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MASTER

PLASMA-PARAMETER MEASUREMENTS USING NEUTRAL-PARTICLE-BEAM ATTENUATION

J. H. Foote
A. W. Molvik
W. C. Turner

July 7, 1982

Lawrence Livermore Laboratory

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AN INTRODUCTION TO NUCLEAR TEST ENGINEERING

William C. O'Neal and Donna Lee Paquette

Nuclear Test Engineering Division
Lawrence Livermore National Laboratory
July 15, 1982

ABSTRACT

The basic information in this report is from a vu-graph presentation prepared to acquaint new or prospective employees with the Nuclear Test Engineering Division (NTED). Additional information has been added here to enhance a reader's understanding when reviewing the material after hearing the presentation, or in lieu of attending a presentation.

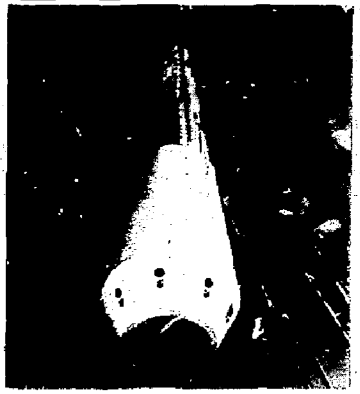
ACKNOWLEDGEMENTS

The authors appreciate the assistance of Larry Gottlieb, Technical Information Department, and of Jim Page and Dick Wasley, NTED, in developing the original vu-graph presentation on which this report is based. Historical information provided or verified by Walt Arnold, Assistant Associate Director for Engineering, Vic N. Karpenko, Mechanical Engineering Department, Bill Wakeman, NTED, and Roland Wallstedt, 'J' Division, is also greatly appreciated.

NUCLEAR TEST ENGINEERING DIVISION

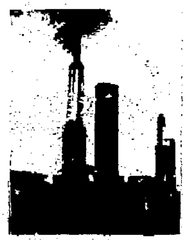
MECHANICAL ENGINEERING DEPARTMENT
LAWRENCE LIVERMORE NATIONAL LABORATORY

We provide the mechanical engineering for three major Laboratory programs



Nuclear
Testing

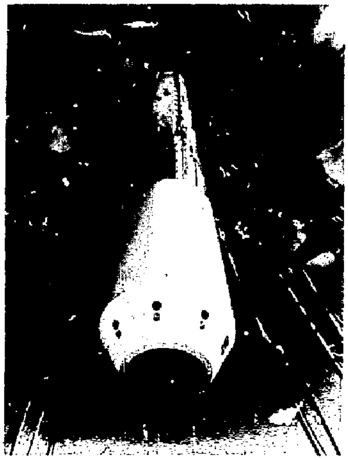
Nuclear
System Safety
(Reactor Safety)



Energy

Nuclear Test Engineering Division (NTED) is one of LLNL's principal engineering divisions.

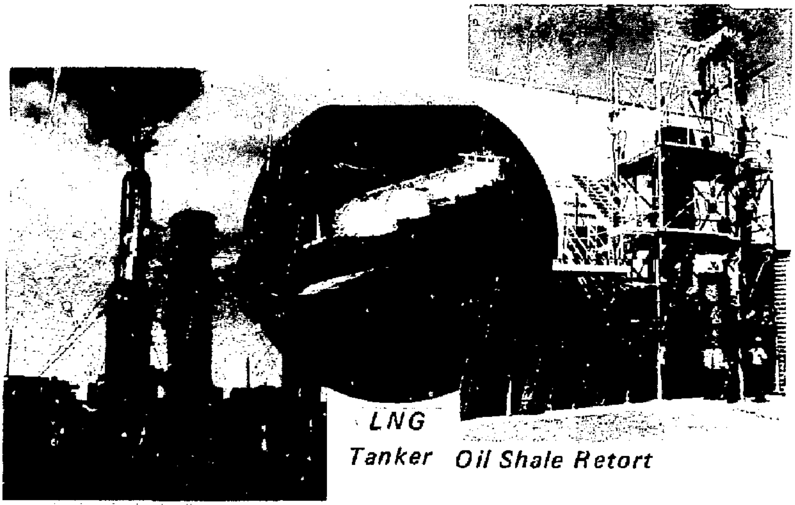
Our primary mission is to support the Nuclear Test Program



Nuclear test canister starting down hole at Nevada Test Site (NTS)

The primary mission of NTED is to provide mechanical engineering, as well as technical expertise, to prepare and field nuclear tests for the LLNL NUCLEAR TEST PROGRAM.

