surrounding hills. Geodetic data for horizontal creep is sparse,²⁶ but indicate that, at least at the western edge of the valley, there is a NW-SE shear stress acting on the valley. This stress is presumably related to the

regional NW-SE shear that the province is experiencing.

STATUS OF FAULTING AROUND THE SITE

We would like to define here the active/inactive status of each fault. There are several criteria available for defining this status. Because we are particularly interested in defining the earthquake hazard for AEC critical structures, we will follow the AEC guidelines from 10CFR, Part 100, Appendix A.²⁷ These guidelines tell us that a fault should be considered active if:

1. There has been movement at or near the ground surface at least once in the past 35,000 years or more than one in the past 500,000 years. In the absence of data permitting absolute dating, faults with recent enough movement to leave perceptible evidence of surface rupture, surface warping, or offset of geomorphic features are considered active faults.
2. There is instrumentally well-determined macroseismicity for a fault located in the continental United States west of the Rocky Mountain Front, or in Alaska, Hawaii, or Puerto Rico.
3. Or there is a relationship to an active fault according to characteristics (1) or (2) such that movement on one could be reasonably expected to be accompanied by movement on the other.

Clearly, several of the faults near the site must be classified as active by any standard; we include here the San Andreas, the Hayward, and the Calaveras faults.

⁶The intensity was derived by the U. C. Seismic Station.

Table 4. Faults considered active by AEC Guidelines.

Fault	Fault length (km)	Rupture length. (km)
San Andreas	1340	670
Hayward	250	125
Calaveras	250	125
Livermore	34	17
Mocho	34	17
Tesla	34	17
Ramp Thrust	17	8.5
Corral Hollow	25	12.5
Doutherty	8.5	4.25
Carnegie	25	12.5
Patterson Pass	13.5	6.75
Greenville - Riggs Canyon	42	21

Further, the geomorphic evidence discussed earlier classifies the Livermore, Greenville-Riggs Canyon, and second strand of the Tesla faults as active by criterion 1. There remain, however, several faults whose status cannot be defined by criterion 1:

- Mocho fault
- Ramp Thrust fault
- Corral Hollow fault
- Doutherty fault
- Carnegie fault
- Patterson Pass fault

The most recent movement on each of these faults cannot be dated with enough confidence to be declared active. Furthermore, there is no apparent geomorphic evidence to indicate that these faults are active. On the other hand, because the errors in locating epicenters is greater than the spacing between these faults, we

cannot attribute all the activity to just a few faults and assume that the rest of the faults are quiescent.

And in addition, geodetic evidence indicates that the depression and shearing of the entire valley is continuing today and that, therefore, there must be differential stresses across each of these faults. We can, therefore, conclude that all of the above listed faults can be considered active by criterion 3, as movement on the

- Livermore fault
- Greenville-Riggs Canyon fault
- Second strand of the Tesla fault

could reasonably be expected to produce movement on the formerly listed faults.

In summary, all of the faults listed in Table 4 are considered active per the AEC guidelines.²⁷

Seismologic Evaluation

The previous sections described the geologic history and the active or inactive status of faulting which could affect the Livermore site. In the following sections we will apply this information to an estimate of the earthquake hazard for the site. Rather than approaching this probabilistically, we will instead search for the worst possible earthquake that the site might experience. This earthquake will be used for design of critical structures, and is designated the Safe Shutdown Earthquake (SSE) for the site. We discuss the application of the SSE to the design and analysis of critical structures in a later section.

Calculationally and physically, the site response to earthquakes conveniently separates into two types. First, we consider the site response which results from shaking of the bedrock surface beneath the site. Here the surface response depends on the intensity of bedrock shaking and the properties of the soil layers which mantle bedrock. This response is clearly associated with earthquakes on more distant faults. Second, we consider the site response to surface rupture on very nearby faults.

However, before examining these two classes of site response, we need to characterize the potential earthquakes that might occur on each of these faults. We do this by first characterizing the earthquake source for each fault in a manner consistent with the known geology, and then associating each source with a maximum possible magnitude earthquake.

CHARACTERIZATION OF THE EARTHQUAKE SOURCE

Ideally, we would like to be able to predict a set of source parameters from the fault geology. For example, a convenient set might include:

- Length of rupture
- Offset
- Area of faulting surface
- Stress drop
- Rock strength

Knowing these properties of the source, we could then resort to empirical correlations to calculate a maximum magnitude earthquake associated with each fault. In practice, however, all of these properties except the rupture length are difficult to associate with the geology, and hence their estimates may contain large errors. Because of this, we will estimate only the rupture length. This is the length of a fault that ruptures in an earthquake and is usually determined by the length of surface rupture and the distribution of aftershocks. We, however, require a priori estimate of the rupture length and therefore we use the results of Alber and Smith.²⁸ Their analysis of California earthquakes showed that although there was a wide scatter in the ratio of rupture length to fault length,^{*} the ratio tended between 0.2 and 0.5. Guided by this, we

^{*} We want to emphasize here that the fault length is the total length of the fault and is defined by geomorphic features and alignment of earthquake epicenters. The rupture length is the length of the fault that slips in a given earthquake, and is determined by the length of surface rupture and the distribution of aftershocks. The surface rupture length is the surface expression of the rupture length.

take the rupture length of each fault to be one-half its total length.

In Table 4 we apply this concept to all the faults near the site. The fault lengths are our best estimates, based on seismic history and geologic and geomorphic evidence. We have uniformly taken the rupture length to be one-half the fault length. We will see later that our results are not sensitive to this ratio.

RUPTURE LENGTH AND EARTHQUAKE MAGNITUDE

Figure 11 summarizes the presently available data relating rupture length to magnitude. The points displayed, which are taken from Ref. 29, are empirical and theoretical. The empirical data are derived from the length of surface rupture and the distribution of aftershocks. The theoretical points are derived from surface wave spectral densities³⁰ and seismic movement calculations.³¹ Also shown is Housner's³² fit to these and other data.

Fig. 11. Rupture length and magnitude data.

We use this relation to relate a given rupture length to an earthquake magnitude.

We summarize in Table 5 our application of this relation to each of the faults that surround the site. The important observation here is that the magnitudes for the faults in the very near vicinity of the site are not very different, in spite of a relatively large variation in rupture length. This shows the insensitivity of the earthquake magnitude to our estimate of the rupture length.

We will now apply this information toward an estimate of the dynamic environment at the site as a result of earthquakes on each of these faults. We consider first the effects of bedrock shaking.

BEDROCK SHAKING

Response of the Site to Earthquakes on the San Andreas System

Our aim here is to calculate the dynamic environment at the site surface due to earthquakes on the San Andreas, Hayward, and Calaveras faults. We start by estimating the bedrock acceleration at the site resulting from maximum magnitude earthquakes on each fault. We then calculate the response of the surficial soil layers to these accelerations.*

Peak Bedrock Accelerations

What we require is data relating the attenuation of peak acceleration with distance as a function of magnitude. The

*The alternative to this procedure is to estimate the accelerations directly at the surface. We believe that these estimates would contain large errors as the empirical data available are inadequate to represent the LLL site.

Table 5. Relation of rupture length and magnitude for faults surrounding the LLL site.

Fault	Rupture length (km)	Magnitude (Richter)
San Andreas	670	8.3
Hayward	125	7.5
Calaveras	125	7.5
Livermore	17	6.5
Mocho	17	6.5
Tesla	17	6.5
Ramp Thrust	8.5	6.2
Corral Hollow	12.5	6.4
Doutherty	4.25	5.8
Carnegie	12.5	6.4
Patterson Pass	6.75	6.1
Greenville - Riggs Canyon	21	6.7

most current and comprehensive compilation of data has recently been presented by Schnabel and Seed³³; their interpretation of the data is summarized in Fig. 12. The accelerations were recorded on rock, and the distance is the shortest distance to the fault rupture.

In Table 6, we summarize the application of these curves to the San Andreas, Hayward, and Calaveras faults. Because the bedrock accelerations at the site are so similar, we will not continue to examine each fault individually, but instead we represent earthquakes on the San

Fig. 12. Earthquake acceleration attenuation (from Ref. 33).

Fig. 13. Taft N21°E accelerogram, scaled to 0.5 g.

Table 6. Relation of attenuation of peak bedrock acceleration to distance as a function of magnitude on three faults.

Fault	Magnitude (Richter)	Distance (km)	Peak bedrock acceleration at site (g)
San Andreas	8.3	58	0.4
Hayward	7.5	42	0.35
Calaveras	7.5	17	0.5

Andreas system by a single representative earthquake record. In our opinion the Taft record from 1952 Kern County earthquake (M7.7) is the most representative. The data (Fig. 13) were recorded at a range of 42 km and the magnitude is within the range of magnitudes estimated for the San Andreas system. Although the Taft record was not recorded on bedrock, we feel that the record nevertheless adequately captures the bedrock frequencies. We will, however, scale the accelerations to bedrock values. We shall search for the most severe response of the surface by calculating the response of the soil layers to several bedrock accelerations.

We will apply the waveshape in Fig. 13 to the base of the soil layers beneath the site, and we will calculate the soil response by a method described by Seed and Idriss.^{34,35} The method solves for the dynamic response of horizontally bedded layers to vertically incident shear waves by solving the equations of motion for an equivalent lumped mass system. By means of equivalent linear analysis, the method takes account of the mechanical nonlinearity of the soils.³⁴ The method assumes that the soil response is not modified by slumping hillsides or soil liquefaction. These are reasonable assumptions to apply to the site as the topography is nearly flat and liquefaction presents no hazard.³⁶

Input to the method is the mechanical properties of the soil layers. These layers were first investigated in 1971 by Shannon and Wilson Inc.³⁷ Based on a log from a 90-ft borehole, they concluded that bedrock was at 400 ft. Additional information from logs of deep oilwells²¹ has become available since their study.

Fig. 14. Soil layer geology to 1000 ft.

These latter logs indicate that the sands, gravels and clays, which are the principal constituents of the surface layers, continue down to a depth of about 1000 ft. Based on these data, we assume that the soil layers at the site are 1000 ft thick and have the properties given in Fig. 14.

Our calculations show that a bedrock acceleration of 0.5 g produces the most

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Fig. 15. Peak surface and peak bedrock acceleration.

severe surface accelerations (Fig. 15) and thus we present these results in detail in Fig. 16. Clearly the thick alluvial cover significantly attenuates the peak accelerations as well as modifying the frequency content of the waveshape.

EFFECT OF EARTHQUAKES ON NEARBY FAULTS

The distinguishing characteristic of earthquakes on the nearby faults is the effect of surface rupture. Whereas we could assume that for more distant faults the effects at the site would simply be shaking from below, here we must take into account the accelerations from nearby ruptures. We would expect that these accelerations could be very large simply because of the proximity of the source. There are indications, however, that the accelerations near surface ruptures are significantly higher than attenuation curves would indicate. This has been explained to be a result of the rupture interaction with the free surface.³⁸

There are two earthquake records that are useful in quantizing the site response. They are the accelerographs recorded during the Parkfield (M 5.5)

earthquake and the San Fernando (M 6.6) earthquake.

The Parkfield data are significant because:

1. The causative fault was right lateral strike slip (similar to what we expect near the site, based on regional tectonics and nearby geodetic measurements).
2. The data were recorded 200 ft from the surface rupture (many critical structures on the site are 200 ft or less from the Tesla fault).
3. The data were recorded on a thick layer of alluvium (the site is underlain by 1000 ft of alluvium).
4. The earthquake magnitude was 5.5 (in the range of magnitudes we estimate for very nearby earthquakes).

A peak acceleration of 0.5 g was recorded at Parkfield on a component transverse to the fault (Fig. 17). Although the component parallel to the fault malfunctioned and no data were recorded, 3.8 sec of the record has been reconstructed by Trifunac and Hudson³⁹ from seismoscope data by a calibrated technique. The reconstruction shows that the acceleration parallel to the fault was at least 0.6 g and that the vector sum of the horizontal components was at least 0.8 g.

The Pacoima Dam record, which indicated a peak acceleration of 1.25 g, is important because the station was only 4 km from the surface rupture and the earthquake magnitude was 6.6. The topography in the vicinity of the station was rugged, and this certainly amplified the peak acceleration. There have been several attempts to correct for this

Fig. 16. Soil response to the Taft record, scaled to 0.5 g.

amplification.⁴⁰⁻⁴³ These analyses indicate that the 1.25 g peak was amplified by as much as a factor of two, but the several cycles of 0.8 g accelerations represent unamplified bedrock accelerations (Fig. 18).⁴⁰

Fig. 17. Parkfield N65°E accelerogram scaled to 0.8 g.

Fig. 18. Corrected Pacoima Dam S74°W accelerogram. (The 1.25 g acceleration has been reduced to 0.8 g).

We can apply both of these data to the site by noting that other acceleration data indicate that close to the surface rupture:

1. The dependence of peak acceleration on magnitude is weak.⁴⁴
2. The correlation of peak acceleration with site geology is low.⁴⁵

In addition to the above data, there is some indirect evidence that is helpful. First, there are the order-of-magnitude calculations performed by Brune⁴⁶ and Ida⁴⁷ which indicate peak accelerations in the vicinity of the surface rupture can easily exceed 1 g. Second, there is some field evidence from near-epicentral damage studies that indicates accelerations greater than 1 g have already been experienced.^{48,49}

All these data, calculations, and observations clearly indicate that accelerations approaching 1 g are possible in near-epicentral regions for earthquakes of all magnitudes. In estimating the

Fig. 19. Response spectra from scaled Parkfield and corrected Pacoima Dam accelerograms, at 2% damping.

peak acceleration possible at the site we consider all these facts, but we place heavy emphasis on the Parkfield and Pacoima Dam records. Both these records indicated peak accelerations of around 0.8 g, and we take this as the peak acceleration that could be experienced at the site. We take the envelope of the Parkfield (N65E) and corrected

Pacoima Dam (S74W) response spectra as the response spectrum associated with this peak (Fig. 19) and we recommend that a synthetic seismogram be generated to represent the waveshape. The synthetic seismogram should have the property that its response spectrum closely matches the response spectrum shown in Fig. 19.

The Safe Shutdown Earthquake

We have considered the response of the site to two classes of earthquakes: those on the San Andreas system (the San Andreas, Hayward, and Calaveras faults) and those on the very nearby faults. The response of the site to each class of earthquakes was very different. For the San Andreas system, we calculate that the site will experience 0.32 g with the response spectrum shown in Fig. 16. For earthquakes on the nearby Tesla fault, we calculate that the peak acceleration at the site will be 0.8 g with the spectrum given in Fig. 19. These, in substance, are the results obtained in Ref. 2.

Our definition of the SSE would be similar to that given in Ref. 2. Because the accelerations from the very nearby faults are so much greater than the accelerations from the San Andreas system, we would recommend that the SSE response spectrum be taken as the envelope of the response spectra in Fig. 19. This spectrum is different both in shape and in peak acceleration, compared to the SSE (Fig. 20) given in Ref. 3. However, the Laboratory management,⁵⁰ after a careful evaluation of the SSE's in this report

Fig. 20. Response spectrum from Reference 3.

and in Refs. 2 and 3, has concluded that the degree of conservatism contained in this report and Ref. 2 is excessive. Their selection of the SSE and the SSE they recommend for inclusion in all SAR's for the site is the SSE in Ref. 3. For completeness, we have included a description of the SSE in Ref. 3 as Appendix A. This is taken directly from the original report.

We will extend this definition of the SSE by recommending a procedure to obtain the SSE waveshape. This waveshape should be a synthetic seismogram that has the property that its acceleration response spectrum closely follows the SSE spectrum in Fig. 20. We have not generated this synthetic seismogram, although there are standard techniques for doing this.

The application of the SSE to structures depends on their use and criticality. For this purpose the AEC has grouped structures, piping and equipment into three categories:

1. "Category I Structures, Piping and Equipment" are those structures, piping, and equipment whose failure or malfunction might cause or increase the severity of an accident which would affect public health and safety. Also included are those structures, systems and components necessary to the safe shutdown and isolation of the facility.

2. "Category II Structures, Piping, and Equipment" are those structures, piping, and equipment other than Category I Structures, Piping, and Equipment that are necessary for continued operation without undue risk to the health and safety of the public.

3. "Category III Structures, Piping, and Equipment" are those structures, piping, and equipment not necessary for continued safe operation and that are not in Categories I or II. Category I structures, piping and equipment are to be designed in terms of the SSE. Category II structures, piping, and equipment are less critical and, consistent with AEC guidelines, we recommend that these items be designed in terms of an Operating Basis Earthquake (OBE) whose spectral accelerations are one-half those given for the SSE. We have not considered here the design parameters for Category III items, as they are presently covered by the Uniform Building Code.

Summary

In response to the AEC request that we submit Safety Analysis Reports for all critical structures on the site, we have examined the seismic hazard at LLL in a form consistent with Section 2.5 of Ref. 1. We have thoroughly reviewed the geology and seismology of the Livermore Valley and surrounding regions. We have identified all the active faults in the region based on seismic history, geomorphology, and geodetic data. After carefully estimating the accelerations that the site would experience from

maximum magnitude earthquakes on each active fault, we conclude that the Tesla fault has the most potential for doing damage at the LLL site. The peak acceleration at the site will be taken as 0.5 g and the waveshape is assumed to have the acceleration response spectrum shown in Fig. 20. The waveshape corresponding to this response spectrum should be constructed synthetically.

We have covered all the applicable items in Section 2.5, with the exception of the risk associated with surface faulting.

Here the hazard is associated with large displacements that occur directly on the faults rather than with the accelerations that result from these displacements. The information presently available is

inadequate to assess this risk. Until this risk has been appraised, critical structures should be sited at least 330 m from the surface expression of the Tesla and Doutherty faults (Fig. 8).

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NOTES

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Appendix A – Seismologic Evaluation*

GENERAL STATEMENT

The prior Blume report of November 1971, which was prepared for Maher and Martens, Architects, of San Francisco, provided a seismologic evaluation for a proposed plutonium facility at the Lawrence Livermore Laboratory. This evaluation was not intended to be in complete compliance with the seismic and geologic siting criteria for nuclear power plants of the AEC. A discussion of seismic history, tabulation of earthquakes, and map of earthquake locations from the 1971 report are included in the Appendix.

One of the objectives of this investigation was to obtain the necessary geologic information to provide seismic design criteria which would be in compliance with the AEC Reactor Site Criteria (see Appendix 10 CFR Part 100). The seismic design criteria previously submitted were reviewed and revised in the light of the new information obtained during the course of this investigation.

The seismic design criteria previously presented were based upon large earthquakes located on more distant faults. The faults on which earthquakes were located for design purposes were the San Andreas, the Hayward, and the Calaveras. The scope of the prior seismic evaluation did not permit the investigation of the location or possible active status of faults in the alluvium near the LLL site. Results of this investigation indicate that

faults do pass through the alluvium near LLL and that these faults are apparently active.

FAULTS NEAR THE LAWRENCE LIVERMORE LABORATORY

The faults which have been identified and located near LLL have been described elsewhere in this report. Beginning south of the Laboratory they are the Tesla fault, consisting of three strands, the Corral Hollow fault, the Ramp Thrust fault, the Doutherty fault, and the Carnegie fault. The Carnegie fault was known prior to this investigation, but the locations and nature of the other faults have not been described in detail prior to this report. The Doutherty fault is a new fault. The Ramp Thrust fault appears to die out at the southeast corner of the LLL property and extends from there to the southeast. The Corral Hollow fault also appears to die out in this area or merges with the Tesla fault. The Doutherty fault has been traced over a distance of about 3 miles, and its eastward continuation would be intersected by the Carnegie fault which puts a definite limit on its possible length. The Corral Hollow fault is about 9 miles long.

The two larger faults which will govern for considerations of vibratory motion are the Tesla, passing southwest of the site, and the Carnegie, passing northeast. A third fault, the Greenville, ends in the hills east of the Laboratory beyond the Carnegie fault and extends from there northwestward. Huey (1948) states that the Greenville fault does not

*Excerpted from Ref. 3.

join the Carnegie, and that its possible connection with other faults to the northwest is very doubtful. He estimates displacement on the Greenville to be about 100 to 300 ft in the vertical direction. The horizontal component is unknown, but is probably not large. Therefore, it is concluded that the fault is not a major structure. The Carnegie fault is about 16 miles long from a point at its junction with the Tesla fault to an estimated point extending 4 miles across the alluvium of the Livermore Valley. Its surface trace is about 1 mile from LLL.

The Tesla fault is the largest fault with the nearest location to LLL, and evidence of its recent activity is more conclusive than in the case of the other faults. The Tesla fault strikes S80°E and continues to the southeast a distance of 11 miles from LLL, where it intersects a major fault trending N45°W. This is considered to be the southeasterly end of the Tesla fault, since it is highly unlikely that two faults such as these intersecting at an angle of 35 degrees would act as one fault in case of surface rupture or fault displacement. The northwesterly limit of the Tesla fault is not known, but appears to be well beyond the area which was investigated as part of this study. A conservative estimate for the northwesterly extension of the Tesla fault is 5 miles across Livermore Valley beyond LLL. The total length of the Tesla fault is therefore estimated to be approximately 16 miles.

MAGNITUDE AND ACCELERATION

To estimate the probable magnitude of an earthquake that might occur on the

Tesla fault, it is necessary to estimate the length of a surface rupture that could occur on such a fault. The distance over which the Tesla fault has controlled the course of Arroyo Seco Creek is about 4 miles. This might be considered indicative of the length of surface rupture for a single displacement. It would be unreasonable to presume that surface rupture might take place along the entire length of the fault simultaneously. A surface rupture length of 6 miles is considered to be a conservative estimate because it equals more than one-third of the total fault length. Data published by Bonilla (1967), relating length of surface rupture on the main fault to earthquake magnitude, show that an earthquake magnitude of 5.7 would be a conservative estimate for a 6-mile length of surface rupture on a reverse fault.

This earthquake of magnitude 5.7 is the Safe Shutdown Earthquake as defined in the reactor siting criteria. It is located on the Tesla fault at its nearest point to LLL. Allowing for an 80-degree south dip on the Tesla fault and a focal depth of 5 miles for the earthquake, the epicentral distance would be about 2-1/2 miles from the center of Section 12, which is occupied by LLL. Because this is a very close earthquake, it is necessary to estimate the peak ground acceleration by comparison with available records of peak acceleration at very small distances from the epicenter. A recent publication by Boore and Page (1972) reviews data relating to accelerations near faults that have moved during moderate-sized earthquakes. This paper, in addition to reviewing prior data, presents a compilation of data which

have become available in recent years and have not been compiled previously.

For an earthquake magnitude of 5.7 and epicentral distance of 2-1/2 miles, a conservative estimate of peak ground acceleration based upon the data of Boore and Page is 0.5 g. Therefore, as a result of this review, our prior estimate of maximum acceleration at the site of 0.4 g must be revised to 0.5 g.

DESIGN BASIS EARTHQUAKE SPECTRA

The attached spectra are recommended for the LLL site. These spectra are based on a standardized configuration tentatively approved by the AEC for nuclear power plants. This spectral shape is based on a report prepared by John A. Blume & Associates for Division of Reactor Licensing entitled "Evaluation and Recommendations for Shape of Earthquake Ground Motion Response Spectra Based on Statistical Analysis of Thirty-Three Earthquake Records" (Report draft submitted October 31, 1972, final report in preparation).

DETERMINATION OF NEED TO DESIGN FOR SURFACE FAULTING AND DETERMINATION OF ZONE REQUIRING DETAILED FAULTING INVESTIGATION

Strand No. 2 of the Tesla fault and the Dougherty fault are nearest to LLL facilities. Both pass through Sec. 12 which is occupied by LLL. Each of these faults has been located only as a single

trace of surface rupture, the width of which is unknown but could be estimated in each case to be on the order of 50 to 100 ft wide. This width would be the control width as defined in 10 CFR 100. For an earthquake magnitude of 5.7, the width of the zone requiring detailed faulting investigation is twice the control width or from 100 to 200 ft wide.

However, the requirement that all Quaternary fault traces along each fault for a distance of 10 miles in each direction from the site be mapped to establish the control width has not been met. Because the faults are not exposed the traces cannot be mapped in the usual sense, but can only be located by indirect geophysical means.

It is stated in 10 CFR 100 that the zone requiring detailed faulting investigation is a zone "in which the possibility of surface faulting is to be considered." This is interpreted to mean that the structure must be designed to resist surface rupture if located within this zone. It is further stated in 10 CFR 100 that if the zone requiring detailed faulting investigation is less than 1/2 mile in width when determined as above, the zone shall be at least 1/2 mile in width.

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SEISMIC AND
GEOLOGIC INVESTIGATION OF THE
SANDIA LABORATORY AT LIVERMORE

prepared for
Sandia Laboratories
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LINEAMENT STUDY

Several types of imagery were examined for visible evidence of possible active faulting near Sandia. Anomalous linear markings and discolorations that did not appear to be man-made (e.g., plowmarks, buried pipelines, or abandoned roads) or by known geologic structure were compiled in Figure 5. Evidence of this kind is suggestive but not conclusive of faulting and should be verified by other geotechnical methods.

Air photos were studied in stereo on a scale of 1:20,000 (flown in May 1966) and on 1:1,250 enlargement (flown in May 1976). Several sets of lineaments were observed. The most prominent of these were the Tesla No. 2, Tesla No. 3, and Las Positas lineaments. The Las Positas approximately parallels the PG&E gas line and possible old pipeline routes near the base of the gentle hillside in the southern part of the Sandia property. Distinct lineations were observed about 1-1/2 mi to the southwest of Sandia, trending approximately northeast. However, they do not clearly connect as a throughgoing feature. Several lineaments were observed trending east-northeast obliquely across Tesla Road south of Sandia. These closely follow old trails and the base of the hill.

Infrared (IR) scanner imagery lines were examined. These film strips (flown in 1972) included imagery of heat radiation at three wavelengths, flown both in the afternoon and at night and at altitudes of 500 and 4,000 ft above the ground surface.

Strong lineations on the nighttime IR imagery were observed corresponding to the general trend of the Las Positas of about 2 mi southwest of Sandia. This lineament trends northeast bounding a dark area on its northwest side. Dark areas indicate cooler temperatures on infrared imagery, possibly due to higher soil moisture content. One possible interpretation of this lineament is a groundwater barrier with higher water levels on the northwest side toward the Livermore Valley. However, this explanation does not seem satisfactory because it appears that groundwater recharge would be from the south and water draw down from the north; thus, the lowest water depth should be to the north.

The Tesla No. 2 and Tesla No. 3 were not observed on night IR. However they appeared on afternoon low-altitude IR imagery, and the Las Positas did not.

High-altitude U2 false-color Infrared imagery at a scale of 1:120,000 (flown in 1971) showed a faint lineation roughly corresponding to the Tesla No. 3 and another unrelated trend 1 mi northwest of Sandia.

Side-looking radar imagery (SLAR) at a scale of 1:400,000 showed a strong lineament corresponding to the Las Positas trend several miles southwest of Sandia. Diffuse lineaments possibly on line with the Tesla No. 2 and Tesla No. 3 were observed to the southeast.

Lineament data is summarized in Table 1. This comparison shows that the Las Positas is the most prominent of the linears that intersect Sandia. The most distinct portions of this trend lie more than a mile to the southwest, but do not clearly connect with the Las Positas lineament identified at Sandia. Several types of photography indicate a Tesla No. 3 lineament. Evidence for the Tesla No. 2 lineament is weaker but was confirmed on IR imagery.

TABLE 1
COMPARISON OF LINEAMENTS NEAR SANDIA

Imagery	Approximate Scale	Tesla No. 2	Tesla No. 3	Las Positas	
				North	South
Air Photo	1:1,250	+	+	+	+
Stereo Photos	1:20,000	0	+	+	+
IR (afternoon)	1:10,000 to 45,000	+	+	0	0
IR (night)	1:40,000	0	-	++	0
IR-Stereo (false color)	1:120,000	-	-	-	-
SLAR	1:400,000	0	0	-	+

Key:

++ strong lineament

+ lineament observed

0 diffuse lineament or not consistently locatable

- no lineament observed

EXPLORATORY TRENCHING

General Statement

A program of exploratory trenching was undertaken on January 25, 1978, at Sandia. The purpose of trenching was to expose and evaluate subsurface evidence of faulting along the trace of the reported Las Positas fault. One trench was also excavated on the probable location of the Tesla fault. The trench locations shown in Figure 6 were selected to intersect lineaments and features distinguished by examination of air photos and imagery, from geophysical surveys conducted for this study, and from findings of a geotechnical investigation by URS/Blume (1972) and the USGS (Herd, 1977).

The trenching revealed inconclusive evidence of faulting along the lineament identified as the Las Positas fault by Herd and did not reveal any evidence of faulting in the trench that was intended to transect the Tesla fault.

Field work consisted of visual examination of the soils and logging of trench walls on a scale of 5 ft/in. Logs of the soils observed in the trenches are compiled in Appendix A. Selected trench wall details are shown in Figures 7a through 7d. A complete color photographic record is available for inspection.

Trench excavation was accomplished with a Case 580-B rubber-tired backhoe. This machine, which has a maximum depth reach of about 14 ft, was used to excavate eleven trenches totaling 1,047 ft in length and ranging up to 13-1/2 ft in depth. The dimensions of the trenches are listed in Table 2.

Elevation control was provided by a topographic survey conducted by Sandia during late January 1978.

General Description of Soils

The subsurface soils exposed in trench excavations were found to consist primarily of dense brown sandy gravel with fines of about 5% cobbles and boulders (GM). Sand and clay content varied so that smaller interfingering lenses of clayey gravel (GC) and gravelly sand (SW) were common. Distinctive

FIGURE 6 SITE PLAN SHOWING EXPLORATORY TRENCH LOCATIONS

LEGEND

- well defined contact
- - - gradational contact
- ... diffuse contact

FIGURE 7a PORTION OF LOG OF EXPLORATORY TRENCH T2
ACROSS LAS POSITAS TRACE

LEGEND

- well defined contact
- - - gradational contact
- ... diffuse contact

FIGURE 7b PORTION OF LOG OF EXPLORATORY TRENCH T3
ACROSS LAS POSITAS TRACE

FIGURE 7c PORTION OF LOG OF EXPLORATORY TRENCH 16
ACROSS LAS POSITAS TRACE

FIGURE 7d PORTION OF LOG OF EXPLORATORY TRENCH T10
ACROSS LAS POSITAS TRACE

TABLE 2
EXPLORATORY TRENCH DIMENSIONS

Trench No.	Length (feet)	Average Depth (feet)	Date
T1	204	12	1/26/78
T2	171	12-1/2	1/27/78
T3	71	7-1/2	1/30/78
T4	104	12-1/2	1/31/78
T5	111	12-1/2	1/31/78
T6	115	12	3/29/78
T6a	35	*	--
T7	40	11-1/2	4/05/78
T8	37	11	3/30/78
T9	72	12-1/2	4/01/78
T10	87	12-1/2	4/05/78

*Trench caved before it could be secured for logging.

lenses of light yellow-brown cohesive fine sand (SM-SC) were also found in some of the trenches.

A soil layer varying from about 1 to 4 ft thick unconformably overlies these gravelly materials. The unconformity surface at the base of the soil horizon was found to be undulating and generally deeper and less distinct toward the north. At the northern ends of some of the trenches, the change with depth from soil to underlying gravel was gradational.

Exploratory Trenching, Tesla Fault

Trench T1 was excavated to explore the most probable location for the Tesla fault as determined in prior studies by URS/Blum and from the results of the gravity survey performed during this investigation. The gravity data, described elsewhere in this report, are compatible with a fault striking along Arroyo Seco Creek, along which the south side had moved upward. The trench was located so as to transect this gravity anomaly.

The Tesla fault was not exposed in this trench; however, a great deal of evidence, discussed elsewhere in this report, indicates that the fault is present in the subsurface.

Trench T1 was begun about 150 ft east of the Tritium Building and extended 204 ft in a northeasterly direction (see Figure 6). Horizontally stratified alluvial sediments were revealed, and there was no visible evidence indicating the presence of a fault.

Exploratory Trenching, Las Positas Alignment

The possible trace of the Las Positas fault was explored by excavating four trenches 300 to 400 ft southeast of the Tritium Building and oriented south-eastward across the projected alignment (see Figure 6). Trenches T2, T4, and T5 exposed suggestive but inconclusive evidence indicating the presence of a possible fault zone approximately paralleling the 675-ft elevation contour.

Trench T3 was excavated across a slight topographic depression. This trench was a short distance south of Trench T2 and revealed normally stratified alluvial sediments only.

A second series of trenches was excavated across the Las Positas lineament in the area about 400 ft due south of the Tritium building. No evidence to suggest faulting was found in four of these trenches (T6, T7, T9, and T10). Some features suggestive of faulting were found in trench T9. However, these were inconclusive and less pronounced than the features observed in trenches T2, T4, and T5.

The lineament approximately coincides with the location of a buried PG&E gas main in the vicinity of trench T7 and it therefore could not be extended far enough to the south to be certain of intersecting the desired alignment.

Trench Features Indicative of Possible Faulting

Visible evidence suggestive but not conclusive of faulting was found in four of the eight trenches across the Las Positas alignment. The evidence is categorized below:

1. Silty fine sand strata were found to terminate abruptly against gravelly beds in three trenches -- T2, T4, and T5 (see trench logs).
2. Thin clayey lenses with near-vertical orientation were found in trench T9 in the vicinity of the lineament. Bedding planes in T9 were approximately horizontal.
3. Tabular gravel clasts were found with their long axes oriented approximately vertical near the possible fault zone, whereas elsewhere they were found lying essentially horizontal. Clusters of these vertical clasts were found in four trenches (T2, T4, T5, and T9).
4. Downward-curving contacts and faint discolorations oriented in such a way that the curvature could be explained as being due to drag on a fault were observed in two trenches (T4 and T5).
5. Small water seeps were found within the possible fault zone in trench T2. However, seepage unrelated to possible faulting was found in other trenches (e.g., T7).
6. There was a tendency for the trench walls to cave within the possible fault zone in three trenches (T2, T4, and T5). However, troublesome caving unrelated to disruption also affected trenches T6, T6a, T8, and T9, apparently due to a local lack of cohesive binder in the soils.

7. The topsoil layer was found to be notably thinner and more abundant in gravel and cobbles upslope of the possible fault alignment. Soil variations of this kind were found in trenches T2, T4, T5, and T9. Similar concentrations of cobbles occurred in trenches T6 and T10 with no apparent relationship to a possible fault.

Observations Arguing Against Significant Faulting

No conclusive evidence of a fault motion was found along the Las Positas alignment. Nowhere within the depths explored were there features normally associated with a fault plane, such as a fault gouge or slickensided material. Vertical clasts did not show signs of post-depositional rotation. Close inspection of the contacts bounding abruptly terminated beds revealed that the contacts were not sharply defined or sheared.

An apparently unbroken and conformable sequence of northward-dipping beds was found in four of the eight trenches across the lineament (T6, T7, T8, and T10). In these trenches, there was a fairly distinct contact between the topsoil and the underlying gravel beds. No offset was observed on this apparent unconformity surface.

These observations indicate that if the Las Positas fault exists, its trace is discontinuous at least in the near-surface soils. The anomalous features observed in some of the trenches suggest but do not require a fault explanation. Other processes could be called upon -- for example, basin subsidence or progressive folding and fracturing of the bedrock along an axis parallel to the valley margin.

Water Line Trench

A shallow trench was dug for placement of a water main along the entire western margin of the Sandia property. Most of the trench was 6 ft in depth and ranged up to 8 ft deep in some locations. The excavation between stations 700 and 3,400 was inspected during construction and photographed for later examination. No signs of faulting were observed.

The area crossing the Las Positas alignment was of particular interest. Near station 3,320, about 150 ft south of the PG&E gas line, the trench revealed

a light brown gravelly unit dipping gently northward beneath dark brown topsoil. This dipping contact was observable and continuous over a length of about 40 ft. No signs of faulting were observed.

Conclusions

Tesla Fault. No evidence of faulting was found within the depths explored; therefore, the hazard of surface fault rupture is considered to be very remote.

Los Positas Fault. Although positive evidence of a fault (such as a fault gouge, a zone of slickensided material, or a clear-cut line of separation) was not found within the depths explored, other features seen in trenches T2, T4, and T5 suggest the presence of a fault zone, and the potential hazard of surface fault rupture along the fault trace must be regarded as a real possibility.

However, the trend of this possible fault as determined by the exposures in trenches T2, T4, and T5 indicate that it lies some distance south of the Sandia Tritium Building. If surface fault rupture should take place along this possible fault tract, it would not affect the Tritium Building.

GRAVITY SURVEY

Field Procedures

A gravity survey was carried out near Sandia in the southeastern portion of Livermore Valley during two periods: November 12 to 16, 1977, and March 3 to 14, 1978. The purpose of this survey was to determine whether evidence of faulting could be discovered by means of variations of gravity along the Las Positas trace proposed by Herd (1977) as well as along projections of the Tesla fault traces in the vicinity of the Tritium Building (URS/Blume 1972). The second survey was carried out to augment data from the first, as well as to look for small-scale gravity anomalies along that part of the possible Las Positas fault in the vicinity of the Tritium Building and where it intersects the Sandia's restricted area.

The survey was composed of four traverse lines along roads bordering the Sandia property on the east and west: four traverse lines trending north-south in the Sandia restricted area, one traverse line parallel to one of the exploratory trenches excavated to the east of the restricted area, and a 13-by-13-station grid which encompassed a $1/2\text{-mi}^2$ area centered on the Tritium Building. The locations of the road traverse lines and grid are shown in Figure 8, and the locations of the traverse lines internal to the Sandia property are shown in Figure 9. The purpose of the grid was to obtain a high-resolution picture of any possible subsurface density contrasts caused by fault displacements within the grid area.

The data were obtained using a La Coste Romberg gravimeter in both surveys. In the first survey (November 1977), the instrument drift rate was determined by using closure on three separate road lines (J, E, and D), and a computer program was used to remove tidal gravity variations due to the moon and sun.

In the second survey (March 1978), the lines were close sufficiently often to reference or base stations to allow for a correction involving both instrumental drift rate and tidal variations. In both surveys, the instrumental accuracy on hard surface (e.g., asphalt) was found to be ± 0.01 mgals, and ± 0.08 mgals on softer surfaces (e.g., soil and grassy surfaces) and in areas where there was a large noise component (wind, cars, etc.).

FIGURE 8 LOCATIONS OF GRAVITY SURVEYS, LINEMENTS, FAULTS, AND POSSIBLE FAULTS

FIGURE 9 GRAVITY SURVEY LINES, SANDIA

Elevations of stations where measurements were made were determined to an accuracy of ± 0.03 ft for both surveys, using a Zeiss level and Philadelphia rod.

Data Reduction

Data reduction consisted of the following procedures:

1. Removal of instrumental drift rate and tidal variations.
2. Calculation of the free-air and Bouguer plate corrections to obtain the simple Bouguer anomaly.
3. Removal of the best-fitting linear regional trend from the data (by a least-squares computer program) to obtain the residual anomaly.
4. Graphical portrayal of the residual anomalies and station elevations to determine the importance of terrain effects, as well as to identify and describe any significant gravity anomalies.
5. Graphical portrayal and inspection of the residual anomaly data to determine whether any correlation exists with locations of possible fault traces.

Description of Data

Following is a description of residual anomalies and their locations for each of the traverse lines and for the Sandia grid. Residual anomaly plots are shown in Figures 10a through 10j. The layout of the gravity grid and the anomaly patterns observed are shown in Figures 11 and 12.

1. J-Line: length = 1,600 ft; station spacing = 50 ft; rms deviation of residuals = 0.061 mgals.

Observations: Bouguer gravity shows a decrease to the north of approximately 1.05 mgals, with a modest downward curvature. The best-fitting linear gradient was found to be approximately 6.8×10^{-3} mgals/ft. The residual anomaly plot shows no significant anomaly patterns.

2. E-Line: length = 2,400 ft; station spacing = 50 ft; rms deviation of residuals = 0.068 mgals.

Observations: Bouguer gravity shows a decrease to the north of approximately 2.2 mgals, with a slight downward curvature. The best-fitting linear gradient was found to be approximately 1.02×10^{-3} mgals/

FIGURE 10a PROFILE OF RESIDUAL GRAVITY ALONG NORTH D-LINE

FIGURE 10b PROFILE OF RESIDUAL GRAVITY ALONG SOUTH D-LINE

FIGURE 10c PROFILE OF RESIDUAL GRAVITY ALONG E-LINE

FIGURE 10d PROFILE OF RESIDUAL GRAVITY ALONG J-LINE

FIGURE 10e PROFILE OF RESIDUAL GRAVITY ALONG K-LINE

FIGURE 10F PROFILE OF RESIDUAL GRAVITY ALONG L-LINE

FIGURE 10g PROFILE OF RESIDUAL GRAVITY ALONG M-LINE

FIGURE 10h PROFILE OF RESIDUAL GRAVITY ALONG N-LINE

FIGURE 10: PROFILE OF RESIDUAL GRAVITY ALONG 0-LINE

FIGURE 103 PROFILE OF RESIDUAL GRAVITY ALONG P-LINE

200 100 0 200 400 ft
 Scale

FIGURE 11 GRAVITY SURVEY GRID, SANDIA

FIGURE 12 SANDIA GRID, CONTOUR MAP OF RESIDUAL GRAVITY ANOMALY

ft. There is a significant anomaly located approximately 1,100 ft north of Tesla Road on Vasco Road. The anomaly has a maximum variation of approximately 0.20 mgals and a wavelength of approximately 200 ft and indicates a substantial decrease in g towards the north; it appears to be the only significant anomaly on this line.

3. South D-Line: length = 1,900 ft; station spacing = 50 ft; rms deviation of residuals = 0.141 mgals.

Observations: Bouguer gravity shows a decrease to the north of approximately 2.65 mgals, with a slight downward curvature. The best-fitting linear gradient was found to be approximately 1.68×10^{-3} mgals/ft. There is a significant anomaly located approximately 550 ft north of the crossing of Arroyo Seco and Greenville Road. The anomaly has a maximum variation of approximately 0.38 mgals and a wavelength of approximately 250 ft and indicates a moderate decrease in g toward the north. The minimum in g at Arroyo Seco is most likely a terrain effect associated with the creek, as the measurement was taken on the highway bridge, approximately 12 ft above the creek bed. The anomaly described above appears to be the only significant anomaly on this portion of the D-Line.

4. North D-Line: length = 1,200 ft; station spacing = 50 ft; rms deviation of residuals = 0.044 mgals.

Observations: Bouguer gravity shows a decrease to the north of approximately 1.2 mgals, with little curvature. The best-fitting linear gradient was found to be approximately 1.02×10^{-3} mgals/ft. There is a moderately large anomaly, in the form of a minimum in g, located approximately 350 ft south of East Avenue on Greenville Road. The anomaly has a maximum variation of approximately 0.06 mgals and a wavelength of approximately 250 ft and indicates a minimum in g, as noted above. This anomaly appears to be the only significant anomaly on this portion of the D-Line.

5. K-Line: length = 1,200 ft; station spacing = 50 ft; rms deviation of residuals = 0.085 mgals.

Observations: Bouguer gravity shows a nonuniform decrease to the north of approximately 1.3 mgals, with little curvature. The best-fitting linear gradient was found to be approximately 1.34×10^{-3} mgals/ft. There are no significant anomaly patterns that have amplitudes differing significantly from the overall variation in g along this line. The modest gravity minimum in the vicinity of Arroyo

Saco is most likely a terrain effect associated with the depressed stream bed.

6. L-Line: length = 400 ft; station spacing = 10 ft; rms deviation of residuals = 0.031 mgals.

Observations: Bouguer gravity shows a uniform decrease to the north of approximately 0.40 mgals, with little evidence of curvature. The best-fitting linear gradient was found to be approximately 1.0×10^{-3} mgals/ft. There is a small anomaly, in the form of a minimum in g, located approximately 75 ft north of the PG&E gas pipeline. The anomaly has a maximum variation of approximately 0.14 mgals and a wavelength of approximately 60 ft. There are no other significant anomalies on this line.

7. M-Line: length = 340 ft; station spacing = 10 ft; rms deviation of residuals = 0.019 mgals.

Observations: Bouguer gravity shows a systematic decrease to the north of approximately 0.29 mgals. The best-fitting linear gradient was found to be approximately 8×10^{-4} mgals/ft. There are no significant anomalies on this line.

8. N-Line: length = 380 ft; station spacing = 10 ft; rms deviation of residuals = 0.023 mgals.

Observations: Bouguer gravity shows a systematic decrease to the north of approximately 0.39 mgals. The best-fitting linear gradient was found to be approximately 1.1×10^{-3} mgals/ft. There appears to be a small anomaly, in the form of a maximum in g, located near the midpoint of this line; however, there appears to be a modest downward curvature in the residual anomaly data, so that the departure of the anomalous maximum from the mean may not be significant. There are no other significant anomalies on this line.

9. O-Line: length = 600 ft; station spacing = 10 ft; rms deviation of residuals = 0.029 mgals.

Observations: Bouguer gravity shows a fairly uniform decrease to the north of approximately 0.67 mgals. The best-fitting linear gradient was found to be approximately 1.2×10^{-3} mgals/ft. There are no obvious anomaly patterns along this line, although there may be some indication of a feature approximately 80 ft north of the PG&E gas pipeline.

10. P-Line: length = 300 ft; station spacing = 10 ft; rms deviation of residuals = 0.047 mgals.

Observations: Bouguer gravity shows a fairly uniform decrease to the north of approximately 0.41 mgals. The best-fitting linear gradient was found to be approximately 1.4×10^{-3} mgals/ft. There

appears to be an anomalous step-increase in g towards the south, approximately 120 ft south of the beginning of this line, with maximum variation and wavelength of approximately 0.09 mgals and 40 ft, respectively. The location of this anomaly appears to coincide closely with a vertical contact between sand and denser gravels found in trench T2 (see discussion on exploratory trenching in previous chapter). There are no other significant anomalies on this line.

11. Sandia Grid: dimensions = 2,400 ft x 2,400 ft; station spacing = 200 ft; rms deviation of residuals = 0.130 mgals.

Observations: Bouguer gravity shows a general decrease from southeast to northwest across the grid, with some downward curvature in both the southeast-northwest and southwest-northeast directions. The best-fitting linear gradient was found to be approximately 8.8×10^{-4} mgals/ft (north-south) and 6.18×10^{-4} mgals/ft (east-west). The residual anomaly map (Figure 12) shows several distinct features:

- a. There are local gravity "highs" in the northwest and southeast portions of the grid area, and gravity "lows" in the southwest and northeast portions, reflecting the fact that the gravity surface possesses curvature of second, and possibly higher, order. The decrease in g to the northeast may be a reflection of the "Livermore syncline" which is located to the northeast of the grid area, with an axis striking west-northwest. The decrease could also be related to possible density contrasts caused by the Tesla fault, the major strand of which approximately coincides with Arroyo Seco in this area. The significance of the + and - residuals is due partly to the manner in which the best-fitting plane was found, and partly to real lateral density inhomogeneities.
- b. The most prominent feature on the map is an east-northeast trending linear feature running through the southern portion of the grid area. This feature is characterized by an abrupt decrease in gravity from southeast to northwest of approximately 0.10 mgals over a horizontal distance of roughly 200 ft. There is a strong correlation between the gravity contours associated with this feature and the topographic

contour lines associated with the range of low hills bordering the southern portion of the Sandia property.

- c. The linear feature described in (b) terminates abruptly at its northeast end, being intersected by a north-northwest striking feature that is characterized by gravity decreasing from southwest to northeast. Once again, the southeast-trending gravity contour lines closely parallel the topography of the eastern part of the Sandia grid area.
- d. The linear feature described in (b) strikes almost due south of its southwest end at the southwest corner of the grid area. This trend does not correlate strongly with local topography, which strikes to the southwest beyond the grid area.
- e. There is a general gravity low, in the rough shape of a trough, which trends northeast, just north of the linear feature described in (b).

Regional Gravity Model

The most complete picture of gravity near Sandia is given by the USGS open-file Bouguer anomaly map of the Livermore Valley area (Holden, 1976), which is reproduced in part in Figure 13. Mean gravity gradients were calculated from this map and compared with gradients determined from the URS/Blume survey for corresponding locations. The results of this comparison are shown in Table 3. Examination of this table shows that the mean gradients determined from the URS/Blume survey by means of linear least-squares fitting to the data are within approximately 10% to 15% of the corresponding gradients obtained from the USGS map except for the K-Line, in which the discrepancy is ~30%. The overall southeast-northwest linear regional gradient determined from both sources lies between 5×10^{-4} mgals/ft and 8×10^{-4} mgals/ft.

An attempt was made to account for the overall regional trend in the gravity by means of simple density contrast models. The first model along with the computed gravity associated with it is shown in Figures 14a and 14b. The model assumes a basement of Franciscan rock dipping to the northwest at 20° . The basement is assumed to outcrop approximately 4 km southeast of

FIGURE 13 COMPLETE BOUGER ANOMALY MAP OF THE LIVERMORE VALLEY AREA

TABLE 3
DATA FROM URS/BLUME GRAVITY SURVEY (NOVEMBER 1977, MARCH 1978)

	Mean Gravity Gradients	Data Taken from USGS Bouguer Anomaly Map (1976)
E-Line	1.02×10^{-3} mgals/ft	$\approx 1 \times 10^{-3}$ mgals/ft
South D-Line	1.68×10^{-3} mgals/ft	$\approx 1.9 \times 10^{-3}$ mgals/ft
North D-Line	1.02×10^{-3} mgals/ft	$\approx 1 \times 10^{-3}$ mgals/ft
K-Line	1.34×10^{-3} mgals/ft	$\approx 1.8 \times 10^{-3}$ mgals/ft

FIGURE 14a DIPPING BASE MENT MODEL FOR SOUTHEAST LIVERMORE VALLEY

FIGURE 14b DIPPING BASEMENT MODEL

Sandia, and a density contrast of 0.20gm/cm^3 is assumed between the basement rock and the overlying gravels and alluvium. The dip angle was determined from the URS/Blume report (1971), and the density contrast was determined from well data in the area between the Franciscan outcrop and the Sandia property. The mean gradient determined from the graph in Figure 14b at a position 4 km to the northwest of the outcrop ($x = 0$) is approximately 7×10^{-4} mgal/ft.

Thus, the regional gradient near the URS/Blume survey can be reasonably well explained in terms of a simple dipping basement, as described in Figure 14a.

Fault Models

Data from the 1972 URS/Blume report also indicated the possibility of a reverse fault (see plate 4, Appendix A) located along the reported Las Positas fault trace. This possibility stemmed from the observation that an exploratory well called the Pestana well, located north of the trace, showed the basement rock to be nearly $1/3$ km closer to the surface than the corresponding basement horizon determined from wells approximately $1-1/2$ mi to the south of the trace.

A model was assumed, consisting of a vertical offset in the basement rock (with the north side 0.33 km higher than the south side), once again in the presence of a dipping basement. The model and calculated gravity are shown in Figures 15a and 15b. The calculations imply that the regional gravity in the vicinity of the Las Positas trace would be increasing to the north, exactly the opposite of what is actually observed. Thus, with the structure assumed from the well data, along with the density contrast quoted above, a reverse fault below the Las Positas lineament seems extremely unlikely. Further examination of the well data indicates that identification of features in the Pestana well was based strictly upon cuttings brought to the surface. Our review of the well log indicates that identification of Franciscan bedrock near the bottom of the hole is questionable at best and probably erroneous.

FIGURE 15a REVERSE FAULT MODEL FOR SOUTHEAST LIVERMORE VALLEY

FIGURE 15b CALCULATED GRAVITY FOR REVERSE FAULT MODEL

An analysis was made to consider whether or not a normal fault might exist beneath the Las Positas lineament in the Franciscan basement assemblage. Here matters were much more speculative, as the offset of a steeply dipping normal fault could be only estimated, the density contrast being the only likely reliable figure. As shown in Figures 15c and 15d, for a depth of 1.46 km to an assumed offset of 1.0 km, the mean slope above the fault is changed from its value in Figure 14b by less than 15%. Thus, it appears that, even with a fairly substantial offset, the presence of a normal fault confined to bedrock and displacing an inclined bedrock surface at depth would be difficult to prove on the basis of gravity survey data.

Near-Surface Anomalies

The anomalies that were located in the course of the URS/Blume survey, with their smaller amplitudes (tenths of a milligal) and wavelengths (hundreds of feet) would generally reflect variations in structure and density considerably closer to the surface than the depths assumed for the basement rock. In the case of an active fault, offsets will exist in the medium above the basement (rocks of Tertiary age) as well as in the basement itself. However, the very low density contrast within the tertiary formations ($.1 \text{ gm/cm}^3$), together with their highly heterogeneous composition, makes the likelihood that they would generate large gravity anomalies at the surface very low. Thus, it will be assumed for the purpose of discussion that the anomalies located are representative of near-surface density variations within 200 ft.

The large anomaly on the E-Line together with the smaller anomaly on the north D-Line both fall within 50 ft of the Las Positas trace proposed by Herd (1977). In addition, the linear feature running through the Sandia grid coincides closely with the reported Las Positas fault trace. However, it must be noted that both the E-Line and north D-Line anomalies occur right at mapped locations of contacts between surficial material so that the possibility exists that these anomalies could be caused in part by density variations present at these contact surfaces.

The three separate gravity anomalies along the reported Las Positas fault trace, on the E-Line, the D-Line, and across the grid suggest that there

FIGURE 15c NORMAL OFFSET MODEL

FIGURE 15d NORMAL FAULT MODEL FOR VERTICALLY DIPPING NORMAL FAULT AT LAS POSITAS TRACE

may be a more or less continuous anomaly along the trace, interrupted locally where crossing Arroyo Seco and perhaps elsewhere. This line also coincides with a break in slope where the alluvial floor of Livermore Valley meets hills rising to the south. Even on the E-Line, where the topography is very subdued, a break in slope is evident.

The geologic structure of the area also parallels the northeast trends. Geologic mapping indicates that the Livermore gravels making up the hill to the south strike parallel to the hill and to the gravity anomaly. Beds along the north side of the hill have a dip slope, and the hill comprises the north flank of an anticline. The area within a few hundred feet of the base of the hills would probably be underlain by north-dipping strata of the Livermore gravels, which have been eroded off and covered by a thin blanket of alluvium. Because these strata have been eroded away leaving resistant gravels on the hill in place, it appears that there is a contrast in resistance to erosion. This contrast is also probably accompanied by contrasting densities. An example would be the poorly cemented fine silty sand seen in the trenches compared to the more dense consolidated gravels exposed on the hill.