We engineer the development and safety of new energy sources



LNG Tanker

Oil Shale Retort

Coal Gasification

Within NTED's Test Systems Section and Mechanical Technician Section are groups that provide support for a number of DOE-funded projects in the areas of ENERGY AND EARTH SCIENCES. Ongoing programs of the energy groups include oil shale, underground coal gasification, geophysics research and testing, and liquefied gaseous fuels safety.

We analyze reactor systems to assure their safety during earthquakes

Three Mile Island Nuclear Power Plant

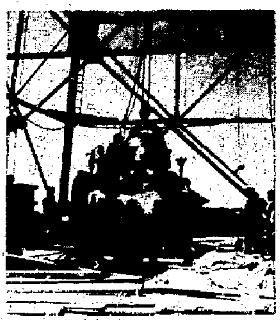
We perform most of our **NUCLEAR SYSTEM SAFETY** *work* in support of the Nuclear Regulatory Commission (NRC) in three basic areas related to reactor safety: seismic engineering, applied mechanics, and systems and risk analyses.

This section on the history of nuclear test engineering presents some of the key developments in this unique technology.

Nuclear test engineering began with the Trinity test in 1945

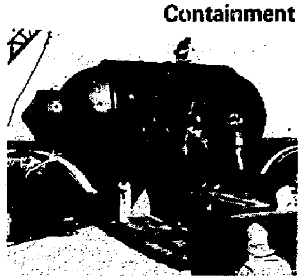
Trinity, the first nuclear device test, was conducted near Alamagordo, NM in 1945. The U.S. Army Corps of Engineers provided the mechanical engineering support for this test.

Historically, nuclear test engineering has served four roles, as defined on Trinity



Nuclear device safety operations

Diagnostics



Containment

Nuclear chemistry

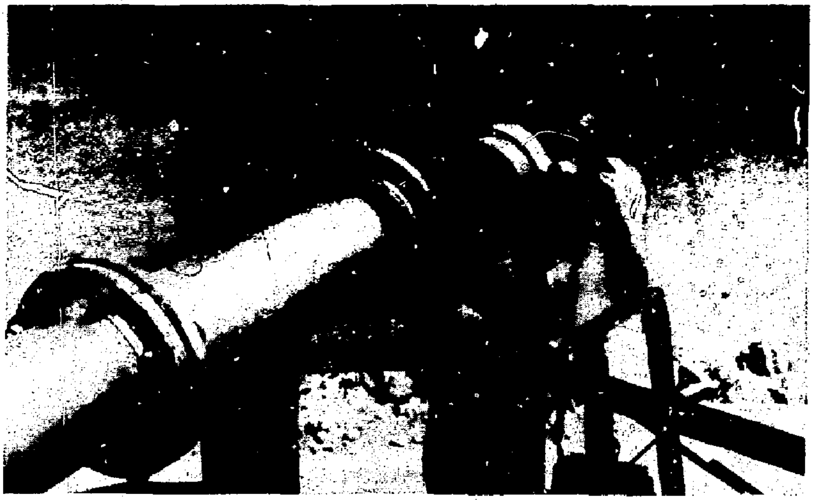
Safe procedures used in transporting and handling the nuclear device were of primary concern during ground zero test preparations. Responsibility for nuclear safety and engineering aspects of scheduling, planning, final assembly, and arming operations was the beginning of 'device systems engineering.'

'Diagnostics engineering' on Trinity provided camera systems, tower design, mirror systems and other nuclear blast sensors.

'Containment engineering' on Trinity provided a pressure vessel in which the device was to be detonated. If the device did not go critical, the vessel would have contained the plutonium (the entire world's supply at that time). However, calculational results looked good so it was decided to fire the device outside the vessel, and the device did go critical.

A lead-shielded tank was used to collect ground zero debris samples right after the shot. This was the first 'nuclear chemistry' operation.

In the 1950's we detonated devices over land and water in the Pacific



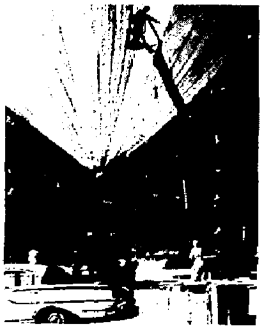
Aligning diagnostics with the device at Bikini Atoll (1956)

LLNL started at Livermore in 1952. One of the mechanical engineers who joined the Laboratory in 1952 was Bill Wakeman, shown above, who is still doing nuclear test engineering in 1982.