Depositional contacts between such contrasting beds coinciding in strike and location with the gravity anomaly could have produced the observed anomaly. This model -- Figure 16 (a and b) -- is compatible with the amplitude and wavelength of the observed anomaly.

The large anomaly on the south D-Line falls close to both the Tesla No. 2 (URS/Blume, 1972) and an unnamed southern fault proposed by Herd (1977). In the absence of additional evidence, the significance of this anomaly cannot be addressed. However, the decrease in g from south to north is consistent with the sense of motion that has been assumed for the Tesla No. 2 fault but is inconsistent with movement downward to the south as suggested by Herd (1977).

While the anomaly located on the P-Line did seem to coincide with the contact found in trench T2, the absence of any significant anomalies along

a. Theoretical Gravity Profile

b. Model

FIGURE 16 GRAVITY PROFILE FOR ANTICLINAL STRUCTURE

the Las Positas trace on lines L through O would seem to imply that if there is near-surface faulting in the Sandia restricted area, it is discontinuous.

Conclusion

The results of the recent gravity survey carried out by URS/Blume coincide quite closely on a large scale with the regional picture supplied by the USGS Bouguer anomaly map of the area. The mean regional gradients from both sources agree to within 10% to 15%. These regional gradients can be adequately explained in terms of a basement rock of the Franciscan assemblage dipping at approximately 20° to the northwest beneath the alluvium and gravels of the Livermore Valley.

The USGS Bouguer anomaly map implies that there is a high-density region extending northwest into the southeastern corner of Livermore Valley. Such an interpretation is consistent with the existence of a northwest-plunging anticlinal structure, in which the Franciscan basement has been uplifted in this region through the action of northwest-striking folding and possibly faulting.

The Las Positas trace cuts across the Bouguer anomaly contours (see Figure 13) throughout most of the segments designated A and B. Along Segment A, the trace passes through a region in which the gravity gradient is very small, so that a normal offset in basement rock would have to be quite small to be consistent with the regional gravity slope in this area. At the southwest and northeast ends of Segment B, the Las Positas trace cuts sharply across the gravity contour lines. Such behavior is not consistent with a single normal fault below the Las Positas trace through Segments A and B.

In addition, examination of the gravity contour lines associated with the Calaveras and Greenville faults at the west and east sides of the Livermore Valley, respectively, indicates a much more consistent correlation between the strike of these faults and associated gravity contour lines than is apparent in the vicinity of the Las Positas trace.

On the basis of both the URS/Blume and USGS gravity surveys, it is our opinion that the most straightforward, consistent view of the gravity data in the southern Livermore Valley does not include faulting along the Las Positas trace as a likely feature.

There is no conclusive evidence from these surveys for the existence of either the Tesla No. 2 or Tesla No. 3 fault trace in the immediate vicinity of the Sandia restricted area. The decrease in gravity in the southeast portion of the grid and the anomaly located on the south D-Line could belong to the Tesla No. 2 trace, but in the absence of other anomalous features, no definite conclusions can be drawn on the basis of the gravity survey alone.

MAGNETIC AND RESISTIVITY SURVEYS

General Statement

Magnetometer and electrical resistivity measurements were made along traverses located near Sandia (see Figure 17) as part of the investigation of faulting.

The traverses were selected to cross possible fault traces with alignments similar to those of faults located in previous geophysical surveys conducted in this area. Some traverses were located to cross the suspected Las Positas fault trace.

Field Procedures

In the case of the magnetometer surveys, both the total field strength and vertical gradient of the Earth's magnetic field were recorded at each station, using a Geometrics model G-816 proton-precession type magnetometer. The vertical gradient was obtained by taking two readings at each station, one with the sensing head 5 ft above the ground and the other with the sensing head 12 ft above the ground. The difference between these two readings was then divided by the appropriate scale factor to obtain the vertical gradient. The vertical gradient was used as a discriminant against shallow magnetic sources (buried pipes, etc.). All readings were taken at 50-ft intervals. All lines were sufficiently short that diurnal variations in the main field were not taken into account.

The electrical resistivity surveys were carried out using a Bison model 2350-B resistivity meter. Readings were taken at intervals of 75 ft using a fixed electrode spacing of 75 ft. This technique results in a continuous profile of ground conductivity at a depth of the same order as the electrode spacing. The purpose of this survey was to detect significant vertical offsets in the groundwater level as a possible indicator of impermeable barriers associated with near-surface faulting.

The locations of both the magnetic and resistivity survey lines are shown in Figure 17.

FIGURE 17 LOCATION OF MAGNETOMETER TRAVERSES AND RESISTIVITY SURVEY LINES

Results

Plots of magnetic and resistivity data are given in Figures 18a through 18e and 19a through 19c, respectively.

In general, the area in which the surveys were conducted is contaminated by the presence of many sources of magnetic noise, specifically pipelines, power lines, structures, debris, fencing, etc. In particular, the Las Positas lineament is locally nearly coincident with the PG&E high-pressure gas pipeline. This pipeline caused magnetic interference at distances up to approximately 300 ft. Magnetic profiles on relatively quiet traverses showed no evidence of anomalies significantly larger than normally expected background fluctuations. In conclusion, there is no strong evidence of faulting as determined from the magnetic surveys.

The resistivity surveys failed to show any anomalies along suspected traces of the Tesla fault. Anomalous features aligned with the Las Positas lineament (see Figure 19b) failed to show any consistent correlation between adjacent traverse lines. The results of the resistivity surveys must be considered inconclusive with respect to fault location.

FIGURE 18a MAGNETOMETER SURVEY, LINE M1

FIGURE 18b MAGNETOMETER SURVEY, LINES M2-M5

FIGURE 18c MAGNETOMETER SURVEY, LINES M6, M10, M11

FIGURE 18d MAGNETOMETER SURVEY, LINES M7-M9

FIGURE 19a RESISTIVITY SURVEY, LINES R1-R4

FIGURE 19b RESISTIVITY SURVEY, LINES R8-R10

FIGURE 19c RESISTIVITY SURVEY, LINES R5, R6

APPENDIX A

EXPLORATORY TRENCH LOGS

APPENDIX B

GRAVITY DATA

FIGURE A.1 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T1

FIGURE A.2 GEOLOGICAL CROSS SECTION OF
TRENCH T2

FIGURE A.3 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T3

FIGURE A.4 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T4

FIGURE A.6 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH 76

FIGURE A.7 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T7

FIGURE A.8 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T8

FIGURE A.9 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH 19

FIGURE A.10 GEOLOGIC CROSS SECTION OF EXPLORATORY TRENCH T10

GRAVITY DATA

The Bouguer anomalies for both survey periods were calculated using an effective Bouguer density of 2.2 gm/cm^3 . Terrain effects were found to be negligible, except in the vicinity of Arroyo Seco on the south D-Line and on the K-Line.

Pages B.2 to B.14 of this appendix are from the November 1977 survey, and give station identification code (1-6), coordinates, elevation (both in feet), Bouguer gravity at mean sea level, the Bouguer Anomaly, and the Residual Anomaly (all in milligals).

Pages B.15 to B.19 list the station, elevation (in feet), raw gravity from the gravity meter, Bouguer Anomaly (in milligals) relative to the smallest elevation for each line, and the Residual Anomaly (in milligals).

STATION	COORDINATES	ELEVATION	BOUGUER GRAVITY	BOUGUER ANOMALY	RESIDUAL ANOMALY
1 north	0.	0.	600.91	979927.79	-00.69
1	50.	0.	601.10	979927.97	-00.61
1	100.	0.	601.45	979927.91	-00.57
1	150.	0.	601.99	979927.96	-00.52
1	200.	0.	601.45	979928.00	-00.60
1	250.	0.	602.10	979928.00	-00.60
1	300.	0.	602.50	979928.05	-00.63
1	350.	0.	602.93	979928.19	-00.39
1	400.	0.	603.20	979928.18	-00.30
1	450.	0.	603.31	979928.17	-00.31
1	500.	0.	603.05	979928.23	-00.25
1	550.	0.	603.10	979928.26	-00.22
1	600.	0.	603.52	979928.32	-00.10
1	650.	0.	603.01	979928.30	-00.10
1	700.	0.	604.18	979928.37	-00.10
1	750.	0.	605.73	979928.44	-00.02
1	800.	0.	605.07	979928.07	-00.01
1	850.	0.	605.24	979928.91	-00.97
1	900.	0.	605.01	979928.97	-00.91
1	950.	0.	606.10	979928.97	-00.91
1	1000.	0.	606.80	979928.64	-00.80
1	1050.	0.	607.07	979928.67	-00.80
1	1100.	0.	608.07	979928.71	-00.77
1	1150.	0.	608.55	979928.74	-00.74
1	1200.	0.	608.80	979928.70	-00.72
1	1250.	0.	608.91	979928.76	-00.73
1	1300.	0.	609.22	979928.77	-00.71
1	1350.	0.	609.98	979928.80	-00.68
1	1400.	0.	610.50	979928.77	-00.71
1	1450.	0.	610.10	979928.83	-00.65
1	1500.	0.	610.95	979928.83	-00.65
1	1550.	0.	610.60	979928.83	-00.65
1	1600.	0.	611.11	979928.80	-00.67

J-Line (N + S)

A0 = 979,927.88 mgals

AX = $.681 \times 10^{-3}$ mgals/ft

rms = .22 mgals

south

STATION	COORDINATES	ELEVATION	BOUGUER GRAVITY	BOUGUER ANOMALY	RESIDUAL ANOMALY	
2 South	0, 0.	655.41	979930.21	-88.27	-19	E-Line (S + N)
2	50, 0.	656.88	979930.21	-88.27	-18	
2	100, 0.	658.04	979930.20	-88.28	-16	
2	150, 0.	660.07	979930.17	-88.31	-8	A0 = 979,930.40 mgals
2	200, 0.	660.39	979930.17	-88.31	-8	AX = $-.102 \times 10^{-2}$ mgal/ft
2	250, 0.	660.62	979930.12	-88.36	-02	
2	300, 0.	660.56	979930.08	-88.40	-02	
2	350, 0.	659.69	979929.98	-88.50	-07	
2	400, 0.	658.91	979930.01	-88.67	-07	
2	450, 0.	658.73	979929.88	-88.60	-06	
2	500, 0.	659.70	979929.98	-88.58	-04	
2	550, 0.	651.58	979929.88	-88.64	-00	
2	600, 0.	649.78	979929.83	-88.66	-03	
2	650, 0.	648.88	979929.76	-88.72	-02	
2	700, 0.	647.45	979929.76	-88.72	-07	
2	750, 0.	647.31	979929.71	-88.77	-07	
2	800, 0.	647.20	979929.67	-88.81	-08	
2	850, 0.	646.94	979929.63	-88.95	-08	
2	900, 0.	646.83	979929.54	-88.98	-06	
2	950, 0.	646.81	979929.45	-89.03	-02	
2	1000, 0.	647.03	979929.43	-89.05	-02	
2	1050, 0.	647.13	979929.36	-89.12	-03	
2	1100, 0.	646.98	979929.35	-89.13	-07	
2	1150, 0.	646.91	979929.30	-89.16	-07	
2	1200, 0.	646.88	979929.25	-89.23	-07	
2	1250, 0.	646.98	979929.20	-89.28	-07	
2	1300, 0.	646.89	979929.13	-89.35	-05	
2	1350, 0.	646.29	979929.12	-89.36	-08	
2	1400, 0.	645.83	979929.06	-89.42	-08	
2	1450, 0.	645.26	979929.01	-89.47	-08	
2	1500, 0.	644.22	979929.00	-89.49	-11	
2	1550, 0.	642.03	979929.00	-89.58	-08	

2	1600.	0.	640.62	070028.82	-45.64	.04
2	1650.	0.	637.65	070028.76	-45.72	.04
2	1700.	0.	634.68	070028.65	-45.83	-.03
2	1750.	0.	631.81	070028.59	-45.89	-.03
2	1800.	0.	628.98	070028.49	-46.00	-.04
2	1850.	0.	626.09	070028.43	-46.05	-.04
2	1900.	0.	623.55	070028.41	-46.07	-.04
2	1950.	0.	622.42	070028.38	-46.10	-.04
2	2000.	0.	620.56	070028.32	-46.16	-.04
2	2050.	0.	619.27	070028.28	-46.19	-.03
2	2100.	0.	617.73	070028.26	-46.24	-.02
2	2150.	0.	616.99	070028.21	-46.27	-.02
2	2200.	0.	614.02	070028.16	-46.38	-.04
2	2250.	0.	612.36	070028.06	-46.42	-.05
2	2300.	0.	610.99	070028.01	-46.47	-.05
2	2350.	0.	609.51	070027.95	-46.53	-.06
2	2400.	0.	608.19	070027.89	-46.59	-.07

north

STATION	COORDINATES	ELEVATION	BOUQUER GRAVITY	BOUQUER ANOMALY	REGIONAL ANOMALY	
1 SOUTH	0, 0,	709.33	070030.35	-40.13	-4.23	S. D-Line (S → N)
3	50, 0,	709.25	070030.26	-40.22	-4.20	
3	100, 0,	708.92	070030.20	-40.20	-4.18	
3	150, 0,	708.60	070030.16	-40.32	-4.17	AO = 979,934.59 mgals
3	200, 0,	708.46	070030.11	-40.37	-4.18	AX = -0.168×10^{-2} mgal/ft
3	250, 0,	708.21	070030.04	-40.44	-4.13	
3	300, 0,	707.61	070030.04	-40.46	-4.08	
3	350, 0,	707.65	070033.06	-40.52	-4.08	
3	400, 0,	707.38	070033.02	-40.56	.00	
3	450, 0,	707.19	070033.00	-40.58	.07	
3	500, 0,	706.96	070033.01	-40.67	.06	
3	550, 0,	706.61	070033.73	-40.75	.07	
3	600, 0,	706.38	070033.78	-40.76	.14	
3	650, 0,	706.28	070033.60	-40.76	.20	
3	700, 0,	706.20	070033.50	-40.69	.17	
3	750, 0,	706.37	070033.32	-41.16	-4.03	
3	800, 0,	706.77	070033.32	-41.16	.09	
3	850, 0,	707.47	070033.32	-41.16	.16	
3	900, 0,	708.42	070033.25	-41.23	.18	
3	950, 0,	709.37	070033.10	-41.30	.10	
3	1000, 0,	710.47	070033.12	-41.36	.21	
3	1050, 0,	711.01	070033.07	-41.41	.28	
3	1100, 0,	712.74	070032.90	-41.50	.19	
3	1150, 0,	715.75	070032.06	-41.62	.29	
3	1200, 0,	717.03	070032.75	-41.73	.10	
3	1250, 0,	720.21	070032.58	-41.46	.00	
3	1300, 0,	722.90	070032.01	-42.06	.01	
3	1350, 0,	724.06	070032.20	-42.20	-4.12	
3	1400, 0,	727.30	070032.12	-42.36	-4.12	
3	1450, 0,	729.04	070032.02	-42.46	-4.10	
3	1500, 0,	732.19	070031.93	-42.55	-4.10	

3	1550.	0.	730.61	970031.00	=42.63	=.13
3	1600.	0.	737.11	970031.03	=42.65	=.08
3	1650.	0.	740.31	970031.06	=42.62	=.08
3	1700.	0.	741.02	970031.74	=42.74	=.00
3	1750.	0.	743.95	970031.59	=42.80	=.07
3	1800.	0.	746.15	970031.40	=43.00	=.10
3	1850.	0.	748.00	970031.33	=43.15	=.15
3	1900.	0.	751.30	970031.03	=43.25	=.17

north

STATION	COORDINATES	ELEVATION	BOUGUER GRAVITY	BOUGUER ANOMALY	RESIDUAL ANOMALY	
4 south	94	0	979929.65	-85.80	.00	N. D-line (S + N)
4	99,	0,	979929.59	-85.89	.00	
4	104,	0,	979929.53	-85.95	-.01	AO = 979,929.64 mgals
4	150,	0,	979929.48	-85.98	-.04	AX = $-.102 \times 10^{-2}$ mgals/ft
4	200,	0,	979929.43	-85.95	-.01	
4	250,	0,	979929.42	-85.96	.05	
4	300,	0,	979929.36	-85.92	.03	
4	350,	0,	979929.26	-85.82	-.02	
4	400,	0,	979929.19	-85.80	-.02	
4	450,	0,	979929.21	-85.87	.03	
4	500,	0,	979929.16	-85.51	.06	
4	550,	0,	979929.05	-85.43	-.02	
4	600,	0,	979929.65	-85.43	.02	
4	650,	0,	979929.01	-85.47	.05	
4	700,	0,	979929.66	-85.60	-.06	
4	750,	0,	979929.84	-85.66	-.05	
4	800,	0,	979929.76	-85.71	-.06	
4	850,	0,	979929.67	-85.61	-.10	
4	900,	0,	979929.67	-85.61	-.05	
4	950,	0,	979929.63	-85.63	-.02	
4	1000,	0,	979929.61	-85.67	-.01	
4	1050,	0,	979929.55	-85.63	-.02	
4	1100,	0,	979929.52	-85.65	.01	
4	1150,	0,	979929.55	-85.60	.11	
4	1200,	0,	979929.60	-85.60	.00	
north						

STATION	COORDINATES	ELEVATION	BOUGUER GRAVITY	BOUGUER ANOMALY	RESIDUAL ANOMALY	
1	South 04.	04	721.44	979935.91	-38.97	-4.00
2	50.	04	721.45	979935.88	-39.00	-4.15
3	100.	04	721.45	979935.88	-39.10	-4.08
4	150.	04	721.45	979935.82	-39.16	-4.08
5	200.	04	721.44	979935.86	-39.22	-4.07
6	250.	04	720.17	979935.84	-39.19	-4.05
7	300.	04	719.37	979935.85	-39.25	-4.05
8	350.	04	719.45	979935.17	-39.31	-4.04
9	400.	04	719.02	979935.18	-39.37	-4.00
10	450.	04	719.04	979935.02	-39.44	-4.01
11	500.	04	718.72	979934.98	-39.50	-4.04
12	550.	04	718.12	979934.87	-39.61	-4.00
13	600.	04	718.03	979934.79	-39.69	-4.01
14	650.	04	721.14	979934.75	-39.75	-4.06
15	700.	04	727.87	979934.83	-39.85	-4.06
16	750.	04	721.09	979934.86	-39.82	-4.04
17	800.	04	720.92	979934.83	-39.84	-4.10
18	850.	04	721.57	979934.84	-39.84	-4.02
19	900.	04	723.80	979934.95	-39.93	-4.15
20	950.	04	725.93	979934.31	-40.17	-4.05
21	1000.	04	728.26	979934.21	-40.27	-4.06
22	1050.	04	730.32	979934.18	-40.34	-4.07
23	1100.	04	733.75	979934.03	-40.45	-4.11
24	1150.	04	736.44	979933.98	-40.54	-4.14
25	1200.	04	740.55	979933.88	-40.67	-4.20

K-Line

AO = 979,935.60 mgals

AX = -0.132×10^{-2} mgal/ft

north

STATION	COORDINATES	ELEVATION	BOUGUER GRAVITY	BOUGUER ANOMALY	RESIDUAL ANOMALY
0.	0.	0.	979927.45	-80.53	.26
0	0.	200.	979928.07	-80.41	.26
0	0.	400.	979929.13	-80.35	.20
0	0.	600.	979929.20	-80.28	.14
0	0.	800.	979929.27	-80.26	.10
0	0.	1000.	979929.34	-80.14	.04
0	0.	1200.	979929.40	-80.08	-.02
0	0.	1400.	979929.55	-80.03	.00
0	0.	1600.	979929.77	-80.71	-.03
0	0.	2000.	979929.87	-80.61	-.05
0	0.	2200.	979929.76	-80.72	-.08
0	0.	2400.	979929.92	-80.84	-.25
0	200.	200.	979929.14	-80.34	.17
0	200.	400.	979929.30	-80.10	.20
0	200.	600.	979929.55	-80.14	.12
0	200.	800.	979929.56	-80.04	.20
0	200.	1000.	979929.56	-80.02	.00
0	200.	1200.	979929.64	-80.00	-.07
0	200.	1400.	979929.74	-80.69	-.05
0	200.	1600.	979929.97	-80.51	.01
0	200.	2000.	979929.06	-80.42	-.03
0	200.	2200.	979929.86	-80.62	-.15
0	200.	2400.	979929.10	-80.36	-.23
0	400.	0.	979929.12	-80.30	.11
0	400.	200.	979929.07	-80.60	.74
0	400.	400.	979929.41	-80.07	.19
0	400.	600.	979929.47	-80.01	.00
0	400.	800.	979929.00	-80.00	.00
0	600.	1000.	979929.67	-80.61	.04
0	800.	1200.	979929.69	-80.76	-.06

Average Bouguer Anomaly

= -45.063 mgals

-45.1 mgals

Sandia Grid

BU = 979,927.68 mgals

BX = .818 x 10⁻³ mgal/ft

BY = .618 x 10⁻³ mgal/ft

6	800.	1800.	653.20	979926.60	-45.49	-0.10
6	400.	1400.	653.72	979926.46	-45.48	-0.06
6	400.	1800.	655.97	979926.14	-45.53	-0.02
6	800.	2000.	657.94	979926.83	-45.25	-0.01
6	400.	2200.	659.68	979926.24	-45.24	-0.13
6	800.	2400.	661.22	979926.27	-45.20	-0.22
6	600.	0.	658.64	979926.20	-46.20	-0.23
6	600.	200.	660.64	979926.27	-46.11	-0.07
6	800.	400.	663.20	979926.55	-45.93	-0.17
6	800.	800.	669.38	979926.76	-45.72	-0.00
6	600.	1200.	668.90	979926.44	-45.54	-0.02
6	600.	1400.	669.37	979926.85	-45.47	-0.03
6	600.	1600.	656.45	979926.18	-45.30	-0.02
6	600.	1800.	657.85	979926.85	-45.23	-0.03
6	600.	2000.	668.36	979926.36	-45.12	-0.05
6	600.	2400.	664.73	979926.65	-45.81	-0.14
6	800.	0.	637.55	979926.31	-46.17	-0.13
6	800.	200.	659.53	979926.66	-46.02	-0.00
6	800.	400.	661.97	979926.67	-45.88	-0.00
6	800.	600.	664.55	979926.70	-45.88	-0.06
6	800.	800.	669.95	979926.83	-45.88	-0.00
6	800.	1000.	654.96	979926.1	-45.56	-0.06
6	800.	1200.	657.11	979926.16	-45.38	-0.03
6	800.	1400.	655.57	979926.15	-45.32	-0.05
6	800.	1600.	652.26	979926.33	-46.15	-0.00
6	800.	1800.	651.55	979926.46	-45.80	-0.05
6	800.	2000.	662.15	979926.55	-46.93	-0.05
6	800.	2200.	664.14	979926.66	-46.61	-0.06

0	000,	2000,	007,42	070020,70	-00,70	-0,12
0	1000,	0,	030,25	070020,01	-00,07	-0,00
0	1000,	200,	001,90	070020,51	-00,97	-0,12
0	1000,	400,	003,92	070020,70	-00,70	-0,01
0	1000,	600,	007,07	070020,00	-00,00	-0,01
0	1000,	800,	001,20	070020,03	-00,30	-0,00
0	1000,	1000,	005,50	070020,07	-00,31	-0,10
0	1000,	1200,	000,00	070020,10	-00,32	-0,00
0	1000,	1400,	002,20	070020,27	-00,21	-0,10
0	1000,	1600,	000,11	070020,00	-00,00	-0,01
0	1000,	1800,	001,00	070020,50	-00,00	-0,02
0	1000,	2000,	001,07	070020,07	-00,01	-0,10
0	1000,	2200,	002,01	070020,00	-00,00	-0,00
0	1000,	2400,	001,13	070020,00	-00,50	-0,00
0	1200,	0,	001,00	070020,00	-00,00	-0,12
0	1200,	200,	005,57	070020,00	-00,00	-0,10
0	1200,	400,	000,03	070020,07	-00,01	-0,00
0	1200,	600,	000,05	070020,01	-00,07	-0,03
0	1200,	800,	002,00	070020,00	-00,00	-0,11
0	1200,	1000,	000,00	070020,17	-00,31	-0,11
0	1200,	1200,	000,31	070020,30	-00,00	-0,01
0	1200,	1400,	003,30	070020,00	-00,00	-0,00
0	1200,	1600,	005,07	070020,07	-00,01	-0,02
0	1200,	1800,	000,00	070020,12	-00,30	-0,00
0	1200,	2000,	000,00	070020,02	-00,00	-0,11
0	1200,	2200,	007,00	070020,07	-00,01	-0,00
0	1200,	2400,	000,00	070020,10	-00,32	-0,01
0	1400,	0,	030,01	070020,73	-00,70	-0,10
0	1400,	200,	003,05	070020,01	-00,07	-0,10
0	1400,	400,	000,00	070020,02	-00,00	-0,00
0	1400,	600,	001,15	070020,10	-00,32	-0,00
0	1400,	800,	007,21	070020,15	-00,33	-0,17

0	1000.	1000.	061,00	070020,30	-05,11	-0,08
0	1000.	1200.	060,10	070020,50	-04,90	-0,07
0	1000.	1400.	065,20	070020,71	-04,76	,02
0	1000.	1600.	070,03	070020,92	-04,55	,11
0	1000.	1000.	060,10	070030,11	-04,36	,17
0	1000.	2000.	063,07	070030,33	-04,25	,16
0	1000.	2200.	061,93	070030,20	-04,20	,06
0	1000.	2400.	067,00	070030,30	-04,10	-0,01
0	1000.	0.	040,01	070020,00	-03,04	-0,15
0	1000.	200.	040,07	070020,90	-03,50	-0,10
0	1000.	000.	040,00	070020,10	-03,30	-0,00
0	1000.	000.	053,90	070020,33	-03,15	-0,00
0	1000.	000.	061,72	070020,01	-03,07	-0,00
0	1000.	1000.	065,02	070020,50	-03,02	-0,05
0	1000.	1200.	060,00	070020,70	-02,70	,00
0	1000.	1400.	061,10	070030,00	-02,00	,15
0	1000.	1600.	061,02	070030,11	-02,37	,12
0	1000.	1000.	071,27	070030,32	-02,10	,21
0	1000.	2000.	062,07	070030,39	-02,00	,17
0	1000.	2200.	060,07	070030,00	-02,02	,11
0	1000.	2400.	072,21	070030,50	-02,90	,00
0	1000.	0.	050,10	070020,07	-02,01	-0,00
0	1000.	200.	053,75	070020,15	-02,35	-0,15
0	1000.	400.	050,51	070020,33	-02,15	-0,00
0	1000.	000.	063,57	070020,32	-02,05	-0,00
0	1000.	000.	060,30	070020,00	-02,90	,00
0	1000.	1000.	060,90	070020,70	-02,70	,00
0	1000.	1200.	062,00	070020,00	-02,00	,10
0	1000.	1400.	700,00	070020,00	-02,00	-2,03
0	1000.	1000.	710,13	070030,31	-02,17	,16
0	1000.	1000.	060,55	070030,00	-02,00	,21
0	1000.	2000.	060,10	070030,50	-02,00	,10
0	1000.	2200.	063,70	070030,02	-02,00	,10
0	1000.	2400.	073,00	070030,00	-02,90	,05

0	2000.	0.	699,54	979929,16	-45,32	-0,16
0	2000.	800.	676,32	979929,60	-44,88	-0,03
0	2000.	600.	681,61	979929,77	-44,71	-0,08
0	2000.	400.	686,66	979930,87	-44,61	-0,06
0	2000.	200.	692,70	979930,83	-44,29	-0,17
0	2400.	1400.	695,02	979930,33	-44,14	-0,15
0	2000.	1600.	714,32	979930,02	-44,66	-0,11
0	2000.	1400.	714,21	979930,57	-43,90	-0,13
0	2000.	2000.	701,50	979930,70	-43,70	-0,16
0	2000.	2200.	698,34	979930,60	-43,60	-0,20
0	2000.	2400.	693,34	979930,81	-43,67	-0,21
0	2200.	0.	686,39	979929,34	-45,12	-0,12
0	2200.	200.	707,50	979929,52	-44,06	-0,09
0	2200.	400.	711,98	979929,70	-44,08	-0,06
0	2200.	600.	719,24	979929,94	-44,53	-0,09
0	2200.	800.	709,46	979930,87	-44,51	-0,09
0	2200.	1000.	723,56	979930,18	-44,33	-0,05
0	2200.	1200.	721,57	979930,10	-44,33	-0,08
0	2200.	1400.	717,19	979930,62	-44,00	-0,07
0	2200.	1600.	710,48	979930,64	-43,82	-0,19
0	2200.	1800.	720,30	979930,39	-43,89	-0,08
0	2200.	2000.	711,30	979930,80	-43,60	-0,16
0	2200.	2200.	694,43	979930,94	-43,48	-0,15
0	2200.	2400.	71,09	979931,07	-43,41	-0,10
0	2400.	0.	730,10	979929,96	-44,92	-0,04
0	2400.	200.	750,15	979929,69	-44,79	-0,08
0	2400.	400.	748,72	979930,00	-44,40	-0,10
0	2400.	600.	756,32	979929,95	-44,33	-0,07
0	2400.	1000.	738,78	979930,33	-44,15	-0,07
0	2400.	1200.	740,49	979930,50	-43,98	-0,15
0	2400.	1600.	736,63	979930,80	-43,67	-0,17
0	2400.	1800.	729,51	979931,09	-43,39	-0,23

0	2000,	2000,	710,00	070031,10	-03,30	.20
0	2400,	2200,	710,00	070031,20	-03,20	.10
0	2000,	2400,	713,90	070031,27	-03,21	.10

L-Line 3/14/78 1057 + 1158

Station	Elevation	Raw Gravity	Bouguer Anomaly	Residual Anomaly
L-00	659.11	3,514.24	0.00	+.01
L-20	660.15	3,514.17	-0.001	-.02
L-40	661.09	3,514.14	+.03	0.0
L-60	662.09	3,514.11	+.07	+.02
L-80	663.11	3,514.04	+.06	-.01
L-100	664.62	3,514.02	+.15	+.06
L-120	665.15	3,513.93	+.09	-.03
L-140	666.05	3,513.91	+.06	-.08
L-160	666.89	3,513.90	+.17	+.02
L-180	667.95	3,513.86	+.20	+.03
L-200	669.09	3,513.80	+.22	+.02
L-220	670.24	3,513.70	+.20	-.02
L-240	671.38	3,513.67	+.24	0.0
L-260	672.82	3,513.57	+.24	-.02
L-280	674.48	3,513.52	+.30	+.02
L-300	676.55	3,513.40	+.31	+.01
L-320	678.92	3,513.28	+.35	+.03
L-340	681.75	3,513.05	+.31	-.04
L-360	684.64	3,512.93	+.38	+.02
L-380	687.72	3,512.78	+.43	+.05
L-400	690.77	3,512.55	+.40	-.01
L-00	659.09	3,514.22		

Note:

Instrument Correction Negligible

M-Line 10/78 0925 - 1142

Station	Elevation	Raw Gravity	Bouguer Anomaly	Residual Anomaly
M-00	659.68	3,514.53	0.00	+ .01
M-20	661.28	3,514.42	-0.00	- .01
M-40	662.53	3,514.30	+ .03	+ .01
M-60	663.60	3,514.33	+ .06	+ .02
M-80	664.34	3,514.25	+ .04	- .02
M-100	664.89	3,514.28	+ .09	+ .02
M-120	665.33	3,514.23	+ .08	- .01
M-140	665.75	3,514.23	+ .10	- .01
M-160	666.26	3,514.23	+ .14	+ .02
M-180	666.79	3,514.22	+ .16	+ .02
M-200	667.34	3,514.17	+ .16	0.0
M-220	668.26	3,514.11	+ .15	- .03
M-240	668.88	3,514.13	+ .22	+ .03
M-260	669.35	3,514.08	+ .19	- .02
M-280	669.50	3,514.08	+ .21	- .02
M-300	669.63	3,514.10	+ .23	- .01
M-320	669.75	3,514.14	+ .29	+ .03
M-340	669.85	3,514.15	+ .29	+ .01
M-100	664.91	3,514.20		

Note:

Tidal Correction = +.005 mgal/station

N-Line 3/10/78 1216 + 1427

Station	Elevation	Raw Gravity	Bouguer Anomaly	Residual Anomaly
N-00	663.45	3,514.11	0.00	-.04
N-20	663.74	3,514.14	+.06	0.0
N-40	664.09	3,514.15	+.08	0.0
N-60	664.38	3,514.13	+.09	-.01
N-80	664.63	3,514.14	+.11	-.01
N-100	664.90	3,514.18	+.16	+.03
N-120	665.34	3,514.14	+.15	-.02
N-140	665.89	3,514.14	+.20	+.01
N-160	666.02	3,514.16	+.22	+.01
N-180	666.20	3,514.15	+.23	0.0
N-200	667.03	3,514.18	+.31	+.06
N-220	668.39	3,514.07	+.30	+.03
N-240	669.15	3,514.02	+.29	-.01
N-260	669.38	3,514.04	+.33	+.01
N-280	669.75	3,514.02	+.33	-.01
N-300	670.06	3,514.00	+.34	-.02
N-320	670.12	3,514.05	+.38	0.0
N-340	669.80	3,514.10	+.42	+.02
N-360	669.71	3,514.11	+.41	-.01
N-380	669.72	3,514.11	+.41	-.04
M-100	664.92	3,514.08		

Note:

Instrument Correction = +0.006 mgal/station

Station	Elevation	Raw Gravity	Bouguer Anomaly	Residual Anomaly
0-00	660.55	3,514.26	0.00	+0.03
0-20	660.67	3,514.30	+0.04	+0.04
0-40	660.81	3,514.27	+0.03	+0.01
0-60	661.04	3,514.30	+0.06	+0.02
0-80	661.28	3,514.26	+0.05	-0.02
0-100	661.56	3,514.25	+0.05	-0.04
0-120	661.94	3,514.29	+0.12	0.0
0-140	662.37	3,514.28	+0.13	-0.01
0-160	662.81	3,514.28	+0.17	+0.01
0-180	663.49	3,514.22	+0.14	-0.05
0-200	664.15	3,514.19	+0.17	-0.04
0-220	664.87	3,514.18	+0.20	-0.06
0-240	665.69	3,514.20	+0.28	+0.02
0-260	666.63	3,514.18	+0.31	+0.03
0-280	667.64	3,514.12	+0.33	+0.02
0-300	668.81	3,514.02	+0.30	-0.03
0-320	669.78	3,514.01	+0.36	0.0
0-340	670.99	3,513.95	+0.37	-0.01
0-360	672.29	3,513.90	+0.42	+0.02
0-380	673.70	3,513.80	+0.40	-0.03
0-400	675.13	3,513.74	+0.44	-0.01
0-420	676.43	3,513.75	+0.53	+0.05
0-440	677.51	3,513.69	+0.55	+0.05
0-460	678.29	3,513.62	+0.52	-0.01
0-480	679.09	3,513.62	+0.59	+0.04
0-500	679.90	3,513.55	+0.56	-0.01
0-520	680.72	3,513.51	+0.58	-0.02
0-540	681.71	3,513.47	+0.60	-0.02
0-560	682.82	3,513.46	+0.67	+0.02
0-580	684.08	3,513.39	+0.68	+0.01
0-600	685.72	3,513.26	+0.66	-0.03
M-100	664.90	3,514.20		

Note:

Instrument Correction = -.004 mgal/station

P-Line 3/14/78 1224 + 1431

Station	Elevation	Raw Gravity	Bouguer Anomaly	Residual Anomaly
P-00	666.19	3,513.89	0.0	.14
P-20	666.46	3,513.75	-.13	-.02
P-40	666.75	3,513.78	-.08	0.0
P-60	666.64	3,513.79	-.08	-.03
P-80	667.29	3,513.75	-.08	-.05
P-100	668.50	3,513.71	-.04	-.04
P-120	670.01	3,513.60	-.05	-.08
P-140	671.62	3,513.59	+.07	+.01
P-160	673.96	3,513.44	+.08	-.01
P-180	677.55	3,513.26	+.13	+.02
P-200	680.27	3,513.07	+.12	-.02
P-220	682.02	3,513.04	+.21	+.04
P-240	683.31	3,512.97	+.22	+.02
P-260	684.41	3,512.90	+.22	0.0
P-280	685.30	3,512.90	+.28	+.03
P-300	685.64	3,512.86	+.27	-.01
BM-117		3,515.14		

Note:

Instrument Correction = +.01 mgal/station

TRITIUM ACCOUNTABILITY SYSTEM
FOR THE
TRITIUM RESEARCH LABORATORY

B. L. Wood
Computing Division 8323
Sandia Laboratories, Livermore

January 3, 1977

Tritium Accountability System

I. Purpose

The purpose of this system is to provide a detailed accountability of all amounts of tritium in the SLL Tritium Research Laboratory (TRL). All transfers of tritium to and from the Tritium Research Laboratory as well as all internal transfers are documented. These transfers are recorded on magnetic tape in ledger form as a double entry bookkeeping system.

The decay of all tritium within the system is computed monthly for reporting purposes. Several inquiry programs are available to query the various ledgers (containers) within the system.

II. Program Sequence

Several programs are involved in this system, namely:

1. Tritium Edit
2. Tritium Posting
3. Tritium Decay
4. All Inquiry Programs

1. Tritium Edit

This program will be run weekly, or, initially, on request. After the transfers for the period have been coded on keypunch forms (LS 6476), the keypunch section will hand the punched cards to the 8323 I/O clerk, at which time the edit is run. The edit listing will detect such errors as bad E-numbers, erroneous transaction codes, etc. This listing will be scrutinized by the TRL control clerk and errors corrected. The original worksheets will be returned to the TRL control desk for filing and retention. The punched cards will be filed temporarily by the 8323 I/O clerk.

2. Tritium Posting

After any errors have been corrected, the Tritium Posting program may be run. This program re-edits the input cards and creates a debit and credit entry for each. These entries are then added to the last tritium ledger tape in date and time sequence.

3. Tritium Decay

Once each month the decay will be computed on each applicable container containing tritium for the period of time it is in the system. Decay credit entries will be posted to the various ledgers involved and a new balance entry generated for each container. Debit entries will be posted to the account entitled "Decay." The total amount of decay for the period will be accumulated for reporting purposes.

Input parameters for this program as well as the date this program is to be run will be furnished by Price Hennen, Organization 8252. Tritium will be decayed by the formula:

$$\text{Remaining Quantity} = \frac{\text{Initial Quantity}}{2.7182} \times \frac{-.693 \text{ no. of days}}{4500}$$

4. Tritium Inquiry

Several programs are available for querying the ledger file. More may be added if the need exists.

- a. QUERY 1. E-No., 1 container. All entries for one container are listed for a specific time frame.
- b. QUERY 2. E-No., all containers. All entries for this E-No. are listed by container number for a specific time frame.
- c. QUERY 3. All E-Nos., all containers. All entries are listed for the lab by container and E-No. for a specified time frame.

To use any of these Query programs the user simply has to call the 8323 I/O clerk, phone X3076, giving her the number of the program desired and the input parameters. (See "Control Cards," page 6.)

TRITIUM LEDGER

<u>Field</u>	<u>Length</u>	
Primary E-Number	5	
Primary Container No.	12	
Debit/Credit Code	1	D = debit, C = credit
Type	1	T = transaction B = balance D = decay E = experiment
Date	6	MMDDYY
Time	4	24-hour military time
"FROM" E-Number	5	
"FROM" Organization	4	
"FROM" Container	12	
"TO" E-Number	5	
"TO" Organization	4	
"TO" Container	12	
Experiment Number	5	
Quantity (grams)	6	999v999 where v = assumed decimal point

In addition to the container ledgers, auxiliary ledgers will be set up to complement the system. Those defined at this writing are:

Decay
Stack
Sieves:
GPS1
GPS2
GPS3
VERS1
VERS2

File Back-Up

All ledger entries are simply additions to the previous ledger tape. Should the situation arise whereby the number of entries on any one tape get to the point where volume impedes speedy processing, the older entries will be archived.

Once each month after the decay program has been run, the tape librarian will copy the new ledger master and send the copy to the tape vault in Building 916.

All input worksheets (form LS6476) will be numbered consecutively and filed in the Tritium Research Laboratory. The punched cards created from these worksheets will be retained in Building 912.

All of the programs used in this system will be backed up on tape in the Building 916 vault.

Control Cards

1. Decay Program

- a. Cols 1-6 Beginning date, decay period (YRMODA)
- b. Cols 7-12 Ending date, decay period (YRMODA)
- c. Cols 13-18 First date next period (MODAYR)
- d. Cols 19-24 First date since last decay (MODAYR)

2. Query 1 - 1 E-No., 1 Container

- a. Cols 1-5 E-number of requesting user
- b. Cols 6-11 Beginning date of period (YRMODA)
- c. Cols 12-17 Ending date of period (YRMODA)
- d. Cols 18-29 Container number, right justified

3. Query 2 - 1 E-No., All Containers

- a. Cols 1-5 E-number of requesting user
- b. Cols 6-11 Beginning date of period (YRMODA)
- c. Cols 12-17 Ending date of period (YRMODA)

4. Query 3 - All E-Nos, All Containers

- a. Cols 1-5 Blank
- b. Cols 6-11 Beginning date of period (YRMODA)
- c. Cols 12-17 Ending date of period (YRMODA)

TRITIUM TAPE LOG

[illegible]

T R I T I U M L E D G E R

E-NO. 09053 BYROADS WILLIAM T JR

PERIOD CF 11-01-76 TO 12-31-76

CONTAINER 33

QUERY 1

1 E-NO

1 CONTAINER

DATE	TIME	C	T/C	FROM	TO	QUANTITY
11-01-76	0001	B	B	E BAL	E	.500
11-05-76	0930	D	T	E 00013	E 00083	.100
11-10-76	1340	C	T	E 38083	E 00013	.200
11-10-76				BAL		.400

QUERY 2
ALL E-NOS
ALL CONTAINERS

T R I T I U M L E D G E R

PAGE NO. 1

E-NO. 06063 BYRDAVS WILLIAM T JR

PERIOD OF 11-01-76 TO 12-01-76

CONTAINER 33

DATE	TIME	C	T/C	FROM	TO	QUANTITY	TOTAL QUANTITY ASSIGNED THIS PERSON
11-01-76	0001	B	B	RAL		,500	
11-05-76	0950	B	T	E 00013	E 00083	,100	
11-10-76	1540	B	T	E 00083	E 00013	,200	
11-10-76				RAL		,400	

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T R I T I U M L E D G E R

PAGE NO. 2

E-NO. 06083 BYRDAVS WILLIAM T JR

PERIOD OF 11-01-76 TO 12-01-76

CONTAINER 44

DATE	TIME	C	T/C	FROM	TO	QUANTITY	TOTAL QUANTITY ASSIGNED THIS PERSON
11-01-76	0001	B	B	RAL		,500	
11-01-76				RAL		,500	,900

T O T I U M L E D G E R

QUERY 3
ALL E-NOS
ALL CONTAINERS

E-NO. 00033 BYDONS WILLIAM T JR

PAGE NO. 1

PERIOD OF 11-01-76 TO 12-31-76

CONTAINER 33

DATE	TIME	C T/C	FROM	TO	QUANTITY	TOTAL QUANTITY ASSIGNED THIS PERSON	TOTAL QUANTITY ASSIGNED THIS LABORATORY
11-01-76	0001	B C	PAL		.500		
11-05-76	0010	D T	E 00013	F 00013	.100		
11-10-76	1340	C T	F 00013	F 00013	.200		
11-10-76			PAL		.400		

T O I T I U M L E D G E R

E-40. 08083 BYRQADS WILLIAM T JR

PAGE NO. 2

PERIOD OF 11-01-76 TO 12-01-76

CONTAINERS 44

DATE	TIME	S T/C	FROM	TO	QUANTITY	TOTAL QUANTITY ASSIGNED THIS PERSON	TOTAL QUANTITY ASSIGN THIS LABORATORY
11-01-76	0001	9 0	PAL		.500		
11-01-76			PAL		.500	.000	

T R I T I U M L E A D E R

E-NO. 11-61 HALL WILLIAM P

PAGE NO. 3

PERIOD OF 11-01-76 TO 12-31-76

CONTAINED 55

DATE	TIME	C	T/C	FROM	TO	QUANTITY	TOTAL QUANTITY ASSIGNED THIS PERSON	TOTAL QUANTITY ASSIGNED THIS LABORATORY
11-01-76	0001	3	P	BAL		.500		
11-02-76	1000	C	*	= 11141	F 00017	.050		
11-02-76				BAL		.450	.450	1.350

SAFE OPERATING PROCEDURE NO. 709
TRITIUM RESEARCH LABORATORY BLDG. 968

PREFACE

Sandia Laboratories Policy is that Safety is an integral part of the laboratories activities. Operations must be planned and conducted in a manner that will prevent injury to personnel and damage to property and the environment. The minimum safety regulations and practices necessary to achieve these goals in the Tritium Research Laboratory, Building 968, are presented in this Safe Operating Procedure.

Everyone working in the TRL is required to comply with this procedure and the Sandia Laboratories Health and Safety Manual to protect himself and other personnel from injury. TRL operational personnel are responsible for assisting others in the laboratory to understand these safety regulations. Each individual in the TRL must use this guidance effectively to avoid accidents.

L. Gutierrez - 8100

SAFE OPERATING PROCEDURE NO. 709
TRITIUM RESEARCH LABORATORY BLDG. 968

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2. Safety Engineering and Environmental Health Division 8252
3. Health Physics Representative
4. User Division Supervisors
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SAFE OPERATING PROCEDURE NO. 709
TRITIUM RESEARCH, LABORATORY BLDG. 968

A. General

1. Building

The Tritium Research Laboratory (TRL) is to be used for experimental work with isotopes of hydrogen and their compounds. All tritium operations will be planned so as to preclude the accidental release of radioactive materials.

The TRL was designed to conform to the LRDA philosophy, which is to limit a tritium release to a level "as low as reasonably achievable", (ALARA). The principal difference between the TRL and other existing facilities is its provision for environmental protection through the use of secondary containment which can be connected on demand to tritium cleanup systems.

2. Secondary Containment

Secondary containment is provided by sealed glove boxes which are operated at a pressure slightly negative to the room. The atmosphere of each glove box is constantly monitored for tritium. In the event the tritium concentration exceeds a predetermined limit, the glove box will be automatically connected to a cleanup system called the Gas Purification System (GPS). The sealed glove box may also be used in the high velocity air hood mode (HVAH). When used in this mode a linear velocity of 200 fpm is required through any/all openings in the box. The glove box operation is described in detail in SDP 710.

3. Cleanup Systems

The Tritium Research Laboratory uses two tritium cleanup systems. A 200 SCFM system called the Gas Purification System (GPS) is used to remove tritium from the sealed glove box atmosphere. A 10 SCFM system called the Vacuum Effluent Recovery System (VERS) is used to remove tritium from vacuum pump effluent before it is released to the atmosphere.

- a. GPS - The GPS is a recirculating system capable of reducing tritium concentration in the air stream to the ppb level. The tritium is oxidized on a precious metal catalyst. The resulting tritiated water is then collected on molecular sieve dryers. The glove boxes in the laboratory are connected to the GPS through a central manifold. The GPS is designed to process only one glove box at a time. The GPS operation is described in detail in SOP 711.
- b. VERS - A central vacuum manifold is used to collect all vacuum pump effluent and store it in holding tanks. When a holding tank is filled, its contents are processed through the VERS to remove the tritium and are then exhausted to the atmosphere. The VERS removes tritium from the vacuum pump effluent to the same level and in the same manner as the GPS. The VERS operation is described in detail in SOP 712.

4. Building Ventilation System

The TRL ventilation system is a temperature and humidity conditioned "once through" high flow system providing from 6-10 room air changes per hour. The building is maintained at a slightly negative pressure with respect to the outside atmosphere and uses a pressure zoning system to insure that the air flow is from the non-radioactive part of the

facility through the experimental laboratories and then to the stack. To maintain the correct pressure differentials, and therefore, the correct air flow, the doors between the hallway and the individual rooms are kept closed at all times when not in use. Use of the outside doors from the individual rooms will require prior approval of the operating staff except during an emergency evacuation.

5. Liquid Effluent

Two separate underfloor drainage systems have been installed within the TRL. Radioactive materials are not to be disposed of in either of the systems.

The main system¹ called the "liquid waste" system collects liquid effluent from the floor drains, sinks and restroom showers. This waste is collected in two underground 2500 gallon holding tanks. The effluent collected in the holding tanks will be monitored for tritium contamination and its disposition determined by the Health Physics representative. Solid or semi-solid waste is not to be disposed of through any of the drains in the facility. Liquid waste such as lubricants, solvents, etc., will be collected and disposed of by the Health Physics representative.

The second system, which includes the toilets and urinals, drains into the sanitary sewer.

B. Scope

This procedure establishes responsibilities and general safety controls for laboratory and maintenance operations conducted by all persons working in or visiting the TRL. The Sandia Laboratories Health and Safety Manual applies to all TRL operations. Specific operations may require their own Safe Operating Procedure (SOP) or Safe Work Permit (SWP). These procedures are discussed in Section E.

C. Changes and Review

Changes to this procedure shall be accomplished as follows:

1. Any change that alters the scope or significantly increases the hazard requires a formal revision which must be reviewed and approved as required by normal SOP procedures.
2. Any change that in the judgement of the operations staff decreases or has no effect on the hazard may be made with the approval of the operations staff and Health Physics representative.

Such changes must be documented with the signatures of the staff members and Health Physics representative.

This SOP shall be reviewed annually by the operations staff and Safety Engineering and Environmental Health Division 8252 to determine its adequacy for current conditions. Procedures shall be revised whenever the need arises.

0. Responsibilities

1. TRL Operations Supervisor, Division 8143

The supervisor of Engineering Division 8143, and his designated alternates have the responsibility and authority to control all experimental, service, and support work under the general regulations of the Sandia Health and Safety Manual, the instructions of this SOP and its appendices, and the specific instructions of any particular operating procedure.

The TRL operations supervisor may delegate in writing secondary responsibility for safe work conduct to specific individuals who have a prime interest in a particular operation.

The TRL operations supervisor, his alternates, and at least one person from Safety Engineering and Environmental Health Division 8252, comprise the operations staff. The operations staff and those individuals delegated with the responsibility for safe work conduct are responsible for the safe performance of TRL operations.

2. Safety Engineering and Environmental Health Division 8252

Safety Engineering and Environmental Health Division will provide guidance and assistance in all safety aspects relating to the work in the TRL. Division 8252 will provide at least one full time member to the operations staff, to serve as the facility Health Physics representative and to insure application of the resources of the entire Safety Engineering and Environmental Health Division, if, and when it should become necessary.

3. Health Physics Representative

At the TRL the Health Physics representative is primarily responsible for planning and implementing a program of radiological control and surveillance to ensure the radiological safety of all personnel at the TRL. In addition, the program includes conventional safety and industrial hygiene.

The Health Physics representative will coordinate with the Sandia SS representative on all transfers or releases of radioactive materials to or from the TRL.

4. User Division Supervisors

User division supervisors are responsible for the safe operation of the individual laboratories assigned to them. They are further responsible for compliance by their personnel with the procedures set forth for operations within the TRL.

5. Individual Employees

Each employee is responsible for taking all reasonable precautions to prevent injury to himself and his associates and to prevent damage to property. He is expected to understand and follow the approved safety and operational procedures that apply to the work. If he is in doubt regarding the safety of any phase of the operation, he is expected to check with his supervisor or a member of the operations staff before proceeding. No employee is required to perform a task that he

believes he cannot do safely. Before starting an experiment he shall comply with the requirements of Operational Instruction (OI) 6476-L-8330-1.

Each individual is responsible for the condition of the room and equipment he uses. This includes housekeeping, the safe operation and maintenance of the laboratory and any decontamination required of the work area or equipment.

6. Safety Review Committee

The TRL Safety Review Committee (TRL/SRC) has been established to assist TRL users in fulfilling their safety responsibilities. The SRC will review experiments in the conceptual, final design and pre-operational phases (See OI 6476-L-8330-1). The SRC is composed of representatives of Materials, Stress Analysis, user divisions, Safety and Environmental Health, and TRL operations.

The function of the SRC is to insure that adequate safety precautions are taken to protect both the health of personnel and the environment. The measure of performance of the SRC will be the overall safety, personnel radiation exposure, and environmental radiation levels records achieved. To achieve this goal, the SRC will assess the inherent safety of the experimental system and its operation, and assure adherence to relevant safety regulations.

The SRC will address the safety of the experiment but will make no judgements as to its scientific relevancy.

E. Operations

1. General

Individuals desiring to conduct tritium operations within the TRL must comply with the procedures of Sandia Laboratories Operating Instruction 016476-L-8330-1. This Operating Instruction presents procedures for request and approval of the use of TRL facilities and provides construction guidelines for experimental apparatus.

2. Safe Operating Procedure (SOP) and Safe Work Permit (SWP)

- a. SOP - All experimental operations within the TRL must be described by an up to date SOP. The effect that a change in operating procedures or a system modification will have on the SOP for an experiment will be determined by the operations staff and Safety Engineering and Environmental Health Division. The Safety Review Committee may be called to review a change to an SOP.
- b. SWP - A Safe Work Permit (Appendix V) must be prepared for a routine operation not covered by an SOP if the operation has the potential for affecting personnel safety or the operation of existing TRL systems. This can include but is not limited to maintenance or modifications to the laboratory containment, cleanup and utility systems, and modifications to experimental apparatus. The SWP will contain a description of the proposed task, its purpose and an analysis of the potential hazards and the means that will be

used to protect against these hazards. A detailed operational checklist is required for those aspects of the operation deemed potentially hazardous.

- c. Preparation and Approval - SWP's will be prepared by a member of the operations staff with the assistance of the Health Physics representative and those personnel required to perform the service or operation. The operations staff and the Health Physics representative will determine required review and approval levels.

3. Health and Safety Indoctrination

All personnel assigned to work at the TRL are required to attend a safety indoctrination that reviews the hazards associated with tritium and the TRL systems for personnel and environmental protection.