Nuclear Testing History

In the 1950's we detonated devices on balloons, towers and in tunnels in Nevada

Nevada Test Site



Hood 1957

Teapot 1955

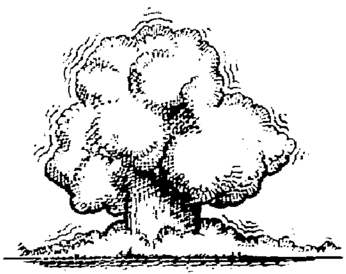
Rainier 1957

Nuclear weapons tests were all detonated in the atmosphere or under water until the Rainier event, the first deep underground test. Most of the radioactivity was contained underground on the Rainier test.

Nuclear Testing History

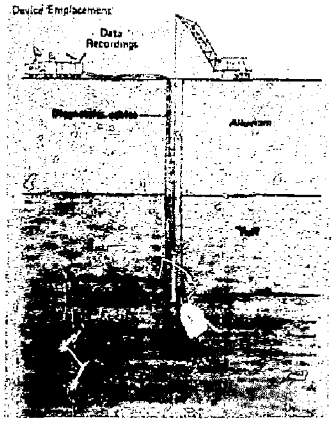
After 1963 we engineered all nuclear systems for underground detonations

Before Atmospheric Test Ban Treaty



At our Nevada Test Site

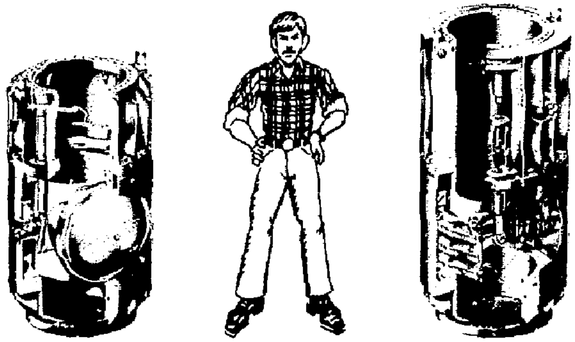
The 1960's to date



To prevent further atmospheric dispersion of radioactivity, we designed systems for underground emplacement of device tests in tunnels and deep bore holes. These activities required much more engineering and technical support than for above-ground testing.

Nuclear Testing History

In the late 1960's we developed fast closing valves to contain radioactivity after underground detonations



We developed fast-closing valves to allow exposure and recovery of various materials and structures. The open pipes leading down to the detonation point had to be shut off after the radiation flux reached the test materials at the surface, but before radioactive debris shot out into the atmosphere.

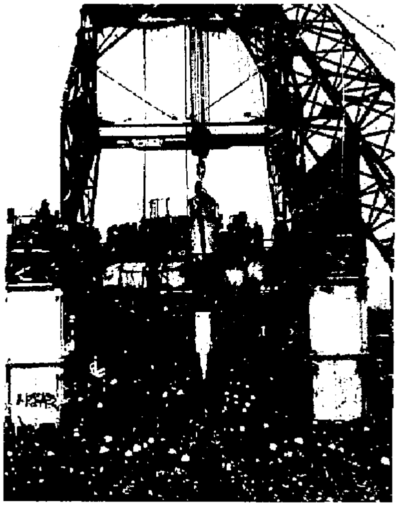
Nuclear Testing History

In 1968 we engineered the mechanical pinex system for neutron photography of detonations

By applying engineering principles of function and reliability, we developed the neutron pinex system into a 99%+ reliable diagnostic system. We used the system on more than 100 nuclear detonations in the late 1960's and 1970's, and it is still being used occasionally.

Nuclear Testing History

In 1971 we designed test systems for the Amchitca, Alaska nuclear test



Although nuclear test systems had been successfully engineered for conditions of high heat and humidity in the Pacific and extreme cold and heat in Nevada, the combination of high winds, dampness and cold in Alaska was unique. All NTED-designed systems, however, performed as required in the Cannikin test at Amchitka.

In the 1970's we developed quality-assured technology for containment of radioactivity

The Laboratory's new policy of quality assurance was implemented for nuclear test engineering activities. Technology associated with the containment of radioactivity was improved to meet the nation's higher requirements for containment.