F. Facility Controls

1. Laboratory Areas

The facility is divided into two zones of differing relative hazard. They are the office area and radioactive materials area.

- a. The office area, where no work with dangerous or radioactive materials is allowed, is the area west of the double security doors of the main hallway. This includes the office, restrooms, Health Physics office, control room and the west hallway, i.e., the shaded area in Figure 1.
- b. The radioactive materials area is that part of the building east of the double security doors of the main hallway and includes the east corridor and all of the laboratories.

Figure 1. TRL Floor Plan

Entry to the radioactive materials area does not normally require protective clothing. However, entry into glove boxes that are tritium contaminated or the hooded area of Room 115A will require special protective clothing unless it is determined by the Health Physics representative that these areas are safe for unprotected entry.

2. Personnel Access

Building 968 is not operated as a security exclusion area. However, to minimize the potential exposure of Sandia personnel to tritium, it is desirable to limit access only to those persons having a need to be in the building.

Some time after 10/1/77, when modifications to the west corridor are completed, this will be accomplished by a badge exchange system. Until that time access to the building will be controlled by a sign in/sign out procedure. Access to each room containing tritium will be controlled by installing a push button combination lock on the door. The door combination will be provided only to those individuals on an access list for that particular room. Personnel not on an access list who desire entry to a room containing tritium must have the approval of either the person in charge of the room or the TRL operations supervisor or his alternate.

3. Personnel Limitations

- a. The number of persons present in a high hazard area at any one time shall be limited to the minimum required to perform operations safely.
- b. Potentially hazardous work will not be performed unless two qualified persons are present.

4. Work Area Regulations

- a. The TRL operations supervisor and the Health Physics representative must be notified of work to be performed by service groups in the building prior to the start of work. Safe Work Permits shall be obtained for work that may involve handling radioactive materials. Non-scheduled maintenance operations will not be performed in the TRL during non-working hours.
- b. The control room will be manned at all times during normal working hours.
- c. The equipment in the Technical Support Laboratory, Room 129, will not be used without approval of the TRL supervisor.
- d. To maintain ventilation flow control, laboratory doors are to be kept closed except during actual use.
- e. Service personnel and visitors will not adjust, handle, or operate equipment or experimental apparatus without the consent of the person responsible.
- f. Eating, smoking and drinking coffee is restricted to the office area unless specifically authorized.
- g. Gloves will be examined for external contamination and leaks before and after they are used for work in an enclosure containing particulate radioactive materials.
- h. All containers for shipping contaminated hardware (empty or full) will be surveyed by the Health Physics representative before they are allowed into or out of the building. Tools, equipment and experimental apparatus that have had exposure or contact with radioactive/toxic materials will also be surveyed and disposed of or decontaminated as required.
- i. All experimenters and operational staff will be instructed in how to use the radiation detection instruments in the laboratory.

- j. Work shall not be performed with radioactive material unless the required radiation detection instruments are in operation.
 - k. Modifications to experimental apparatus that may affect the operation of the TRL ventilation, utility power and decontamination systems will require prior written approval by the TRL supervisor.
 - l. Halogens, mercury, and sulfur are elements which are known to poison the cleanup system catalyst. Compounds containing these elements may not be used in the glove boxes or systems which interface with the GPS and VERS without written permission of the TRL supervisor. Solvents for general use in the facility will be limited to those which do not contain halogens or sulfur. If special circumstances arise mandating the use of halogen or sulfur containing solvents, written permission of the TRL supervisor is required prior to such use. Equipment using mercury will require a trap to collect the mercury where it interfaces with the two decontamination systems. The TRL supervisor will maintain a list of compounds approved and disapproved for TRL use.
5. Material Transportation and Control
- a. All movements of radioactive and SS materials, contaminated equipment, and radioactive waste to and from the TRL are to be arranged through the Health Physics representative.
 - b. Individual experimenters working in the TRL are responsible for the correct handling, packaging, and movement of their radioactive and SS materials.

c. Radioactive materials shall be packaged with the approval of Division 8252 in the following manner:

- (1) Radioactive gases in pressure vessels approved for the pressure and amounts of gas involved.
- (2) Pyrophoric materials will be sealed in a metal can before removal from the glove box. The can will be placed in a secondary container which will be purged with a dry inert gas while still in the enclosure. It will be placed in a third container immediately after removal from the enclosure.
- (3) Solutions of radioactive material will be packaged in a container designed to withstand the pressure buildup expected from radiolysis. The containers will be approved by the TRL Division Supervisor and Safety Engineering and Environmental Health (8252) before they are used.

d. All off-site receipts and shipments of tritium will be processed directly to and from the TRL SSMBAs.

6. Fire Protection

Building 968 is provided with automatic sprinkler protection. In the event of fire, fire alarm code 6-8-2-1 will be transmitted to Sandia Guard Headquarters, and the LLL Fire Department and the building evacuation bells will ring.

All glove boxes inside the building are provided with a 165°F combination fixed temperature and the rate of rise heat detector. These detectors will transmit a fire alarm code 6-8-2-1 to Sandia Guard Headquarters and the LLL Fire Department. It will also sound the building evacuation alarm.

To report a fire pull one of the fire alarm boxes located either on the north or south side of the building. Fire alarm code 6-8-1-1 will be transmitted to Sandia Guard Headquarters and the LLL Fire Department. Fires or other emergencies may also be reported by telephoning extension 2222. Fire extinguishers have been placed throughout the building. Fire and evacuation teams will be organized consisting of personnel who work in the building.

7. SS Materials Accountability

The procedures set forth in the Procedures for Controlled Materials are to be followed for accountability control. The TRL is designated as a Materials Balance Area (MBA). Monthly inventories will be accomplished by computer balances. The system will be audited by Sandia and ERDA annually and on demand.

8. Surveys

The Health Physics representative will make periodic surveys to check conformance with safety requirements and verify adequacy of established safety procedures. The routine program of checking radiation levels and degree of contamination is described in the Health Physics summary.

9. Bioassay

It is Sandia policy that all persons who work in areas where radioactive materials are handled periodically submit urine samples for bioassay. Within the TRL this program is administered by the TRL operations supervisor. The TRL operations supervisor and Health Physics will establish a list of individuals whose work warrants routine testing. This list is sent to the Medical Department and a copy is

posted in the TRL. The minimum frequency for individual sampling is once per month. A sample will be submitted weekly by individuals working primarily in the TRL. More frequent sampling may be required if there is a possibility of significant exposure. Empty sample bottles will be provided in the TRL for each person listed. When the urine sample has been collected, the filled bottles are placed in the "pick up" rack. A person designated by the division supervisor returns the samples to the Safety Engineering and Environmental Health Division 8252. The results of the analysis will be reported to the employee, the employee's supervisor, and Hazards Control Health Physics Group. If the urine tritium concentration exceeds 20 $\mu\text{Ci/liter}$, it will be reported to the TRL division supervisor or the Health Physics representative immediately by telephone.

10. Explosives

Explosives will be permitted within the TRL only after approval by the Safety and TRL operations divisions. Explosives will be handled in accordance with SLL SOP 594.

11. Emergency Procedures

Basic guidelines are provided in the SLL Emergency Preparedness Handbook and the Emergency Preparedness Program Master Plan. Actions required by an accident situation are outlined below.

Reciprocal assistance agreements are in effect between SLL and LLL for the notification and assistance in the event of a release from the TRL. This assistance includes emergency response for protection of

life and property and coverage by the LLL Atmospheric Release Advisory Capability (ARAC). Emergency environmental monitoring will also be provided by the California Department of Public Health, Division of Radiological Health. SLL Security Division and the LLL Fire Department will control the TRL site during an emergency. Access will be authorized by Health Physics personnel, (Safety Engineering and Environmental Health Division 8252). Notification to ERDA will be made by the supervisor of the Safety Engineering and Environmental Health Division should that be required.

TRL alarms are summarized in Appendix VI. Alarms of major significance are summarized as follows:

1) Room Air Low	50 $\mu\text{Ci}/\text{m}^3$
2) Room Air High	500 $\mu\text{Ci}/\text{m}^3$
3) Glove Box Low	1 Ci/m^3
4) Glove Box High	100 Ci/m^3
5) Glove Box HVAH Low	100 $\mu\text{Ci}/\text{m}^3$
6) Glove Box HVAH High	500 $\mu\text{Ci}/\text{m}^3$
7) Stack Low	50 $\mu\text{Ci}/\text{m}^3$
8) Stack Intermediate 1	500 $\mu\text{Ci}/\text{m}^3$
9) Stack Intermediate 2	5 mCi/m^3
10) Stack High	50 mCi/m^3
11) Evacuation Alarm	Composite (High Stack and High Room)

Actions to be taken by TRL personnel at the various alarm levels are described below:

- 1) Room Air Low Alarm: The building Health Physics representative (HPR) will be dispatched to the room in question. Continue working until the HPR advises you to leave the room or the alarm has cleared.

- 2) Room Air High Alarm: Terminate your work in a safe and orderly fashion. Exit the room through the corridor door and await the arrival of the building alarm response team. Inform the response team of any known hazards in the room and the activity in progress at the time of the alarm.
- 3) Glove Box Low Alarm: Locate the source of the leak and rectify in the time frame of 15 minutes. If this cannot be achieved, the experiment will be terminated in an orderly fashion. Room air concentrations will be a factor in the action sequence.
- 4) Glove Box High Alarm: All glove operations will be terminated immediately and the glove ports sealed. Room air concentrations will be a factor in the action sequence.
- 5) Stack Low Alarm: This alarm sounds only in the control room and initiates a review by operations personnel of room air levels and system checks to determine the source of the release. Corrective actions will then be taken.
- 6,7) Stack Intermediate Alarms: These indicate increasing levels of hazard and require increased attention by operational personnel.
- 8) Stack High Alarm: This indicates a serious condition in the TRL. If the source is not a release from the GPS or VERS, it is probably an indication of a high room air concentration. This alarm in conjunction with a high room air alarm causes an evacuation alarm to be sounded.
- 9) Evacuation Alarm: This alarm indicates a requirement for immediate evacuation by personnel to the nearest exit. All personnel will assemble at the entry gate to the compound. At this time, a determination will be made of the whereabouts of all personnel known to be in the TRL at the time of the release. Health Physics will direct reentry.
- 10) Particulate Material: An accident involving tritides will require immediate evacuation to the hallway for monitoring by Health Physics. If the release is accomplished by fire or explosion call 2222. The operator and Health Physics personnel will determine what actions are to be taken.
- 11) Nonoperational/Security Headquarters Alarms: Seven alarm functions are located in Security Headquarters, Bldg. 911.
 - 1) Building Fire Alarm - also LLL Fire Department
 - 2) Glove Box Fire Alarm - also LLL Fire Department
 - 3) Security Alarm

4) Computer Generated Alarms

- a) Operational
- b) Hazard
- c) Danger
- d) Emergency

If any of these alarms are sounded, the appropriate personnel must be notified as listed in Appendix 1.

A release in the TRL will require all or part of the following general actions:

- 1) Any alarm causes immediate notification of Health Physics and operations personnel.
- 2) Notify building occupants of the release and instruct them what actions are to be taken.
- 3) If the release is accompanied by fire, explosion, or injuries, this must be reported to extension 2222.
Give the following information:

- 1) Name
- 2) Location
- 3) Nature of Emergency
- 4) Estimate of Injuries

- 4) Establish and maintain appropriate contamination zones.
- 5) All possibly contaminated personnel will be monitored and advised as to decontamination procedures. Facilities are available in the TRL, Bldg. 913, and Medical.
- 6) Every reasonable effort should be made to rescue trapped or injured personnel. Emergency exposure authorizations as established by ERDA are given in Appendix 11.

First aid should be provided if needed until medical help arrives. Contaminated personnel can be removed to LLL medical facilities if necessary.

- 7) The area which has been evacuated will not be reentered without approval of Health Physics and operations.
- 8) Reentry will be controlled by Health Physics. Emergency monitoring instruments and protective clothing is maintained in Building 916/126 Environmental Health Laboratory. This equipment consists of 12 HR3 portable tritium monitors kept at full charge, and personnel bubble suits.

QUALITY ASSURANCE PROGRAM
FOR
CONTINUING OPERATION
OF THE
TRITIUM RESEARCH LABORATORY
SANDIA LABORATORIES LIVERMORE

(Requirements defined in AEC Manual Chapter 0820 Quality Assurance)

OBJECTIVES

- a. To obtain the level of quality considered necessary for accomplishment of program objectives, commensurate with Sandia Livermore responsibility for health & safety, for the protection of the environment, and for reliability and continuity of operations.
- b. To assure that facilities, systems, components, and equipment procured, fabricated, installed, constructed, tested, operated or modified by and for Sandia Livermore, conform to contract requirements, specifications and drawings.
- c. To prevent delays and costs due to rejections or failures.
- d. To assure that appropriate quality requirements and standards are implemented by Sandia Livermore & Sandia Livermore contractor organizations.

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QUALITY ASSURANCE PROGRAM
FOR
AEROSTATICS LABORATORY
SANDIA LABORATORIES LIVERMORE
I. ORGANIZATION

1.1 Responsibility and Authority. Organizational responsibility and authority for development, implementation, and management of the Quality Assurance Program is clearly defined in Sandia Laboratories directives, policies, procedures and instructions. Quality achievement is verified by individuals and organizations not directly responsible for performing the work, but who are responsible for checking, inspecting, auditing, or otherwise verifying that work has been performed satisfactorily. The Quality Assurance Team Leader, responsible for the direction of the Quality Assurance Program, has direct access to top management via the Division, and reports regularly on the status and adequacy of the Quality Assurance Program. Personnel performing quality assurance functions have the organizational freedom, authority and capability to identify and evaluate quality problems and to initiate, recommend, or provide solutions. The Quality Assurance organization chart is shown in Figure 1.

1.2 Training and Indoctrination. As part of the Quality Assurance Program, Sandia Laboratories Livermore (SLL) has determined the extent to which formal training and indoctrination programs are needed. A full time course to train pressure equipment installers was conducted. Indoctrination programs to familiarize personnel with handling, monitoring, and safety aspects of tritium operations are conducted by organizations responsible for these functions.

X AS REQUIRED

SANDIA LABORATORIES
LIVERMORE

II. QUALITY ASSURANCE PROGRAM

2.1 Policies and Procedures. Activities affecting quality are defined and documented by SLL in appropriate directives, policies, procedures, instructions, drawings, and other technical documents. Such documents include the quantitative or qualitative provisions for ascertaining that the activities are accomplished in compliance with contract requirements. These policies and procedures are outlined in detail in this document. They are applied to the Tritium Research Laboratory equipment, based upon specific design requirements as described in Section III.

2.2 Management Reviews. Quality Assurance Review Meetings are held as necessary by Sandia Laboratories Livermore (SLL) with attendees including SLL management personnel. The reviews provide a means of assessing project quality accomplishments, discussing program audits, and resolving management problems.

2.3 Requirements.

2.3.1 Equipment. The equipment for experiments will generally be purchased from commercial suppliers. The quality control requirements will be determined on an individual basis for each piece of equipment based upon its function. The specific quality control activities that, if required, may be instituted for a piece of equipment are described in Sections IV and VII. The installation of equipment will be controlled by SLL, either directly or by contract with the supplier.

Procurement and inspection of equipment will be based on two levels of quality control. These two levels reflect the H_2 concentration and working pressures to the equipment.

The higher level of quality control will, in general, be typical of standards associated with heavy commercial industry practice, but with additional procedures as controlled by laboratory requirements. In general, these additional requirements will consist of material certifications and qualification testing and inspection at the suppliers plant. In the event new unproven design components are specified, it is likely that destructive tests will be run and post-mortem analysis made to assure the validity of design theory as well as manufacturing practices.

The lower level of quality will apply to equipment with very small risks. At this level, commercial standards will apply, and receiving inspection procedures typical of daily laboratory practice will be employed.

Some additional quality control procedures may also be required at this lower level because of laboratory usage; however, they will be less stringent in nature and, in general, may include minimal material certifications and minimal qualification testing and inspection at the suppliers plant.

The details of equipment fabrication practices for the TRL are defined in OI-6476-L8330-1, titled "TRL Equipment Fabrication Guideline", Appendix A, dated February 17, 1977.

III. DESIGN CONTROL

3.1 Sandia Laboratories Livermore Design Control.

3.1.1 Design Definition and Control. Sandia Laboratories Livermore (SLL) has established and implemented methods for controlling design activities to assure that applicable design criteria, codes, standards, practices, and requirements for those materials, structures, components, systems, facilities, and processes required are defined and correctly translated into specifications, drawings, procedures, and instructions. These established and implemented methods for coordinating and interfacing with other participating organizations assure compliance with these requirements during the design and development phase and throughout succeeding phases of fabrication, testing, construction and operation.

3.1.2 Design Procedures. SLL has defined and documented design procedures stating the requirements to be satisfied by the design. These criteria include the project performance objectives, operating conditions, and requirements for safety and reliability, as well as the requirements for materials, fabrication, construction, testing, operation, maintenance, and quality assurance.

3.1.3 Codes, Standards, and Practices. SLL has established procedures to assure that appropriate codes, standards, and practices for design, materials fabrication, construction, inspection testing, and operation of components, structures, systems, and facilities are defined, documented, and employed. Where applicable, AEC, ASTM, ASME, OSHA, and other recognized codes, standards, and practices are used. Where such recognized engineering codes, standards, and practices are non-existent, or inadequate to meet the needs of the project, SLL develops new or supplemental specifications and practices, SLL coordinates with other appropriate organizations, and furnishes copies of specifications and practices to concerned organizations.

Codes, standards, specifications, and practices which SLL employs are identified and referenced in engineering practices manuals, analyses, description, plans, specifications, drawings, and other applicable engineering documents. The L23000 series of specifications, covering both materials and processes, control component acquisition & assembly in the TRL.

3.1.4 Engineering Studies. SLL has conducted and documented engineering studies to establish that the design meets the design criteria, that it is based on proven practices, and is adequate for the intended service. Engineering studies have focused on those aspects involved in the intended service, such as operation, maintenance, in-service inspection and safety, and are based on analysis of structural stress, environmental, and other effects. Engineering studies include analysis of "trade-offs" and alternatives, identify weaknesses, and provide for incorporation of appropriate preventative design features, operating and maintenance practices, and safety precautions.

3.1.5 Parts, Materials, and Processes. SLL has established methods for the selection, standardization, identification, and application review of essential parts, materials, and processes to be used in each project.

SLL has selected parts, materials, and processes on the basis of proven experience or qualification for the intended service. Where applicable parts, materials, and processes have been developed and qualified by AEC/ERDA or other appropriate programs, or are reflected in applicable recognized standards, they are used. Where necessary parts, materials, and processes have not been so qualified, SLL qualifies the item(s) before they are used. SLL has made very effort to reduce the variety of parts, materials, and processes through standardization.

3.1.6 Specifications, Drawings, and Instructions. SLL has prepared specifications, drawings, instructions, and other engineering documents necessary to define specific design requirements. These documents include as applicable, requirements for detail design, materials, fabrication, construction, installation, testing, inspection, cleaning, packaging, shipping, storage, operation, and quality assurance.

3.1.7 Design Reviews. SLL conducts planned and documented design reviews in accordance with established procedures to verify that the design meets requirements. Design reviews provide assurance that studies calculations, and analyses involving electrical, mechanical, safety, reliability, maintainability, and other pertinent considerations are complete and correct. Design reviews are held to discuss and resolve technical problems concerning design adequacy among the design organizations.

SLL identifies those components and systems for which independent formal design reviews are to be scheduled and conducted by the responsible design organization. Design reviews are independent in the sense that the reviewers have no direct responsibility for the design, but are technically competent and may be from the same organization that prepared the design. Participation in design reviews are interdisciplinary, involving key technical personnel in the areas of design, testing, quality assurance, operation and maintenance, as well as consultants, as appropriate. Joint design reviews with other participating agencies are held by the responsible design organization when design interfaces are under consideration.

Hold points are established in the project, beyond which further design work or initiation of fabrication shall not proceed pending design review.

IV. DOCUMENT CONTROL

4.1 Sandia Laboratories Livermore. Sandia Laboratories Livermore (SLL) controls the release of design documents authorized for equipment. These controls assure that design documents and their changes are properly prepared, coordinated, and released by authorized persons, distributed to prescribed parties, and maintained current and complete. The SLL document-release and change-control system provides for a final review, approval, and sign-off by engineering and quality assurance personnel. Changes to approved design documents are reviewed and approved by the same organizations that performed the original review and approval.

SLL prepares and maintains complete and current lists of engineering drawings, including subcontractor and vendor drawings, which are applicable to the equipment. For each drawing, the list includes specific identification of the applicable revision.

SLL monitors document release and change control activities to assure that the latest authorized documents are used in the work areas. The system provides for the documents to be distributed to, or removed from, the proper points in time to assure that work and quality functions are accomplished in accordance with the latest applicable document.

These documents include the drawings and specifications, work instructions, quality control procedures, inspection instructions, and testing procedures. These documents are permanently retained in SLL record system.

V. CONTROL OF MEASUREMENT AND TEST EQUIPMENT

5.1 Sandia Laboratories Livermore (SLL) provides the selection, acquisition, calibration, adjustment, maintenance, and control of inspection measuring and test equipment necessary to determine conformance of fabricated materials, components, and assemblies to applicable equipment requirements.

5.1.1 Equipment Evaluation. SLL inspects and evaluates inspection measuring and test equipment to determine its accuracy and tolerance before it is used, and the results are documented.

5.1.2 Control of Inspection Measuring and Test Equipment. Inspection measuring and test equipment are calibrated at scheduled intervals against certified standards having known valid relationships to national standards. Records are maintained that indicate the last and the next-due calibration dates. Each item of inspection measuring and test equipment has its last and next-due calibration dates clearly indicated.

The calibration interval for each item is based on the type of equipment required accuracy, use, and other conditions affecting measurement control. Equipment that is not properly maintained or calibrated in accordance with specified schedules is identified and removed from service.

5.1.3 Calibration Standards. SLL provides services, and uses those of an approved standards laboratory for the calibration of inspection measuring and test equipment.

Standards are maintained, calibrated, and used in an environment having temperature, humidity, and contamination controls that are compatible with the required accuracy and operating characteristics of the standards.

Within the limitations of current technology, the accuracy of standards used to calibrate inspection measuring and test equipment have a tolerance no greater than 10 percent of the allowable tolerance for the equipment being calibrated.

5.1.4 Discrepant Equipment. When discrepancies in inspection and testing equipment are found at calibration, SLL determines what corrective action is required. Item inspected with equipment, which are out of calibration, are considered unacceptable until SLL can show that all applicable requirements have been met. Corrective action is accomplished in accordance with the provisions of Section XV.

VI. PROCUREMENT-DOCUMENT CONTROL

6.0 Sandia Laboratories Livermore (SLL) has established and implemented procedures whereby design, procurement, quality assurance, and project-management personnel review procurement documents to assure that requirements are complete and appropriate. Subsequent reviews of procurement contracts and purchase orders are also made to assure that changes made in quality assurance requirements during contract negotiations and after contract award are duly incorporated.

6.1 Control of Configuration.

6.1.1 Contract Change Control-Equipment. SLL has established and implemented procedures to assure control of approved changes in contracts, design drawings, specifications, test procedures, inspection instructions, and other procurement documents. As part of these procedures, affected organizations, including designers, material suppliers, and manufacturers, are notified of changes; and SLL shall receive verification of timely incorporation of changes. Materials, products, processes, drawings, specifications, and other items affected by the change are re-identified when required by the design.

VII. CONTROL OF PURCHASED MATERIAL, EQUIPMENT, AND SERVICE

7.0 Sandia Laboratories Livermore (SLL) employs those controls necessary to assure that procurement functions are accomplished in accordance with the contract, and in accordance with any contract-specified codes, standards, drawings, and specifications.

7.1 Procurement Planning. SLL documents the methods used to accomplish the procurement and related quality assurance activities. The planning provides for evaluation and selection of potential suppliers and identification of source and receiving inspection activities, and controls to be used for acceptance and disposition of purchased items. Procurement planning and outlining of the work effort will be kept current to reflect the progress and status of the activities, and is included as a portion of the Quality Assurance Program plan described in Section II of this document.

7.2 Procurement Requirements. Procurement contracts issued by SLL include quality control requirements for each item or service purchased; refer to applicable codes and standards, and designate the appropriate quality. They also define supplier data, records, and report submittal requirements.

7.3 Evaluation and Selection of Procurement Sources.

7.3.1 General Requirements. SLL selects procurement sources primarily on the basis of demonstrated capability to provide a similar product, process, or service in accordance with the requirements of the Request for Procurement (RFP). When records are not available to indicate quality capabilities, the facilities, organizations, and quality control functions of the potential sources are evaluated to determine their adequacy.

7.3.2 Acceptable Source List. SLL has and maintains lists of suppliers that have demonstrated their capability to provide acceptable specific products or services and uses these lists in selecting sources for similar products or services.

7.3.3 Pre-award Evaluation. Sources for procurement of complex or high-cost products or services are evaluated by qualified SLL personnel prior to contract award to determine capability of the source to perform in accordance with the requirements of the RFP. A procurement source's history of quality performance is considered as an element of this evaluation.

7.4 Personnel Training and Certification. SLL personnel, or outside consultants who perform surveillance and inspection of supplier special processes such as welding, brazing, radiography, magnetic-particle inspection, dye-penetrant inspection, and ultrasonic examination, are knowledgeable of applicable requirements. Certification, if required, shall include a formal training program to be followed by a formal testing procedure to ensure the proficiency of each individual. Records of personnel certifications are maintained.

7.5 Equipment Calibration and Standards. When required to ensure uniformity of inspection and test results, SLL provides for timely and continual coordination and correlation with suppliers, of inspection and test procedures used for inspection measuring, and test equipment. Calibration shall be accomplished as prescribed in Subsection 5.3 of this standard.

7.6 Source Surveillance and Inspection. SLL has established and implemented procedures for maintaining surveillance at the source of materials and services. Source surveillance procedures have been established in accordance with the relative importance, complexity, and quality of items being procured and provide a means for determining the effectiveness of the Quality Assurance Program. A Quality Assurance Planning Document on each supplier contract, where applicable, will define the points or stage of completion where SLL personnel will make actual inspection and/or witness tests. This document also defines the certifications that must be provided by the supplier. Special effort shall be made to inspect items at the earliest practical time so that deficiencies may be detected and corrected before assembly or subsequent work precludes inspection. Source surveillance and inspection may not be required when the quality of an item can be verified to conform to specifications or drawings by review of certified test reports, inspection upon receipt, or other means.

7.7 Receiving Inspection.

7.7.1 Planning and Inspection. SLL will establish and implement procedures for receipt, inspection, test, and distribution of items delivered by suppliers. Receiving inspection has been coordinated with source surveillance and inspection activities. SLL inspects or tests purchased items upon receipt for cleanliness and dimensional, chemical, physical, or other characteristics, as appropriate, to verify conformance to specified requirements. SLL routinely or periodically validates supplier-furnished material certifications by means of independent analyses or overchecks. SLL procurement planning documents define the necessary inspections and tests and provide for upward adjustment depending upon source, quality performance history, lot size, and other factors.

Inspection instructions and test procedures provide for verification of characteristics required in accordance with acceptance criteria in contract drawings and specifications. Emphasis is placed on assuring that items have not been damaged in shipment and that interface characteristics that influence subsequent fabrication, construction, or end use are verified. Special examinations or test required at the point of receipt are identified and conducted in accordance with contract requirements.

Sampling inspection methods may be used when: (1) tests are destructive or (2) inherent characteristics, inspection records, or noncritical applications of the material or product indicate that a reduction of inspection will not jeopardize the quality, reliability, or design intent of the material or product. The use of sampling inspection methods, other than those stated in the contract, shall be subject to approval for use by SLL.

7.7.2 Documentation. SLL will review and provide approval of appropriate supplier-generated documents, such as drawings, manuals, certifications, test results, and inspection data for completeness, acceptability and conformance to contract requirements before accepting completed items.

7.7.3 Disposition of Receiving Items. Materials or products found to be damaged upon receipt are identified and withheld from inspection or end use until disposition is decided. Acceptable materials and products will be identified as to inspection status and processed to stores or end use areas. Nonconforming materials and products shall be identified, segregated, and disposed of in accordance with Section XIV.

7.8 Control of Received Items. SLL has established and implemented procedures for identifying, controlling, handling, and storing received materials and equipment. These procedures provide for maintaining records of marking and identification to assure that the items and pertinent data can be traced to their origin in accordance with contract requirements. Controls have been implemented to protect items that deteriorate from environmental exposure or which may be damaged during handling operations. Material or equipment that deteriorates with age is identified, and controls implemented to assure utilization during its useful life.

7.9 Quality Audits. SLL regularly audits quality control functions related to procurement, in accordance with Section XVII of this standard.

VIII. CONTROL OF SPECIAL PROCESSES

3.0 Sandia Laboratories Livermore (SLL) personnel or outside consultants who perform surveillance and inspection of special processes such as welding, brazing, radiography, magnetic-particle inspection, dye-penetrant inspection, and ultrasonic examination, will be knowledgeable of applicable requirements. In addition, all pressure-oriented equipment will be installed and inspected by Certified Pressure Installers. Certification includes a formal training program to be followed by a formal testing procedure to ensure the proficiency of each individual. Records of personnel certifications are maintained.

Outside contractors or consultants who perform surveillance and inspection of special processes such as welding, brazing, radiography, magnetic-particle inspection, dye-penetrant inspection, and ultrasonic examination, will be knowledgeable of applicable requirements.

IX. INSPECTION AND TEST CONTROL

9.0 Sandia Laboratories Livermore (SLL) performs inspections and tests in accordance with established plans, instructions, and procedures. SLL verifies that inspection and test prerequisites are met, that appropriate instruments and devices are used, and that inspections and tests are performed in the proper sequence under suitable environmental conditions.

SLL implements and maintains procedures to detect, analyze, and record any non-conformances and assures that appropriate corrective action is taken and completed. SLL assures that results of inspections and tests are recorded and can be traced to the individual responsible.

SLL assures that inspection stations are located at appropriate points of fabrication, processing, assembly, and construction so that parts, components, assemblies, processes, and fabrication methods are inspected and tested, and data recorded according to plans and procedures.

Mandatory hold points, which require inspection of selected characteristics of an item or process, or witnessing of testing, beyond which work is not to proceed, are identified in the SLL inspection and test plan.

Preoperation testing plans and procedures are prepared by SLL as applicable to assure compliance with safety standards, prevention of damage to the item being tested, and conformance to testing requirements of the contract.

SLL verifies the completeness of the construction process and assures that equipment has been procured, constructed, and installed as described by the drawings and specifications. SLL verifies that objectives and performance defined during the design phase have not been degraded during subsequent phases of the project.

X. INSTRUCTION, PROCEDURES AND DRAWINGS

10.0 Sandia Laboratories Livermore (SLL) by appropriate design document, identifies those criteria used for acceptance. The documents specify all characteristics required to be reported by code, standards, or specifications, including quantitative measurements, and identifies the authorized inspector who performed the required inspections.

XI. IDENTIFICATION AND CONTROL OF MATERIAL, PARTS, AND COMPONENTS

11.1 Sandia Laboratories Livermore (SLL)

11.1.1 Identification. SLL identifies material, parts, components, and processes on drawings, specifications, and other engineering documents. The identification system controls traceability through the use of lot numbers, serial numbers, or other appropriate means. Those materials, parts, and components requiring specific traceability to original certification data are designated in the applicable documents.

11.1.2 Control. Controls are exercised at all points necessary to assure that only accepted materials and items are used. Materials and items that deteriorate with age are marked to indicate the date when useful life began or the date when useful life expires.

XII. INSPECTION

12.1 Equipment. The experimental equipment in the building will generally be purchased from commercial suppliers. The quality control requirements will be determined on an individual basis for each piece of equipment based upon its function. The specific quality control activities that, if required, may be instituted for a piece of equipment are described in Section IV and VII. The installation of equipment will be controlled by SLL either directly, or by contract with the supplier.

Procurement and inspection of equipment will be based on two levels of quality control. These two levels reflect the H_2 concentration and working pressures in the equipment. Details are contained in O.I. 6476 L-8330-1 dated February 17, 1977.

The higher level of quality control will, in general, be typical of standards associated with heavy commercial industry practice, but with additional procedures as dictated by laboratory requirements. In general, these additional requirements will consist of material certifications and qualification testing and inspection at the supplier's plant. In the event new unproven design components are specified, it is likely that destructive tests will be run and post-mortem analysis made to assure the validity of design theory as well as manufacturing practices.

The lower level of quality supplies to commercial standards, and receiving inspection procedures typical of daily laboratory practices will be employed.

Some additional quality control procedures may also be required at this lower level because of laboratory usage; however, they will be less stringent in nature, and, in general, may include minimal material certifications and minimal qualification testing and inspection at the supplier's plant.

12.2 Planning. SLL has established and implemented those procedures and instructions required to assure that fabrication, processing, and assembly activities related to equipment are planned and conducted in accordance with requirements of the contract and its specified documents. SLL planning activities include identification and sequencing of fabrication, processing, and assembly functions, and their associated inspection and testing activities. The events are shown in the Planning Schedule.

12.3 Inspection and Test Plan. The SLL Quality Assurance Program, where applicable, provides the necessary detailed planning of inspection and test activities related to fabrication and assembly operations. An inspection and test plan is prepared, either as separate documents identified with the parts, components, or assemblies, or an integral part of SLL's work instructions. The inspection and test plan consists of narrative description of the sequence of activities for fabrication, processing, assembly, inspection, and test and indicates the type of characteristics to be measured, the methods of examination, and the applicable acceptance criteria.

The SLL inspection and test plan establishes those inspection and test points from raw materials through fabrication, processing, and assembly at which conformance of parts, components, and sub-systems to design requirements will be verified.

The plan will be kept current and revised when necessary to assure that inspections and tests are properly scheduled and accomplished.

12.4 Material Identification and Control. Materials and items subjected to fabrication, processing, or assembly operations will be identified and controlled throughout manufacturing in accordance with requirements established in specifications, drawings, or other technical documents. Identification will be indicated, either on the fabricated item or assembly, or in related records. Controls will be exercised at all points necessary to assure that only accepted materials and items are used.

The supplier shall provide for proper control, preservation, and storage of materials or items furnished by SLL.

12.5 Control of Processes

12.5.1 Fabrication and Assembly Processes. To assure that the required quality is achieved, SLL has established and implemented procedures and instructions for the control of fabrication and assembly processes, both metallurgical and chemical. Emphasis is placed on prevention, elimination, and correction of nonconformances at the earliest possible stage.

Process controls include: shop orders, process sheets, travelers, inspection instruction, and other shop documents prepared as supplements to specifications, codes, and standards; verification of adequacy of shop documents; assurance of compliance; and maintenance of records.

When a fabrication or assembly process must be conducted in a special environment, such as in a vacuum or an inert atmosphere, the process controls are implemented to assure that the required environment is maintained.

Where applicable, tooling, jigs, fixtures, and other equipment used for process control and precision inspection of dimensions, contours, and locations are identified in planning documents. Such items of equipment are closely controlled and inspected prior to use and at prescribed intervals to assure that their required accuracy is maintained.

12.5.2 Process Qualification. Procedures for performance of designated processes are qualified before fabrication is started and to the extent required by the contract. Upon request of SLL, the supplier shall furnish qualification documents for approval, including procedures and drawings, and the results of tests and inspections.

12.5.3 Nondestructive Examination. Nondestructive examination procedures for processes such as radiography, ultrasonic testing, liquid-penetrant inspection, and magnetic-particle inspection are qualified and controlled to assure that results provide accurate, uniform, and reproducible indications of actual quality. Nondestructive examinations are performed in accordance with qualified procedures and specified acceptance criteria.

12.5.4 Cleaning. The supplier shall prepare and implement procedures to assure that lubricants, chemicals, materials, precision parts, components, assemblies, and systems are cleaned under controlled conditions as specified in the contract, and that required cleanliness is maintained.

12.6 Personnel Training and Certification. SLL personnel responsible for performing and verifying pressure equipment installations will be certified per Section VIII.

12.7 Inspection and Tests.

12.7.1 General Requirements. Throughout the equipment manufacturing and installation phase, SLL performs or has performed inspections and tests in accordance with established plans, instructions, and procedures. SLL verifies that inspection and test prerequisites are met, that appropriate instruments and devices are used, and that inspection and tests are performed in the proper sequence under suitable environmental conditions. SLL has established, implemented, and maintained procedures to detect, analyze, and record any nonconformances and to assure that appropriate corrective action is taken and completed. SLL assures that results of inspections and tests are recorded and can be traced to the individual responsible.

SLL assures that inspections are made at appropriate points of fabrication, processing, and assembly so that parts, components, assemblies, processes, and fabrication methods are inspected and tested, and data recorded according to plans and procedures.

SLL will furnish inspection and test results and related data to ERDA on request.

12.7.2 Procedures. SLL will provide procedures, instructions, and check lists that clearly describe the appropriate inspections and tests for materials, work in process, and completed articles as required by the code standard, specification, and the contract. In addition, the criteria for acceptance or rejection of product are included. All characteristics required to be reported by the code, standard, specification, or contract will be examined as prescribed by procedures and instructions, and the results recorded on check lists or other documents appropriate to the inspection or test.

Instructions and procedures shall be revised and updated as required to reflect design or contract changes.

12.7.3 Completed Item Inspection and Test. Upon completion of manufacturing, fabrication, or assembly, SLL will inspect and test the parts, materials, components, assemblies, or systems before they are delivered or installed. Each completed item shall be inspected for completeness, markings, calibration, adjustments, freedom from damage, deterioration or contamination, safe operating condition, or other attributes to provide objective evidence to conformance to contract requirements.

Modifications, repairs, or replacement made after completion of inspections and tests shall require re-inspection and retest to the extent necessary to verify acceptability and assure compatibility with component, assembly, sub-system, and system interfaces.

12.7.4 Inspection Status Indication. SLL has an established system whereby markings, routing cards, stamps, or other means are used to indicate the status of inspections and tests performed on individual items to provide a means for ensuring that only acceptable supplies and services are used in the completed item.

12.7.5 Certification. When required by the contract, the supplier shall certify that all items manufactured and/or furnished by the supplier conform to specified code, standard, specification, and contract requirements. Certification shall include certified reports of all required tests, analyses, inspections, and examinations, and shall be identified to the applicable item.

12.8 Document Control. In accordance with the requirements of Section IV of this document, SLL has established procedures for release and change control of documents related to fabrication, processing, and assembly. The Q.A. organization monitors document-release and change-control activities to assure that the latest authorized documents are used in work areas.

12.9 Equipment Calibration and Standards. SLL has an established system that provides for the selection, acquisition, calibration, adjustment, maintenance and control of inspection measuring and test equipment which is defined in Section V of this document.

12.10 Statistical Quality Control and Analysis. In addition to the statistical methods required by the contract, statistical planning, analysis and testing techniques may be used by the supplier when such procedures afford advantages in maintaining the required quality. Sampling plans may be used when tests are destructive or when quality records or inherent characteristics of the item, or the nonessential nature of its application, indicate that inspection or testing can be reduced without jeopardizing quality. If the supplier uses sampling plans, SLL will reserve the right to review such plans for approval before they are implemented by the supplier. Any sampling plan used must provide valid confidence that required quality will be achieved and that any defect that might be in a lot accepted under a sampling plan will not result in an adverse condition with respect to safety, operability, and reliability.

12.11 Control of Nonconforming Items. The acceptance or rejection of nonconforming items offered for delivery is the prerogative of SLL. Nonconforming items furnished by suppliers shall be controlled as prescribed in Section XIV of this standard.

12.12 Corrective Action. SLL quality control functions provide for detection of conditions adversely affecting quality and for corrective action and feedback in accordance with the requirements of Section XV of this Standard.

12.13 Handling, Preservation, Packaging, Storage, and Shipping.

12.13.1 Handling. SLL has developed and implemented handling practices, procedures, and instructions as required by applicable codes, standards, and specifications. Special handling practices shall be used during fabrication and assembly operations when damage due to handling might otherwise result.

12.13.2 Preservation, Packaging, and Storage. SLL quality control programs provide procedures and instructions for the preservation, packaging, and storage of items. SLL assured that items subject to deterioration or damage through exposure to air, moisture, or other environments during fabrication, processing, assembly, and interim storage periods are cleaned and have preservative applied at such points and by such methods as required to preclude damage. Items being packaged for shipment shall be preserved in accordance with contract requirements. Items subject to damage shall be packaged in such a manner, and with such materials, as required to prevent damage. Packaging requirements shall allow for conditions that could affect the item at the supplier's plant, in transit to the destination, and at the destination. Items to be stored shall be adequately protected against deterioration and damage. Periodic inspections will be performed to detect deterioration or damage, and corrective action shall be taken as required.

12.13.3 Shipping. The supplier shall provide for inspection and control of all items shipped from his plant to assure that: (1) items to be shipped have received and satisfactorily passed the required inspections and tests; (2) items have been preserved and packaged in accordance with applicable specifications and procedures; (3) items and packaging have been properly identified, and (4) devices to record conditions during shipping have been provided, if required.

12.14 Quality Records. In accordance with the requirements of Section XVIII of this document, inspection, test, and other data related to the quality status of parts, components, assemblies, and systems is collected, processed, analyzed, and distributed to pertinent areas within the SLL organization, to sources of supply when appropriate, and to the AEC when required. Records are kept for at least the life of the equipment.

Examples of records include acceptance test data, inspection and test reports, material certifications, welder qualifications, quality audit reports, summaries of nonconformances, and corrective actions.

12.15 Quality Audits. SLL regularly audits the quality control operations of manufacturers and suppliers in relation to fabrication and assembly operations in accordance with the requirements of Section XVII of this document.

XIII. INSPECTION AND TEST PLANS

13.0 The Sandia Laboratories Livermore (SLL) Inspection and Test Plan for equipment establishes those inspection points from raw materials through fabrication, processing, installing of assemblies, sub-systems, and systems to verify that installation operations have been accomplished in accordance with design drawings, specifications, and codes. Emphasis is placed on prevention, elimination, and correction of nonconformances at the earliest possible stage.

XIV. NONCONFORMING MATERIALS, PARTS, COMPONENTS, OR SYSTEMS

14.1 Equipment. Sandia Laboratories Livermore (SLL) has developed and implemented procedures to control items that do not conform to contract requirements. The procedures provide for prompt identification, documentation, segregation, technical review, and disposition of nonconforming items. Significant nonconformances that cannot be reworked to conform to requirements receive a technical review, and resultant decisions to accept, repair, or return a nonconforming item to its source for correction are supported by records of all cases submitted for action. When deficiencies are detected during contract performance, SLL will promptly feed back all information necessary for correction to the supplier or source. SLL maintains active coordination with suppliers to prevent and resolution of quality problems.

XV. CORRECTIVE ACTION

15.1 Sandia Laboratories Livermore (SLL). The Equipment Quality Control Program provides for prompt detection and correction of all conditions adversely affecting quality, including failures, malfunctions, incidents, trends, deficiencies, deviations, non-performances, and defective materials. SLL establishes and maintains methods for verifying and determining the cause of an adverse condition and for initiating necessary improvements and corrections to preclude repetition. Identification of the adverse condition, its cause, and the corrective action taken is recorded and reported to appropriate levels of management.

XVI. HANDLING, STORAGE, AND SHIPPING

16.1 Sandia Laboratories Livermore (SLL)

16.1.1 Handling. Special handling equipment is to be used during fabrication and assembly operations when damage due to handling might otherwise result. Where special precautions are required during handling or lifting of items to prevent damage because of weight, size, susceptibility to shock, damage, or other considerations, detailed instructions or procedures are prepared and implemented. Items not specifically covered by special instructions or procedures are handled in accordance with sound handling practices. Handling and lifting equipment assemblies are inspected and tested initially and periodically, or prior to use as prescribed in written instructions or procedures. The responsible organization ensures that operators of handling and lifting equipment are competent, experienced, and properly supervised.

16.1.2 Preservation, Packaging, and Storage. SLL Quality Control programs provide procedures and instructions for the preservation, packaging, and storage of equipment received for this laboratory. Items to be stored are adequately protected against deterioration and damage, and corrective action taken as required.

16.1.3 Shipping. SLL provides for inspection and control of all items shipped from Livermore to assure that: (1) items to be shipped have received and satisfactorily passed the required inspections and tests, (2) items have been preserved and packaged in accordance with applicable specifications and procedures, (3) items and packaging have been properly identified, and (4) devices to record conditions during shipping have been provided, if required.

XVII AUDITS

17.1 Equipment

17.1.1 Planning. SLL prepares a written Quality Assurance Planning Document for each major piece of equipment. Each document provides a written plan for audit and evaluation, scheduling and notification of proposed audits and evaluations, designation of the responsible organization, and assignment of specific areas to be audited and evaluated. Each plan also delineates the criteria, methods, procedures, and formats for each audit and evaluation. Check lists are prepared for each quality control activity and the product to be audited.

17.1.2 Evaluation of Quality Control Methods. As defined in Sections VII and XII, SLL will evaluate suppliers quality control methods, procedures, and instructions for the control and verification of activities affecting quality. Quality control methods will be evaluated by experienced personnel not having direct responsibilities for the methods being audited.

17.1.3 Activity Audits. SLL will conduct audits of activities affecting quality on a regular basis, as defined in Q.A. Planning Document. Such activities include designing, purchasing, fabricating, processing, assembling, handling, cleaning, storing, shipping, inspecting, testing, installing, and check-out. Activities will be audited by SLL to determine the status of compliance with requirements of the Quality Assurance Program plan, established quality control procedures and instructions, and applicable standards and codes. Such audits will be conducted by personnel familiar with procedures, standards, and codes applicable to the areas being reviewed, but who have no specific line responsibility in such areas.

17.1.4 Nondestructive Examination Audits. SLL periodically audits nondestructive examination and personnel certification procedures to verify that applicable specifications, standards, and codes set forth in the contract have been implemented and their requirements are being met.

SLL periodically audits the certification process to assure that personnel certified to perform special processes have satisfactorily passed tests indicating their competence in accordance with the requirements of applicable specifications and standards. Results of such audits and of examinations of work performed shall be used to determine if personnel need additional training and re-certification.

Nondestructive examination results, such as test data, readouts, and film will be periodically audited to verify accuracy of equipment and adequacy of interpretation.

17.1.5 Records Audits. Results of inspection, tests, and nondestructive examinations will be audited to assure adequacy and availability.

17.1.6 Reporting and Corrective Action. Results of each audit and activities conducted by SLL will be reported to and reviewed by management. Summaries of audit findings with corrective actions will be prepared and submitted to top management and the purchaser.

SLL quality assurance management personnel will take necessary action to assure that any deficiency in quality control methods and functions will be corrected. Deficient areas will be re-audited as frequently as necessary until the required corrections have been made.

XVIII. QUALITY ASSURANCE RECORDS

18.1 Equipment. Sandia Laboratories Livermore (SLL) maintains records sufficient to furnish documentary evidence of the performance of activities affecting quality, and for use in management of the program. Records are readily retrievable, identifiable, and available to management, purchaser, or designated representative, and other authorized personnel as required. Records maintained include Quality Assurance Program plans, procedures, instructions, personnel training records, quality audit reports, summaries of nonconformances, incident and failure reports, corrective action, and other records required by applicable sections of this document. Records are kept for at least the life of the equipment.

12.2 Planning. SLL has established and implemented those procedures and instructions required to assure that fabrication, processing, and assembly activities related to equipment are planned and conducted in accordance with requirements of the contract and its specified documents. SLL planning activities include identification and sequencing of fabrication, processing, and assembly functions, and their associated inspection and testing activities. The events are shown in the Planning Schedule.

12.3 Inspection and Test Plan. The SLL Quality Assurance Program, where applicable, provides the necessary detailed planning of inspection and test activities related to fabrication and assembly operations. An inspection and test plan is prepared, either as separate documents identified with the parts, components, or assemblies, or as an integral part of SLL's work instructions. The inspection and test plan consists of narrative description of the sequence of activities for fabrication, processing, assembly, inspection, and test and indicates the type of characteristics to be measured, the methods of examination, and the applicable acceptance criteria.

The SLL inspection and test plan establishes those inspection and test points from raw materials through fabrication, processing, and assembly at which conformance of parts, components, and sub-systems to design requirements will be verified.

The plan will be kept current and revised when necessary to assure that inspections and tests are properly scheduled and accomplished.

12.4 Material Identification and Control. Materials and items subjected to fabrication, processing, or assembly operations will be identified and controlled throughout manufacturing in accordance with requirements established in specifications, drawings, or other technical documents. Identification will be indicated, either on the fabricated item or assembly, or in related records. Controls will be exercised at all points necessary to assure that only accepted materials and items are used.

The supplier shall provide for proper control, preservation, and storage of materials or items furnished by SLL.

12.5 Control of Processes

12.5.1 Fabrication and Assembly Processes. To assure that the required quality is achieved, SLL has established and implemented procedures and instructions for the control of fabrication and assembly processes, both metallurgical and chemical. Emphasis is placed on prevention, elimination, and correction of nonconformances at the earliest possible stage.

Process controls include: shop orders, process sheets, travelers, inspection instruction, and other shop documents prepared as supplements to specifications, codes, and standards; verification of adequacy of shop documents; assurance of compliance, and maintenance of records.

When a fabrication or assembly process must be conducted in a special environment, such as in a vacuum or an inert atmosphere, the process controls are implemented to assure that the required environment is maintained.

Where applicable, cooling, jigs, fixtures, and other equipment used for process control and precision inspection of dimensions, contours, and location, are identified in planning documents. Such items of equipment are closely controlled and inspected prior to use and at prescribed intervals to assure that their required accuracy is maintained.

12.5.2 Process Qualification. Procedures for performance of designated processes are qualified before fabrication is started and to the extent required by the contract. Upon request of SLL, the supplier shall furnish qualification documents for approval, including procedures and drawings, and the results of tests and inspections.

12.5.3 Nondestructive Examination. Nondestructive examination procedures for processes such as radiography, ultrasonic testing, liquid-penetrant inspection, and magnetic-particle inspection are qualified and controlled so assure that results provide accurate, uniform, and reproducible indications of actual quality. Nondestructive examinations are performed in accordance with qualified procedures and specified acceptance criteria.

12.5.4 Cleaning. The supplier shall prepare and implement procedures to assure that lubricants, chemicals, materials, precision parts, components, assemblies, and systems are cleaned under controlled conditions as specified in the contract, and that required cleanliness is maintained.

12.6 Personnel Training and Certification. SLL personnel responsible for performing and verifying pressure equipment installations will be certified per Section VIII.

12.7 Inspection and Tests.

12.7.1 General Requirements. Throughout the equipment manufacturing and installation phase, SLL performs or has performed inspections and tests in accordance with established plans, instructions, and procedures. SLL verifies that inspection and test prerequisites are met, that appropriate instruments and devices are used, and that inspection and tests are performed in the proper sequence under suitable environmental conditions. SLL has established, implemented, and maintained procedures to detect, analyze, and record any nonconformances and to assure that appropriate corrective action is taken and completed. SLL assures that results of inspections and tests are recorded and can be traced to the individual responsible.

SLL assures that inspections are made at appropriate points of fabrication, processing, and assembly so that parts, components, assemblies, processes, and fabrication methods are inspected and tested, and data recorded according to plans and procedures.

SII will furnish inspection and test results and related data to ERDA on request.

12.7.2 Procedures. SII will provide procedures, instructions, and check lists that clearly describe the appropriate inspections and tests for materials, work in process, and completed articles as required by the code standard, specification, and the contract. In addition, the criteria for acceptance or rejection of product are included. All characteristics required to be reported by the code, standard, specification, or contract will be examined as prescribed by procedures and instructions, and the results recorded on check lists or other documents appropriate to the inspection or test.

Instructions and procedures shall be revised and updated as required to reflect design or contract changes.

12.7.3 Completed Item Inspection and Test. Upon completion of manufacturing, fabrication, or assembly, SII will inspect and test the parts, materials, components, assemblies, or systems before they are delivered or installed. Each completed item shall be inspected for completeness, markings, calibration, adjustments, freedom from damage, deterioration or contamination, safe operating condition, or other attributes to provide objective evidence to conformance to contract requirements.

Modifications, repairs, or replacement made after completion of inspections and tests shall require re-inspection and retest to the extent necessary to verify acceptability and assure compatibility with component, assembly, sub-system, and system interfaces.

12.7.4 Inspection Status Indication. SII has an established system whereby markings, routing cards, stamps, or other means are used to indicate the status of inspections and tests performed on individual items to provide a means for ensuring that only acceptable supplies and services are used in the completed item.

12.7.5 Certification. When required by the contract, the supplier shall certify that all items manufactured and/or furnished by the supplier conform to specified code, standard, specification, and contract requirements. Certification shall include certified reports of all required tests, analyses, inspections, and examinations, and shall be identified to the applicable item.

12.8 Document Control. In accordance with the requirements of Section IV of this document, SII has established procedures for release and change control of documents related to fabrication, processing, and assembly. The O.A. organization monitors document-release and change-control activities to assure that the latest authorized documents are used in work areas.

12.9 Equipment Calibration and Standards. SLL has an established system that provides for the selection, acquisition, calibration, adjustment, maintenance and control of inspection measuring and test equipment which is defined in Section V of this document.

12.10 Statistical Quality Control and Analysis. In addition to the statistical methods required by the contract, statistical planning, analysis and testing techniques may be used by the supplier when such procedures afford advantages in maintaining the required quality. Sampling plans may be used when tests are destructive or when quality records or inherent characteristics of the item, or the nonessential nature of its application, indicate that inspection or testing can be reduced without jeopardizing quality. If the supplier uses sampling plans, SLL will reserve the right to review such plans for approval before they are implemented by the supplier. Any sampling plan used must provide valid confidence that required quality will be achieved and that any defect that might be in a lot accepted under a sampling plan will not result in an adverse condition with respect to safety, operability, and reliability.

12.11 Control of Nonconforming Items. The acceptance or rejection of nonconforming items offered for delivery is the prerogative of SLL. Nonconforming items furnished by suppliers shall be controlled as prescribed in Section XIV of this standard.

12.12 Corrective Action. SLL quality control functions provide for detection of conditions adversely affecting quality and for corrective action and feedback in accordance with the requirements of Section XV of this Standard.