Nuclear Testing History

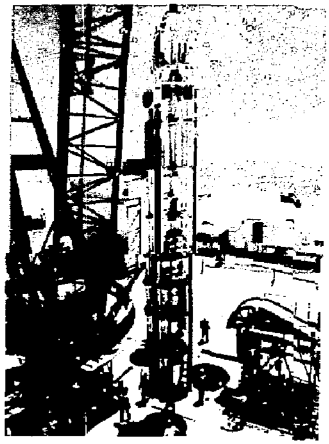
In the 1970's we developed quality-assured technology for high reliability emplacement systems

To improve the already high reliability of mechanical systems, we developed quality-assured technology to achieve virtually 100% reliability. Fracture safe materials and fracture control principles are employed in all critical load-carrying systems.

Nuclear Testing History

During the 1970's tests became fewer and more complicated

1970



1980

In the decade of the 60's, we conducted as many as 46 LLNL nuclear tests in a single year. As budgets were curtailed, we had to learn more from individual nuclear tests. Event designs became more and more complex as we tried to extract more and better quality data from each test. The number of tests per year during the 70's reached a high of only 13.

Nuclear Testing

The augmented testing program means new challenges for NTED's engineers and technical people

Improved alignment and calibration techniques are needed to meet tighter requirements for spatial data from nuclear devices. To further improve electronic resolution of data, fiber optics systems are being developed and used to transmit data from the point of detonation to recording systems.

Nuclear Testing

Device systems engineers are NTED's Event Project Engineers

For a particular nuclear test, the device systems engineer is the event project engineer and is the cognizant individual for all NTED engineering on that project. He also has the traditional responsibilities such as arming and firing, device safety at ground zero, and device canister engineering.

Device systems personnel are responsible for designing and fielding nuclear device systems

Computer aided design and engineering play increasingly important roles in nuclear test engineering, as well as in the other design aspects of NTED work.

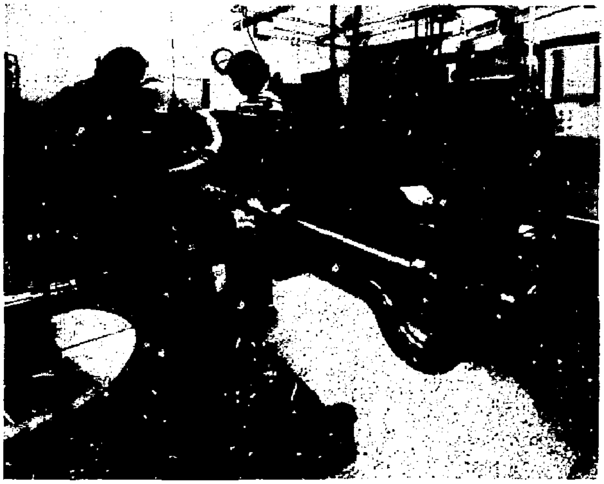
Nuclear Testing

Diagnostics people design and field systems that measure device performance

Test preparation includes much preliminary work in our offices and laboratories at LLNL before we ever go to the test site. We analyze, design and develop many specialized items such as x-ray filters and vacuum systems, which of course must be assembled, tested, aligned and calibrated.

Nuclear Testing

Our mechanical technicians build and calibrate radiation detector systems



Double-reflection x-ray spectrometer

Successful performance of the x-ray diffraction/reflection detectors requires precise dimensional control and alignment. High vacuum and special finish requirements help make design, assembly and calibration a challenge for our highly skilled technicians.

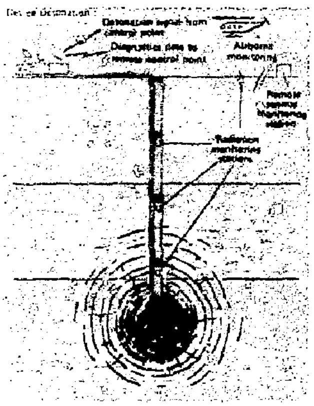
Nuclear Testing

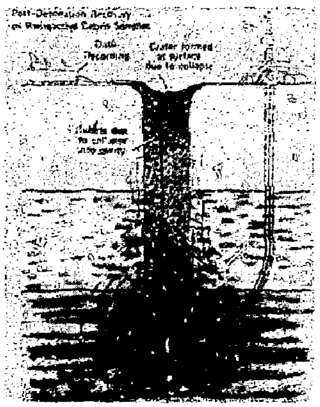
Our engineers run computer analyses of test hardware

Using LLNL's massive computer system, our engineers can do 3-dimensional stress analyses of critical regions of diagnostics canisters. This provides documented, accurate information to help assure the integrity of these systems under field conditions. We also use the results to make design and/or cost-effective improvements on the structures.