12.13 Handling, Preservation, Packaging, Storage, and Shipping.

12.13.1 Handling. SLL has developed and implemented handling practices, procedures, and instructions as required by applicable codes, standards, and specifications. Special handling practices shall be used during fabrication and assembly operations when damage due to handling might otherwise result.

12.13.2 Preservation, Packaging, and Storage. SLL quality control programs provide procedures and instructions for the preservation, packaging, and storage of items. SLL assured that items subject to deterioration or damage through exposure to air, moisture, or other environments during fabrication, processing, assembly, and interim storage periods are cleaned and have preservative applied at such points and by such methods as required to preclude damage. Items being packaged for shipment shall be preserved in accordance with contract requirements. Items subject to damage shall be packaged in such a manner, and with such materials, as required to prevent damage. Packaging requirements shall allow for conditions that could affect the item at the supplier's plant, in transit to the destination, and at the destination. Items to be stored shall be adequately protected against deterioration and damage. Periodic inspections will be performed to detect deterioration or damage, and corrective action shall be taken as required.

12.13.3 Shipping. The supplier shall provide for inspection and control of all items shipped from his plant to assure that: (1) items to be shipped have received and satisfactorily passed the required inspections and tests; (2) items have been preserved and packaged in accordance with applicable specifications and procedures; (3) items and packaging have been properly identified, and (4) devices to record conditions during shipping have been provided, if required.

12.14 Quality Records. In accordance with the requirements of Section XVIII of this document, inspection, test, and other data related to the quality status of parts, components, assemblies, and systems is collected, processed, analyzed, and distributed to pertinent areas within the SLL organization, to sources of supply when appropriate, and to the AEC when required. Records are kept for at least the life of the equipment.

Examples of records include acceptance test data, inspection and test reports, material certifications, welder qualifications, quality audit reports, summaries of nonconformances, and corrective actions.

12.15 Quality Audits. SLL regularly audits the quality control operations of manufacturers and suppliers in relation to fabrication and assembly operations in accordance with the requirements of Section XVII of this document.

XIII. INSPECTION AND TEST PLANS

13.0 The Sandia Laboratories Livermore (SLL) Inspection and Test Plan for equipment establishes those inspection points from raw materials through fabrication, processing, installing of assemblies, sub-systems, and systems to verify that installation operations have been accomplished in accordance with design drawings, specifications, and codes. Emphasis is placed on prevention, elimination, and correction of nonconformances at the earliest possible stage.

XIV. NONCONFORMING MATERIALS, PARTS, COMPONENTS, OR SYSTEMS

14.1 Equipment. Sandia Laboratories Livermore (SLL) has developed and implemented procedures to control items that do not conform to contract requirements. The procedures provide for prompt identification, documentation, segregation, technical review, and disposition of nonconforming items. Significant nonconformances that cannot be reworked to conform to requirements receive a technical review, and resultant decisions to accept, repair, or return a nonconforming item to its source for correction are supported by records of all cases submitted for action. When deficiencies are detected during contract performance, SLL will promptly feed back all information necessary for correction to the supplier or source. SLL maintains active coordination with suppliers to assure rapid resolution of quality problems.

XV. CORRECTIVE ACTION

15.1 Sandia Laboratories (Livermore (SLI)). The Equipment Quality Control Program provides for prompt detection and correction of all conditions adversely affecting quality, including failures, malfunctions, incidents, trends, deficiencies, deviations, non-performances, and defective materials. SLI establishes and maintains methods for verifying and determining the cause of an adverse condition and for initiating necessary improvements and corrections to preclude repetition. Identification of the adverse condition, its cause, and the corrective action taken is recorded and reported to appropriate levels of management.

XVI. HANDLING, STORAGE, AND SHIPPING

16.1 Sandia Laboratories (Livermore (SLI))

16.1.1 Handling. Special handling equipment is to be used during fabrication and assembly operations when damage due to handling might otherwise result. Where special precautions are required during handling or lifting of items to prevent damage because of weight, size, susceptibility to shock, damage, or other considerations, detailed instructions or procedures are prepared and implemented. Items not specifically covered by special instructions or procedures are handled in accordance with sound handling practices. Handling and lifting equipment assemblies are inspected and tested initially and periodically, or prior to use as prescribed in written instructions or procedures. The responsible organization ensures that operators of handling and lifting equipment are competent, experienced, and properly supervised.

16.1.2 Preservation, Packaging, and Storage. SLI Quality Control programs provide procedures and instructions for the preservation, packaging, and storage of equipment received for this laboratory. Items to be stored are adequately protected against deterioration and damage, and corrective action taken as required.

16.1.3 Shipping. SLI provides for inspection and control of all items shipped from Livermore to assure that: (1) items to be shipped have received and satisfactorily passed the required inspections and tests, (2) items have been preserved and packaged in accordance with applicable specifications and procedures, (3) items and packaging have been properly identified, and (4) devices to record conditions during shipping have been provided, if required.

XVII AUDITS

17.1 Equipment

17.1.1 Planning. SLL prepares written Quality Assurance Planning Document for each major piece of equipment. Each document provides a written plan for audit and evaluation, scheduling and notification of proposed audits and evaluations, designation of the responsible organization, and assignment of specific areas to be audited and evaluated. Each plan also delineates the criteria, methods, procedures, and formats for each audit and evaluation. Check lists are prepared for each quality control activity and the product to be audited.

17.1.2 Evaluation of Quality Control Methods. As defined in Sections VII and XII, SLL will evaluate suppliers quality control methods, procedures, and instructions for the control and verification of activities affecting quality. Quality control methods will be evaluated by experienced personnel not having direct responsibilities for the methods being audited.

17.1.3 Activity Audits. SLL will conduct audits of activities affecting quality on a regular basis, as defined in O.A. Planning Document. Such activities include designing, purchasing, fabricating, processing, assembling, handling, cleaning, storing, shipping, inspecting, testing, installing, and check-out. Activities will be audited by SLL to determine the status of compliance with requirements of the Quality Assurance Program plan, established quality control procedures and instructions, and applicable standards and codes. Such audits will be conducted by personnel familiar with procedures, standards, and codes applicable to the areas being reviewed, but who have no specific line responsibility in such areas.

17.1.4 Nondestructive Examination Audits. SLL periodically audits nondestructive examination and personnel certification procedures to verify that applicable specifications, standards, and codes set forth in the contract have been implemented and their requirements are being met.

SLL periodically audits the certification process to assure that personnel certified to perform special processes have satisfactorily passed tests indicating their competence in accordance with the requirements of applicable specifications and standards. Results of such audits and of examinations of work performed shall be used to determine if personnel need additional training and re-certification.

Nondestructive examination results, such as test data, readouts, and film will be periodically audited to verify accuracy of equipment and adequacy of interpretation.

17.1.5 Records Audits. Results of inspection, tests, and nondestructive examinations will be audited to assure adequacy and availability.

17.1.6 Reporting and Corrective Action. Results of each audit and activities conducted by SLL will be reported to and reviewed by management. Summaries of audit findings with corrective actions will be prepared and submitted to top management and the purchaser.

SLL quality assurance management personnel will take necessary action to assure that any deficiency in quality control methods and functions will be corrected. Deficient areas will be re-audited as frequently as necessary until the required corrections have been made.

XVIII. QUALITY ASSURANCE RECORDS

18.1 Equipment. Sandia Laboratories Livermore (SLL) maintains records sufficient to furnish documentary evidence of the performance of activities affecting quality, and for use in management of the program. Records are readily retrievable, identifiable, and available to management, purchaser, or designated representative, and other authorized personnel as required. Records maintained include Quality Assurance Program plans, procedures, instructions, personnel training records, quality audit reports, summaries of nonconformances, incident and failure reports, corrective action, and other records required by applicable sections of this document. Records are kept for at least the life of the equipment.

RADIOACTIVE WASTE MANAGEMENT PLAN

JULY 1978

SANDIA LABORATORIES LIVERMORE

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Radioactive Waste Management Plan

1. Program Administration

- 1.1 This is the Radioactive Waste Management Plan for Sandia Laboratories Livermore, California (SLL).**
- 1.2 The responsible DOE Field Office is the DOE Albuquerque Operations Office (AL) Albuquerque, New Mexico.**
 - 1.2.1 The Area Office is the Sandia Operations Office (SAO) Albuquerque, New Mexico.**
- 1.3 The primary function of SLL is research and development of non-nuclear weapons systems.**
- 1.4 Radioactive waste management in the DOE/ALO complex is under the direction of T. C. Jones, Director, Weapons Production Division.**
- 1.5 Waste management is funded from Phase 3 Weapon Research Development funds.**

2. Description of Waste Generating Process

- 2.1 Uranium contaminated wastes presently account for about 75 percent of the total SLL wastes. The Tritium Research Laboratory (TRL) is in the system testing experiment initiation phase and will become fully operational in FY 79. Low specific activity wastes are being generated due to initial testing and startup experimentation. Significantly larger amounts will be generated starting in FY 79. The uranium waste, primarily turnings from the machine shop, is a small percentage of the total volume buried but accounts for most of the radioactivity. Almost all of the uranium is depleted in the isotope U-235 (D-38). Classified radioactive waste is accumulated in temporary storage at SLL, and when a sufficient quantity for shipping has been accumulated, it is combined with waste from Lawrence Livermore Laboratory (LLL) and shipped for burial to:

Atlantic Richfield Hanford Company
P. O. Box 250
Richland, Washington 99352

Unclassified wastes are transferred to LLL and disposed of by the most efficient means at the time.

FIGURE 1 - SLL RADIOACTIVE WASTE FLOW CHART

3. Description of Waste Management Facilities

3.1 Uranium contaminated wastes are generated primarily in the machine shops and the test assembly group (TAG) area located in Building 913. Other low level FP/IA wastes are delivered to the vault area (Building 921) for temporary storage. Tritium contaminated wastes are generated at the TRL.

3.2 The waste treatment facility is Building 921 vault. Wastes are bagged in polyethylene bags, and stored in one of two plywood 4'x4'6' waste hold boxes (also used as shipping containers). A garbage compactor is on hand to be used in the future if warranted, but is not used now.

Classified and unclassified wastes are separated prior to transfer to LLL. This is accomplished by maintaining two separate waste hold boxes in the 921 vault. The classified waste storage container is retained in this area until full at which time it is removed to the temporary storage facility (structure 9622 in Figure 2). The unclassified wastes are disposed of on a more frequent basis: either by direct delivery to LLL or short term storage at the temporary storage facility.

Outside of Bldg. 921, a 30 gallon drum is kept where uranium turnings are immersed in oil. When this barrel is about 90% full it is transferred to the temporary waste storage area where it is solidified with calcium silicate.

Low level tritium contaminated wastes result from decontamination activities and normal operations. These wastes are collected in polyethylene bags, sealed with tape when full, and placed in a 30 or 50 gal drum. As the drum is filled, it is sealed and moved to the waste hold area.

3.3 The temporary waste storage area is a small (approximately 24 ft. x 24 ft.) building. It has a weather tight roof and wire mesh -- wooden slat sides to restrict entrance to authorized personnel only. The classified waste is stored in this area until enough is accumulated for a load to be shipped to the burial site through LLL.

Wastes generated at the TRL are stored temporarily in a hold area adjacent to the building. They are transferred to the waste storage area to await shipment through LLL.

4. Radioactive Wastes Stored

4.1 At present there is no high-level waste generated at SLL.

4.2 Solid waste is only stored long enough to accumulate a load for shipment. This period of time is approximately one year.

5. Plans and Budget Projections

5.1 We generate no high-level waste at present.

5.2 Not applicable.

5.3 All liquid waste from areas where radioactive materials are used is stored in a hold tank and monitored for radioactivity. If the waste is below the maximum permissible concentration stated in DOE Manual, Chapter 0524, it is dumped into the sanitary sewer system. If the waste were ever over the prescribed limits, it would be mixed with absorbent materials and disposed of as solid waste. To date the latter method of disposal has never been necessary.

5.4 The management of solid waste contaminated with radioactivity is as stated in 4.2.

5.5 At SLL all points where radioactive airborne effluents may be released to the atmosphere are continuously monitored. The effluent levels have not exceeded our lower detection limits which are well below the maximum permissible by Manual Chapter 0524. It is not expected that this condition will change in the future.

5.5.1 The Tritium Research Laboratory has been designed to handle large curie quantities of tritium. A classified document, "Aerostatics Proposal," dated March 3, 1972, RS 4500/74, contains the preliminary safety analysis report for this facility. The final SAR should be completed in FY 78. By using the latest technology and good administrative and operational control, the release of tritium will be maintained at or below acceptable standards.

Details of the air effluent cleaning systems and operational goals are discussed in the unclassified report. "Containment and Decontamination Systems Planned for the Tritium Research Laboratory Building at Sandia Laboratories Livermore," 1975, SAND 75-8653.

5.6 Budget projections through FY 1984 are based on our past experience combined with estimates of future volume of waste (see Table #1) on the following page.

Table 1. Estimated Volume and Costs for Radioactive Waste Generated at SLL

Fiscal	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>
Volume (ft ³)	1000	1000	1000	1000	1000	1000
Storage/Burial Cost*	0.38	0.40	0.42	0.44	0.46	0.48
Total Cost for Radioactive	2.48	2.60	2.75	2.90	3.05	3.20

*These costs reflect a 5%/yr increase per ft³ buried, and any changes noted will reflect the latest information available on burial/storage costs. This figure is only an estimate of the cost per ft³ for burial/storage. It does not include transportation, handling, charges, etc.

6. Description of Decontamination and Decommissioning

- 6.1 The existing buildings and property would not likely require decontamination before they could be released for public use; however, a thorough radiation survey to verify this would be required prior to release.**

Sandia Laboratories Livermore Site Plan

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PREOPERATIONAL ENVIRONMENTAL MONITORING REPORT
FOR THE SLL TRITIUM RESEARCH LABORATORY

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ABSTRACT

The Tritium Research Laboratory is designed to conform with the ERDA philosophy to keep tritium release "as low as practicable." Though the main emphasis is on controlling tritium release at the source, an environmental monitoring program is maintained to ascertain the effectiveness of the control and containment measures and to determine whether any radiological changes in the environment are the result of TRL operations.

PREOPERATIONAL ENVIRONMENTAL MONITORING REPORT FOR THE SLL TRITIUM RESEARCH LABORATORY

Introduction

Sandia Laboratories, Livermore, (SLL) is located 50 miles southeast of San Francisco in the Livermore Valley midway between the Pacific Ocean and the San Joaquin Valley. Climate in the valley is typically warm and dry with an average annual rainfall of 14 inches occurring during the winter months. Surface water drainage from the valley is from east to west through various arroyos with outflow near Sunol in the southwestern corner of the valley. Prevailing winds are from the west and there are frequent nighttime thermal inversions.

Sandia Laboratories is a prime contractor to the Energy Research and Development Administration (ERDA) and is operated under the provisions of a nonprofit, no-fee contract with the Western Electric Company. SLL employs approximately 900 people. The SLL site comprises 164 acres located approximately three miles east of the City of Livermore, immediately adjacent to the Lawrence Livermore Laboratory.

The Tritium Research Laboratory (TRL) is an 80 x 180 foot, single-story building located in the test area east of the main complex. The laboratory will be used for research and development on various isotopes of hydrogen. All tritium activities formerly carried out in other locations will be moved to the TRL and when fully operational, the facility may contain as much as 300 grams (3mCi) of tritium.

The TRL was designed to conform to the ERDA philosophy, which is to limit tritium release to "as low as practicable" (ALAP). To this end, the TRL employs a secondary containment system connected to the central gas purification system (GPS). This system is used to remove and recover tritium before venting to the 30m stack. Thus release of tritium to the environment will be minimal. A separate drain system is provided for liquid effluent that may be contaminated with tritium. The effluent empties into holding tanks, where it is checked to make certain that tritium content is below applicable discharge limits before release to the SLL sanitary sewer.

Pollutants other than tritium will be virtually nonexistent. The TRL uses steam produced at the SLL steam plant, which is fired primarily by natural gas backed up occasionally by fuel oil. The pollutant inventory

produced by the TRL is well within air quality guidelines. The sanitary effluent from the rest rooms is the only source of liquid waste other than the holding tanks. No chemical wastes are disposed of via the sewer system. Any nonradioactive liquid wastes are disposed of in accordance with California guidelines and approval. Nonradioactive solid wastes are disposed of in the usual manner at the Alameda County disposal site.

Even though the main emphasis is on controlling effluents at the source, an environmental monitoring program is maintained to ascertain the effectiveness of the control and containment measures and to determine whether any radiological changes in the environment are the result of TRL operations. Because of its location next to the Lawrence Livermore Laboratory, by agreement the LLL environmental monitoring program evaluates the effectiveness of the SLL program as well as their own. This monitoring program uses complex analytical techniques capable of detecting the activity of numerous radionuclides in the environment at natural background levels. SLL has been granted an exemption from filing a separate Environmental Monitoring Report. Close contact is maintained between the labs concerning changes in the sampling program and any significant increases in discharge levels.

The principal sources of tritium release in the Livermore-Amador Valley are building 331 at LLL and the TRL at Sandia. Thus the environmental measurements of tritium predominantly amount to effluent surveillance of these facilities. Tritium may be released either as the elemental gas (HT) or in chemical combinations such as tritiated water (HTO). The stack effluent from the TRL will be continuously monitored with a real time, auto-ranging monitor capable of reading from $1 \mu\text{Ci}/\text{m}^3$ to $2\text{kCi}/\text{m}^3$. The output will also drive a totalizer which integrates the total amount of tritium which is exhausted through the stack. Another system will measure the integrated ratio of HT/HTO. Since the maximum permissible concentration for HTO is 200 times lower than that for HT, environmental monitoring is restricted to HTO measurements. Ratios measured in the stack are probably applicable to the environmental measurements, but at present, the environmental ratio is not measured.

The environmental tritium monitoring conducted by LLL consists of: (1) air sampling at perimeter locations, (2) analysis of vegetation collected on a monthly basis in the vicinity of the laboratory, and (3) analysis of rain-water and other open sources. Also, both the LLL sewer effluent and the City of Livermore sewage treatment plant effluent are analyzed for HTO. Sampling locations at the LLL perimeter and elsewhere in the Livermore Valley are shown in Figures 1 and 2, respectively. Typical annual average wind pattern is shown in Figure 3.

Figure 1. Lawrence Livermore Laboratory On-Site Environmental Sampling Locations

Wind rose shows relative frequency of wind direction (by the length of the line) obtained from the tabulated annual data below.

Frequency of Wind In Percent for Livermore — 1971

Mo	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Caln
Jan	2.7	2.2	7.2	12.1	17.8	6.8	6.2	2.2	3.9	3.8	4.9	7.0	9.7	7.6	2.0	2.6	1.3
Feb	2.2	2.5	6.9	12.9	14.8	7.2	5.1	2.8	3.5	3.0	4.9	8.0	11.2	8.5	3.4	2.0	1.4
Mar	2.1	2.2	6.4	12.3	13.5	6.9	4.9	2.7	3.3	2.6	4.6	10.5	12.2	9.1	3.1	1.8	1.7
April	2.1	2.3	4.6	8.7	9.4	5.1	3.2	2.1	3.0	4.8	10.8	16.1	13.9	7.4	2.2	1.8	2.3
May	2.2	1.9	3.8	6.5	7.1	4.0	2.4	1.7	2.4	4.7	15.3	17.7	16.7	6.0	1.9	1.9	3.8
June	2.1	1.7	3.4	5.6	6.7	3.5	2.1	1.4	2.2	4.6	16.9	19.8	17.7	5.4	1.7	1.6	3.9
July	1.7	1.4	2.8	4.6	5.1	2.9	1.8	1.3	2.0	5.3	19.5	22.9	17.2	4.6	1.4	1.4	4.0
Aug	1.6	1.4	2.7	4.5	5.0	2.8	1.7	1.3	2.1	5.3	19.8	23.5	17.0	4.5	1.4	1.4	4.1
Sept	1.9	1.4	2.5	4.0	4.4	2.5	1.6	1.3	2.2	5.4	21.1	23.3	17.3	4.7	1.4	1.2	3.7
Oct	2.4	1.6	2.7	4.1	4.5	2.7	1.6	1.3	2.2	5.7	20.6	22.5	16.3	4.6	1.5	2.2	3.5
Nov	2.6	2.5	3.4	4.5	4.9	2.7	1.9	1.9	2.6	5.4	19.2	20.5	15.5	4.7	2.0	2.3	3.3
Dec	2.8	3.0	3.9	4.6	5.3	3.0	2.6	2.2	2.7	5.1	17.7	19.2	15.3	4.8	2.1	2.4	3.1
Annual Average	2.2	2.0	4.2	7.0	8.7	4.2	2.9	1.8	2.7	4.7	14.6	17.6	15.0	6.0	2.0	1.9	3.0

Figure 3. Typical Annual Average Wind Pattern for Livermore, California (LLL Data - 1971)

Measurements of tritiated water (HTO) in the air at LLL perimeter air-sampling locations were begun in 1973. Water vapor is collected on silica gel samplers and analyzed on a weekly basis. The results of these measurements are summarized below.

TABLE I
AIRBORN TRITIATED WATER CONCENTRATIONS
ON LLL PERIMETER -- 1973-75
(in $\mu\text{Ci}/\text{m}^3$)

<u>Location</u>	<u>1973 Annual Average</u>	<u>1974 Annual Average</u>	<u>1975 Annual Average</u>
1	2.8×10^{-5}	3.3×10^{-5}	3.5×10^{-5}
2	3.5×10^{-5}	5.6×10^{-5}	4.9×10^{-5}
12	6.2×10^{-5}	8.6×10^{-5}	8.8×10^{-5}
13	2.4×10^{-5}	2.7×10^{-5}	2.5×10^{-5}
14	6.2×10^{-5}	5.4×10^{-5}	5.0×10^{-5}
15	2.0×10^{-5}	2.8×10^{-5}	3.5×10^{-5}
Annual Average	3.85×10^{-5}	4.7×10^{-5}	4.7×10^{-5}
%RCG*	1.9×10^{-2}	2.4×10^{-2}	2.4×10^{-2}
Release**	2500 Ci	1900 Ci	3380 Ci***

*RCG for HTO in air is $0.2 \mu\text{Ci}/\text{m}^3$.

** The total tritium release from all LLL sites.

*** Increase attributed to increased sensitivity of slack monitoring.

The average annual background concentrations are comparable to natural background levels. The effect of releases from LLL is not measurable, except perhaps at location 12 which is situated between two tritium release points.

Water samples are collected from various locations in the Livermore Valley as shown in Figures 1 and 2. The annual average for these locations as determined since 1971 is shown in Table II.

TABLE II
TRITIUM CONCENTRATIONS IN
LIVERMORE VALLEY WATER -- 1971-75
(in $\mu\text{Ci/ml}$)

<u>Location</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
11	2.6×10^{-7}	1.9×10^{-7}	1.3×10^{-7}	1.3×10^{-7}	1.2×10^{-7}
15	2.8×10^{-7}	1.8×10^{-7}	1.6×10^{-7}	1.5×10^{-7}	1.7×10^{-7}
16	8.7×10^{-7}	2.3×10^{-7}	2.3×10^{-7}	2.5×10^{-7}	2.7×10^{-7}
19	1.6×10^{-7}	1.0×10^{-7}	1.1×10^{-7}	1.3×10^{-7}	1.2×10^{-7}
20	8.1×10^{-7}	3.1×10^{-7}	4.6×10^{-7}	8.7×10^{-7}	3.1×10^{-7}
21	2.7×10^{-7}	2.0×10^{-7}	1.4×10^{-7}	1.5×10^{-7}	---
22	4.0×10^{-7}	3.0×10^{-7}	1.7×10^{-7}	1.5×10^{-7}	---
24	6.0×10^{-7}	9.0×10^{-7}	6.7×10^{-7}	1.1×10^{-6}	1.1×10^{-6}
25	---	---	1.4×10^{-7}	2.3×10^{-7}	9.1×10^{-7}
Annual Average				3.3×10^{-7}	4.3×10^{-7}

$$\text{RCG (HITO)} = 3 \times 10^{-3} \mu\text{Ci/ml.}$$

These values are typical of tritium concentrations which occur naturally.

Liquid effluents from the Tritium Research Laboratory are collected in one of two 2500-gallon stainless steel holding tanks. When the tank is full, the contents are analyzed for tritium content and released to the sanitary sewer.

The effluent is monitored at the outfall for pH, radioactivity, and various trace metals. The tritium content is measured at the outfall and at the Livermore Water Reclamation Plant (LWRP). The annual averages are summarized in Table III.

TABLE III
TRITIUM CONCENTRATIONS IN LWRP AND LLL
LIQUID EFFLUENTS -- 1971-75
(in $\mu\text{Ci/ml}$)

	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
L.I. 1. Outfall			4.9×10^{-5}	5.1×10^{-5}	7.6×10^{-5}
L.WRP	1.3×10^{-5}	4.2×10^{-6}	3.3×10^{-6}	6.0×10^{-6}	9.3×10^{-6}

The concentration guide for HTO is $3 \times 10^{-3} \mu\text{Ci/ml}$.

Vegetation samples are collected on a monthly basis and analyzed for tritium. The samples, usually native grasses, are freeze-dried and the tritium activity in the recovered water is determined by liquid scintillation counting. The tritium data on the Livermore Valley vegetation sampling program are summarized in Table IV.

TABLE IV
TRITIUM CONCENTRATIONS IN
LIVERMORE VALLEY VEGETATION -- 1971-75
(in $\mu\text{Ci/g-dry wt}$)

Location	1971	1972	1973	1974	1975
4	3.3×10^{-7}	5.6×10^{-7}	1.5×10^{-6}	1.5×10^{-6}	4.8×10^{-7}
5	4.7×10^{-6}	2.7×10^{-6}	1.3×10^{-5}		
7	4.5×10^{-7}	3.1×10^{-7}	5.3×10^{-7}		
10	1.1×10^{-5}	1.9×10^{-6}	7.6×10^{-6}		
11	3.9×10^{-5}	2.0×10^{-6}	9.9×10^{-6}		
12	1.8×10^{-6}	1.9×10^{-6}	4.2×10^{-6}		
13	3.0×10^{-7}	4.0×10^{-7}	1.2×10^{-6}		
15	1.4×10^{-6}	1.5×10^{-6}	6.8×10^{-6}	6.6×10^{-6}	1.9×10^{-6}
16	3.5×10^{-6}	4.3×10^{-7}	7.5×10^{-7}	8.0×10^{-7}	4.0×10^{-7}
17	1.6×10^{-7}	7.0×10^{-7}			
18	2.8×10^{-7}	4.3×10^{-7}			
19	2.2×10^{-7}	2.7×10^{-7}	6.2×10^{-7}		
20	6.4×10^{-6}	8.3×10^{-6}	5.0×10^{-6}	2.2×10^{-6}	1.4×10^{-6}
21			4.9×10^{-6}	2.9×10^{-6}	1.4×10^{-6}
22			2.2×10^{-6}	4.6×10^{-6}	9.3×10^{-7}
23			4.1×10^{-6}	1.1×10^{-5}	4.1×10^{-6}
24			4.5×10^{-6}		
25			2.5×10^{-6}		
28			1.8×10^{-5}		
29			1.8×10^{-5}	1.3×10^{-5}	2.4×10^{-6}
30			1.1×10^{-5}	1.0×10^{-6}	1.4×10^{-6}
31			3.4×10^{-6}	5.8×10^{-6}	2.9×10^{-6}
Annual Average	5.3×10^{-6}	1.6×10^{-6}	6.0×10^{-6}	5.5×10^{-6}	1.7×10^{-6}

Department of Energy
Albuquerque Operations
Sandia Area Office
P.O. Box 5400
Albuquerque, New Mexico 87115

January 10, 1979

Mr. K. Lovell, 5252, SLL

TRITIUM RESEARCH FACILITY - SAFETY ANALYSIS REPORT (FINAL DRAFT)

Enclosed is a memo from Operational Safety Division and comments relative to OSD's review of the draft SAR.

OSD's approval of the SAR is conditional to submittal of the final document for approval. I trust OSD will be as laudatory in their review of the final document. In any case it's nice to see what a fine job you and Donn have done.

(Handwritten signature: A. R. Sneddon, Jr.)

SBF/ARS

A. R. Sneddon, Jr.
Chief, Facilities Branch

Enclosures:

Memo, Roeder/Cordova, 12/6/78
w/comments (2 cc's)

cc: J. R. Roeder, Dir., OSD, ALO/DOE,
w/o encl.
M. E. Autio, Dir., F&CMD, ALO/DOE,
w/o encl.

6232

JAN 15 1979

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

Gil Cordova, Area Manager, Sandia Area Office

TRITIUM RESEARCH LABORATORY - FINAL SAFETY ANALYSIS REPORT (DRAFT) -
SANDIA-SLL

We have reviewed the subject Safety Analysis Report for the Tritium Research Facility and have a few comments which should be incorporated in the final version of the document. This FSAR provides a facility safety assessment of excellent technical depth and clarity. Would you please extend my compliments to Messrs. Perry Lovell and Donn Wright of SLL for their efforts and contributions in the preparation of this high quality FSAR.

At this time we would like to formally approve the FSAR. This approval coupled with: (1) Previous checkout tests of the facility safety systems where a member of my staff participated as an observer, and (2) Operational Safety Surveys conducted by the OSD staff, serves as the basis for our concluding that the facility and its associated systems provide an adequate margin of safety to permit operations with major quantities of tritium.

Original S-

Willis C. . .

Jack R. Roeder, Director
Operational Safety Division

WOF:WBS

Enclosure:
Review comments

cc: M. E. Autio, Director,
Facilities & Construction
Management Division, ALO

REVIEW COMMENTS - SAFETY ANALYSIS REPORT FOR THE TRITIUM RESEARCH LABORATORY

SEPTEMBER, 1978

SECTION 2 - SUMMARY OF THE SAFETY ANALYSIS

1. Page 2-4 - Does the facility have certain critical systems on an uninterruptible power source (UPS)? It is inferred but not specifically stated.
2. Page 2-8 - Provide a summary paragraph in this section to confirm the conclusions reached in the abstract concerning the safety and acceptability of the facility for operations.

SECTION 3 - SITE DESCRIPTION

1. We are unable to locate the Los Positas fault lineament on any of the figures in this section which should support the discussion on site faulting.
2. The meteorological stability parameters discussed here do not support the use of the Class F stability parameters in the accident analysis. What are the "worst 5%" meteorological parameters for the site?

SECTION 4 - FACILITY DESCRIPTION

- Page 4-13 - Has a sequencing priority of the emergency generator loads been established? What management review is proposed to assure that additional load requirements do not exceed generator capacity?

Page 4-46 - The discussion of the alarm system responses under various operating conditions and the potential personnel exposures postulated for these conditions would be better located in the accident analysis section.

SECTION 5 - DESCRIPTION OF OPERATIONS

1. Page 5-3 - We note that the Control Room is manned at all times during normal operations. Is this to be construed as 24-hr manning when experiments are being performed?
2. Page 5-9 - What is the magnitude of the expected routine releases of tritium on an annual basis? Compare this release also with an average concentration basis to the RCG's.

SECTION 6 - ACCIDENT ANALYSIS

1. Page 6-4 - Explain why a maximum ground acceleration of 0.275 g was chosen to represent the typical severe earthquake for the site. What is its relationship to the earthquake recommended in the 1976 version of the Uniform Building Code?
2. Page 6-26 - We suggest that the paragraph discussing Scheme 1 be eliminated from the text as it detracts from the previous discussion.
3. Page 6-61 - If a tritium release into the laboratory areas from a loss of primary and secondary containment during an

accident is possible, the potential exposure to workers in the facility should be evaluated.

4. A summary should be provided to present the information generated on the potential accident situations analyzed in this section. A table would be sufficient.

ANSWERS TO THE REVIEW COMMENTS ON THE SAFETY
ANALYSIS REPORT FOR THE TRITIUM RESEARCH LABORATORY

SECTION 2 - SUMMARY OF THE SAFETY ANALYSIS

1. Page 2-4--Does the facility have certain critical systems on an uninterruptable power supply (UPS)?

There are no critical systems, or systems which would present a hazard from power interruption to the TRL. All experiments are designed to fail in a safe condition if power is lost or interrupted. This is insured through design reviews by the Safety Review Committee. The only system in the building which does occasionally fail from power interruption is the building control computer. False alarms and temporary dysfunction of the computer results, but does not leave any critical systems or safety related systems in a hazardous condition.

2. Page 2-8--Provide a summary paragraph in this section to confirm the conclusions reached in the abstract concerning the safety and acceptability of the facility for operations.

The following summary paragraph has been added to section 2.

Summary of the Safety Analysis

This report describes the Sandia Laboratory Livermore site, the likelihood and extent of damage from acts of nature or human error, the safety systems incorporated into the TRL and finally the radiological consequences of a

tritium release. Adhering to an as low as reasonably achievable philosophy, gram quantities of tritium in the TRL are doubly contained in controlled-atmosphere glove boxes, which are connected to a gas decontamination system. Releases to the environment shall be minimal and protection of personnel is maximized.

Based upon the analysis in this report, we conclude that the Tritium Research Laboratory can be operated without undue risk to employees, the general public, or the environment.

SECTION 3 - SITE DESCRIPTION

1. We are unable to locate the Los Positas fault lineament on any of the figures in this section which should support the discussion on site faulting.

After reviewing Figure 3-8, page 3-15 and the same figure in the original Blume report SAND78-8187 it was found that the trace of the Los Positas fault in the SAR did not copy well. The lineament is presented in the original Blume report. If I may redirect your attention to the Lineament Study in Appendix B (Figure 5) the visible trace of the Los Positas by aerial photo is shown although not labeled. For your review, a copy of the geologic map presented in the USGS report (77-689) by D. G. Herd is included.

2. The meteorological stability parameters discussed here do not support the use of the Class F stability parameters in the accident analysis. What are the "worst 5%" meteorological parameters for the site?

The dose to an individual at the site boundary was calculated using a Class B stability with a 0.5 m/sec wind speed not a Class F. For the population

CURRENT GEOLOGICAL KNOWLEDGE OF AREA

Table 3-3 Values of X/Q at various distances west of Building 331. Units are sec/m^3

Distance Downwind (Km)	Condition	Distance Downwind (Km)						
		SB ^a	1	2	5	10	20	50
Wet Season	Median	$1.3\text{E-}5^b$	$1.7\text{E-}6$	$5.8\text{E-}6$	$1.7\text{E-}6$	$6.7\text{E-}7$	$2.7\text{E-}7$	$7.6\text{E-}8$
	95th Percentile	$4.3\text{E-}5$	$3.7\text{E-}5$	$2.6\text{E-}5$	$8.9\text{E-}6$	$2.9\text{E-}6$	$6.4\text{E-}7$	$1.9\text{E-}7$
Dry Season	Median	$2.7\text{E-}5$	$1.7\text{E-}5$	$2.4\text{E-}6$	$2.2\text{E-}6$	$8.1\text{E-}7$	$3.2\text{E-}7$	$8.4\text{E-}8$
	95th Percentile	$2.7\text{E-}5$	$4.3\text{E-}5$	$4.7\text{E-}5$	$1.6\text{E-}5$	$4.9\text{E-}6$	$1.4\text{E-}6$	$2.6\text{E-}7$
	TRL SAR	$9\text{x}10^{-5}$	$5\text{x}10^{-5}$	$6\text{x}10^{-5}$	$2\text{x}10^{-5}$	$1\text{x}10^{-5}$	$3\text{x}10^{-6}$	$6\text{x}10^{-7}$
All Season	Median	$1.4\text{E-}5$	$1.1\text{E-}5$	$5.5\text{E-}6$	$1.7\text{E-}6$	$6.5\text{E-}7$	$2.6\text{E-}7$	$7.5\text{E-}8$
	95th Percentile	$5.4\text{E-}5$	$5.9\text{E-}5$	$1.8\text{E-}5$	$6.6\text{E-}6$	$2.5\text{E-}6$	$8.8\text{E-}7$	$1.9\text{E-}7$

^a Beyond site boundary (0.61 km)^b Values 1.0×10^{-5} 95th Percentile means the probability is 0.95 that the actual X/Q will be less than that stated.

As a comparison, the X/Q values from the TRL SAR have been added for the same distances. The stability categories used for the accident analysis result in an envelope of X/Q values somewhat higher than those calculated for the 95 percentile, dry season X/Q values from real met. data collected at LLL.

Table 2-7. Summary of wind frequency tables by stability categories.^a

Dry season	A	B	C	D	E	F
Most frequent direction	WSW, W	WSW, W	WSW, W	SW, WSW	SW, WSW	SW
Frequency (%)	~34	~48	~55	~55	~57	29
Speed m/s	3	3	4	5	5	5
Least frequent direction	ESE, SE, SSE	SE, SSE	ESE, SE	SE, NW	SE	SSE
Frequency (%)	5	~3	~2	2	<1	0
Speed m/s	2	1-2	2	3-4	4	3
Highest avg speed m/s	3	4	5	8	10	8
Direction	WNW, NW	WNW	N	NRW	NRW	NRW
Frequency	7-9	7	4	2	3	10
Lowest avg speed m/s	2	2	2	2	2	0
Direction	S	SSE	SE	S	E	SSE
Frequency	7	2	1	1	1	0
Wet season	A	B	C	D	E	F
Most frequent direction	N	E	WSW, W	WSW, W	WSW, W	E
Frequency (%)	9	11	~25	~28	~32	15
Speed m/s	2	3	4	5	5-6	6
Least frequent direction	ESE	SSW	N	NRW	NRW	NW
Frequency (%)	3	4	2	2	1	~1
Speed m/s	2	3	4	3	4	2
Highest avg speed m/s	3	~3	4	5	7	12
Direction	NW	WSW, W, WNW	WSW	WSW	ENE	ENE
Frequency (%)	5	~28	12	14	4	9
Lowest avg speed m/s	2	2	3	3	3	2
Direction	ESE	SE, SSE	SSW, NRW	SSE	ESE, SE	NRW
Frequency (%)	3	~9	3-4	2	8	1

^aValues rounded to nearest whole number.

- A = Extremely unstable conditions
 B = Moderately unstable conditions
 C = Slightly unstable conditions
 D = Neutral conditions (applicable to heavy overcast, day or night)
 E = Slightly stable conditions
 F = Moderately stable conditions

dose an envelope of the surface concentration was used assuming a release during Class B conditions which then change to Class F. This change results in the highest ground level sector average concentrations out to 80 km.

SLL is presently installing a 30 meter meteorological tower about 250 meters from the TRL. After completion of the met. station and the interface with the LLL Atmospheric Release Advisory Capability, we shall begin the collection of annual meteorological data specific to the SLL site. LLL can provide the hourly data reduction for determination of the 95% percentile X/Q values, annual average X/Q values (wet and dry season), and the stability category breakdown by percentage. We will then be able to provide the site specific estimates of the X/Q values for the 95% percentile. Attached are two tables from the Draft Environmental Impact Statement for the Livermore Site.

SECTION 4 - FACILITY DESCRIPTION

1. Page 4-13--Has a sequencing priority of the emergency generator loads been established? What management review is proposed to assure that additional load requirements do not exceed generator capacity?

The 200 kVA diesel generator will currently handle the whole building's emergency power requirements and still has enough capacity for any foreseeable future needs. We see no reason for establishing a sequencing priority in the near future.

2. Page 4-46--The discussion of the alarm system responses under various operating conditions and the potential exposures postulated for these conditions would be better located in the accident analysis section.

We felt that alarm set point philosophy and glove box performance is really part of the facility description and was not, therefore, treated as an accident.

SECTION 5 - DESCRIPTION OF OPERATIONS

1. Page 5-3--We note that the control room is manned at all times during normal operations. Is this to be construed as 24 hr manning when experiments are being performed?

TRL operations do not intend to man the control room 24 hrs per day on a routine basis, although this may be done during some hazardous maintenance jobs or experiments. Facility control, including the ventilation system, glove box decontamination systems, tritium monitoring systems, chilled water supply, emergency power, and many of the experiment control systems in the glove boxes are "stand alone" systems requiring no personnel attention. As a rule, experimentation will be conducted during the normal work day so that health physics support is provided. Many low risk type projects, such as aging studies, will be permitted to operate continuously.

Hazards control has recommended to TRL supervision that a "buddy system" be utilized during off hours. This may include security checks on a 30-minute interval when an experimenter must work alone. It is also worth mentioning that the critical safety systems for the building are alarmed at the central security station. A call list has been assigned and, typically, operations, maintenance, or health physics assistance can be provided within 30 minutes.

2. Page 5-9--What is the magnitude of the expected routine releases on an annual basis? Compare this release also with an average concentration basis to the RCG's.

Before estimating the releases on a routine basis it should be mentioned that the minimum sensitivity of the TRL stack HT/HTO monitor is $\leq 1 \times 10^{-3} \mu\text{Ci}/\text{m}^3$. This concentration implies an annual sensitivity of:

$$1 \times 10^{-3} \mu\text{Ci}/\text{m}^3 \times 1560 \text{ m}^3/\text{min} \times 5.25 \times 10^5 \text{ min}/\text{yr} \\ = 0.82 \text{ Ci}/\text{yr}$$

The following estimation of releases to the TRL stack from normal operation is highly speculative at this point and hopefully exaggerated. All of the conceivable release modes in the TRL are described below.

(1) Glove boxes

- (a) Leak-Measurements of leak rate from the TRL glove boxes have been measured in the past. A typical leak rate is $< 1 \times 10^{-3} \text{ cc}/\text{sec-box}$. In addition to this, routine maintenance cleanup of the glove box by the Gas Purification system will begin at $2.6 \text{ Ci}/\text{m}^3$. From this we can calculate a release C_{GBL} of:

$$C_{\text{GBL}} = (2.6 \times 10^{-6} \text{ Ci}/\text{cc})(1 \times 10^{-3} \text{ cc}/\text{sec-box})(3.15 \times 10^7 \text{ sec}/\text{yr}) \\ \times (15 \text{ boxes}), \\ = 1.23 \text{ Ci}/\text{yr}.$$

- (b) Glove permeation-Based on permeation calculations through the glove material, a total of 5.9 mCi per 8 hour day may permeate from a glove with a box concentration of $2.6 \text{ Ci}/\text{m}^3$ (maintenance clean-up level). Assuming that 2 gloves per box are left uncovered for 8 hours each day a total release C_{GBP} by permeation from 15 boxes is given by:

$$\begin{aligned}
 C_{GBP} &= (5.9 \times 10^{-3} \text{ Ci/glove-8 hr day})(2 \text{ gloves/box}) \\
 &\quad \times (5-8 \text{ hr-days/week})(52 \text{ weeks/yr}), \\
 &= 46 \text{ Ci/yr.}
 \end{aligned}$$

(2) GPS Stackmode

Under special circumstances the Gas Purification system may be operated in the "Stackmode." In this condition contaminated gas from a glove box is given a single pass through the GPS and then stacked. Tests performed with tritium have demonstrated that the GPS can decontaminate a gas stream by a factor of 10^5 from a single pass. Although unimaginable, if the GPS was operated in the stack mode and a 1 Ci/m^3 box concentration (arbitrary) was maintained in a box, a total release C_{GPS} is given by:

$$\begin{aligned}
 C_{GPS} &= \frac{(1 \text{ Ci/m}^3)(5.67 \text{ m}^3/\text{min})(5 \times 10^5 \text{ min/yr})}{10^5}, \\
 &= 18 \text{ Ci/yr.}
 \end{aligned}$$

(3) High Velocity Air Hoods and Rooms

Experiment construction guidelines have been established for the IRL which limit the amount of tritium that can be released from normal operations (i.e., equipment disconnection or hookup). The limit placed on HVAH is 10 Ci and for labs the limit is 10 mCi. Assuming that one disconnection is made in a HVAH and one in a room each week, the annual release will be ~ 521 Ci.

(4) Tritium Off-Gassing from Contaminated Equipment

The amount of tritium which will off-gas from contaminated equipment is nearly impossible to estimate at this time. It is very unlikely that equipment off-gassing will result in detectable levels by the tritium room

air monitors. For purposes of analysis we shall assume a constant, uniform lab air concentration of $1 \mu\text{Ci}/\text{m}^3$ in the 10 rooms where experiments are conducted or tritium contaminated hardware is handled. The total air flow from those labs is $\sim 1100 \text{ m}^3/\text{min}$. From these assumptions a total release of $\sim 550 \text{ Ci}$ may result.

(5) VERS Operation

The Vacuum Effluent Recovery System routinely stacks gas from its 5.67 m^3 tanks when their concentration is less than $1.2 \text{ mCi}/\text{m}^3$. More contaminated gas is recycled through the catalyst/dryers until the concentration is reduced to $1.2 \text{ mCi}/\text{m}^3$. Currently, the VERS tanks are stacked 5 times per day. When all the boxes are operational the batch stacking rate may increase to 15 times each day. This would result in a total release rate of $25 \text{ Ci}/\text{yr}$.

From all of these release modes, an annual release of $\sim 2000 \text{ Ci}$ is calculated. However, we expect the routine annual releases to be considerably less than 2000 Ci .

Averaging 2000 Ci over a year ($6.35 \times 10^{-5} \text{ Ci}/\text{sec}$), and applying a class B stability category and 0.5 m/s windspeed ($X/Q = 4 \times 10^{-4} \text{ sec}/\text{m}^3$) the maximum, offsite ground level concentration should not exceed $2 \times 10^{-8} \mu\text{Ci}/\text{ml}$. The RCG_g for an uncontrolled area is $2 \times 10^{-7} \mu\text{Ci}/\text{ml}$. Therefore, routine releases shall remain at least an order of magnitude less than the RCG_g even if the wind was from only one direction.

SECTION 6 - ACCIDENT ANALYSIS

1. Page 6-4--Explain why a maximum ground acceleration of $0.275 g$ was chosen to represent the typical severe earthquake for the site. What is its

relationship to the earthquake forces (added) recommended in the 1976 version of the Uniform Building Code?

The reasoning behind the maximum ground acceleration of 0.275 g is discussed in Section 3, pages 32 to 41. Ground acceleration, were related to earthquake magnitude by the methods of Gutenberg and Richter, 1956, and Hanks and Johnson, 1976. The results of the Blume calculations using these methods were assigned a probability of being exceeded in a 30 yr period. These probabilities, as a function of horizontal ground acceleration, is plotted in Figure 3-13. The median-plus-one standard deviation level of confidence predicts a 16% chance of exceeding 0.275 g acceleration in 30 yrs, which is characterized as a "small" probability.

A 0.275 g ground acceleration results in forces greater than those specified by the 1976 Uniform Building Code. To compare the forces one must compare each structure or vital system, but in each case the force will be greater for the median response spectrum.

2. Page 6-26--We suggest that the paragraph discussing scheme 1 be eliminated from the text as it distracts from the previous discussion.

We agree that this paragraph is not essential to the remedial scheme description. It appears to have been included to explain the theoretical overturning condition, which is an improbable response for a one story structure. The paragraph was removed from the report.

3. Page 6-61--If a tritium release into the laboratory areas from a loss of primary and secondary containment during an accident is possible, the potential exposure to workers in the facility should be evaluated.

Once again, a "worst case" accident is postulated for an individual in the same lab as the tritium release. The following conservative assumptions are employed for the dose calculations.

- (1) The maximum evacuation time after the alarm annunciation is 30 seconds. The dose equivalent for an individual remaining in the lab for 30 seconds and for an individual failing to evacuate was calculated.
- (2) Instantaneous, uniform mixing of the tritium in the room is assumed. A total of 10 grams (100,000 Ci), of which 10% is HTO, is released.
- (3) The ventilation rate for the lab is assumed to be 10 air changes/hour. Effective ventilation rates for most of the labs are higher than 10.
- (4) Room volumes range from 230 m³ to 650 m³. An average room volume of 370 m³ was assumed.
- (5) The air concentration-to-dose conversion factors (DF) for HT gas and HTO vapor are calculated as follows.

For HTO, the DF is given by:

$$DF_{HTO} = 1.3 AB/\lambda_e, \text{ where}$$

DF_{HTO} = the dose conversion factor for HTO vapors,

B = breathing rate for standard man (ICRP 23),

$$= 20 \text{ m}^3/\text{day} = 3.33 \times 10^{-4} \text{ m}^3/\text{sec},$$

λ_e = effective elimination rate for HTO,

$$= \ln 2/\text{Effective half-life},$$

$$= 8.15 \times 10^{-2} \text{ d}^{-1},$$

A = Rem/ μ Ci-day factor,

$$= \frac{(3.2 \times 10^9 \text{ dis/}\mu\text{Ci-day})(1.6 \times 10^{-6} \text{ ergs/MeV})(5.7 \times 10^{-3} \text{ MeV/dis})}{(100 \text{ ergs/g-rad})(4.3 \times 10^4 \text{ g})}$$

$$= 6.8 \times 10^{-6} \text{ rem/}\mu\text{Ci-day},$$

1.3 = skin absorption factor with clothes,

$$\text{Therefore, } DF_{\text{HTO}} = 3.7 \times 10^{-2} \text{ rem-m}^3/\text{Ci-sec}$$

For HT, the dose conversion is assumed to be 1/200 of the DF for HTO (ICRP 2).

$$\text{Therefore, } DF_{\text{HT}} = 1.85 \times 10^{-4} \text{ rem-m}^3/\text{Ci-sec}.$$

The dose equivalent to an individual in the lab exposed to this mixture for time t can be calculated from the equation:

$$DE = \sum_{i=1}^n (DF_i)(A_i/V) \int_0^T \exp[-Ft/V] dt \text{ (60 sec/min) rem},$$

where

DF_i = dose conversion factor for HT or HTO,

A_i = initial activity released,

$$= 9 \times 10^4 \text{ Ci of HT; } 10^4 \text{ Ci of HTO,}$$

V = room volume m^3

$$\int_0^T \exp[-FT/V] dt = \text{time integral of exposure,}$$

$$= 6-6\exp(-t/6) \text{ for 10 air changes/hr.}$$

For a 30 second stay time, the dose equivalent to an individual is approximately 30 rem. If the individual fails to evacuate ($t \geq 60$ min) the dose equivalent would be 380 rem. The 60 minute stay time was included

as the worst possible case, although the chance for this exposure is extremely low. Even if an individual was unconscious, the TRL emergency procedures call for immediate re-entry for injured persons. Such a re-entry could be made in less than 15 minutes.

4. A summary should be provided to present the information generated on the potential accident situations analyzed in this section. A table would be sufficient.

The following table was added to Section 6.

SUMMARY OF ACCIDENT ANALYSIS

Type of Accident

Consequences

Natural Phenomena

A. EARTHQUAKE
0.275 g ground acceleration,
*p ≤ 0.16 for 30 yrs	The capacity of the building and vital systems is greater than the demand after building modifications were made.
B. SEVERE WIND
tornado with wind speed =
60 m/s, p ≤ 10 ⁻⁶ /yr	Wind load and wind induced resonances are not expected to affect the TRL or the stack.
C. LIGHTNING STRIKE
stroke current = 160 kA,
p ≤ 9 x 10 ⁻⁸ /yr	The TRL 30 meter, steel stack has sufficient height and grounding system to intercept and ground a strike of this magnitude.
D. FLOODING	There are no large bodies of water in the SLL drainage basin and an extreme rainfall could result in no more than sheet flow on the sloped SLL site.

Human Error

E. NUCLEAR CRITICALITY	Fissile materials are not presently handled in the TRL except for 14 calorimetry standards (≤ 16 grams).
F. FIRE OR EXPLOSION	A localized fire confined to a glove box or lab is possible. It is expected to be of short duration and minimal lab structure involvement.
G. TRITIUM RELEASE
10 grams (10 ⁹ Ci)
(1) Release into lab	Worker dose for a 30 second stay time = 30 rem, and for a 60 minute stay time the dose = 390 rem.
(2) Release to stack	Nearest site boundary dose = 1 rem,
Population dose = 600 man-rem,
South Bay Aqueduct contamination = 3 x 10 ⁻⁴ µCi/ml.

*p is the assigned risk or probability of occurrence.

Department of Energy
Albuquerque Operations
Sandia Area Office
P.O. Box 5400
Albuquerque, New Mexico 87115

DATE RECD. Mar 7 1979	
8200 ELIZABETH	
1	GEDNEY
	DAVIES
	GLASS
	LITTLE
	FILE
	CENTRAL FILE
	DISPOS

MAR 7 1979

A. H. Blackwell, 8200, SLL

TRITIUM RESEARCH LABORATORY (TRL) - DRAFT FINAL SAFETY ANALYSIS REPORT (DFSAR) - REPLY TO OSD COMMENTS - SLL

Attached is a copy of a memorandum dated February 27, 1979 from Willis B. Johnson, Deputy Director, Operational Safety Division (OSD), ALO, which comments on SLL's reply to the OSD December 6, 1978 comments on the draft document.

Please transmit the FSAR to OSD through the Sandia Area Office.

Gil E. Cordova
Gil E. Cordova
Area Manager

SBA:LPA

Enclosure:
As Stated

DATE RECD. MAR 7 1979	
1	INTL
2	8200
3	3
4	52
5	8200
6	8200
7	DESTROY

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

→ Gil E. Cordova, Area Manager, Sandia Area Office

TRITIUM RESEARCH LABORATORY (TRL) - DRAFT FINAL SAFETY ANALYSIS REPORT
(DFSAR) - REPLY TO OSD COMMENTS - SLL

We have reviewed the SLL reply to our comments of December 6, 1978 on the draft document. The reply is satisfactory and we have the following observations:

1. We note that the installation of the 30 meter meteorological tower at LLL will permit the determination of the 95% X/Q values and other pertinent meteorological data. At some later date (after at least one year's data has been collected and analyzed) this information should be included in the SAR. An evaluation of the accident analysis and the meteorological assumptions used therein should be made and the analysis modified, if appropriate.
2. We understand that the 200 kVA diesel generator will currently handle the building's emergency power requirements and those for the foreseeable future. No equipment sequencing priorities are being planned. We caution that high starting current demands of some electrical equipment as opposed to steady-state demands could overload the system.
3. Additional corrections will be made by SLL, as noted in their reply, prior to issuing the FSAR. The FSAR should be transmitted to OSD through the Sandia Area Office.

Willis B. Johnston
Deputy Director
Operational Safety Division

WOF:WBS

Enclosure:
Ltr. , Wright/Sayer, dtd 2/6/79, w/encl.

cc: G. E. Autio, Director, F&CM Div.,
ALO, w/encl.

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INITIAL DISTRIBUTION

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