Nuclear Testing

The containment staff designs and fields systems to contain test radioactivity

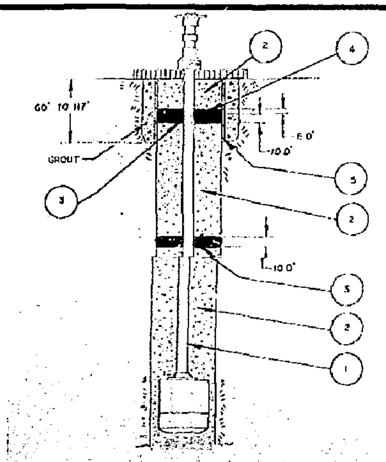




Assuring containment within the cavity region of radioactive materials that are a part or product of a nuclear test consumes a significant portion of our resources. Years of experience and continuing engineering development now provide reliable and cost-effective containment systems.

Nuclear Testing

Containment engineering people design stemming plans to prevent radioactive release

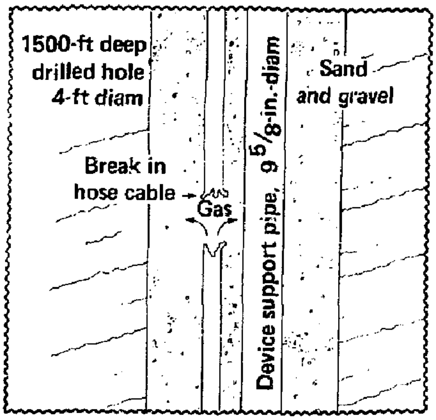


This sketch typically shows the installation of plastic plugs and the surface conductor.

1. Emplacement string
2. Stemming material
3. Rigid plastic plug
4. Soft plastic plug
5. Surface conductor

The specifications, location, and performance of all materials and systems affecting containment are critical. We carefully plan, analyze, test, build and emplace the materials and systems to assure containment, as well as the recovery of necessary data from the nuclear test.

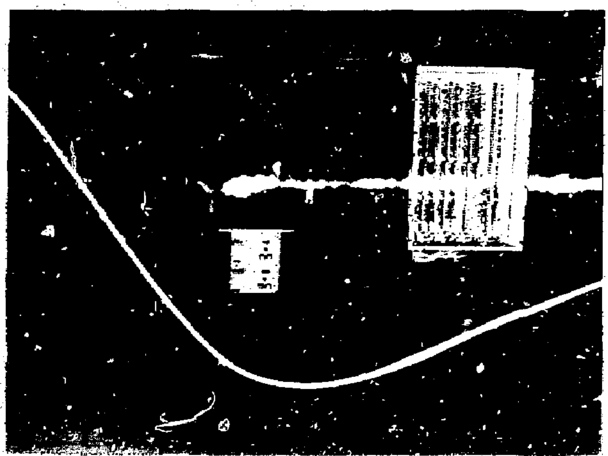
Thermo-fluids engineers are developing improved technology for radioactive gas sampling



Radioactive gases generated by the exploding device can be analyzed to determine device performance. Our engineers face the challenge of recovering some of this gas using a system that is designed to keep the gas captive. Experience from many tests has shown that the system works successfully.

Nuclear Testing

Nuclear chemistry people design and field systems that sample radioactive gases

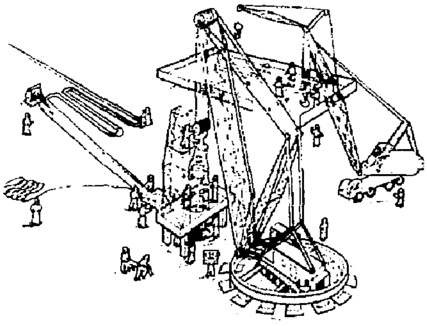


Nuclear test gas-sampling spectrometer system

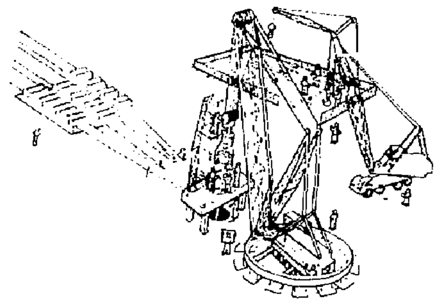
Our nuclear chemistry engineers and technical people designed and built this gas-pumping and spectrometric analyzer system. In conjunction with the established methods of later analysis in the laboratory, we use this system to analyze radioactive gases near ground zero, right after the shot, before short-lived daughter elements can decay to an unanalyzable low level.

Our advanced development projects seek improved state-of-the-art engineering

Cable Downhole System



Old system
(duration: 2 weeks)

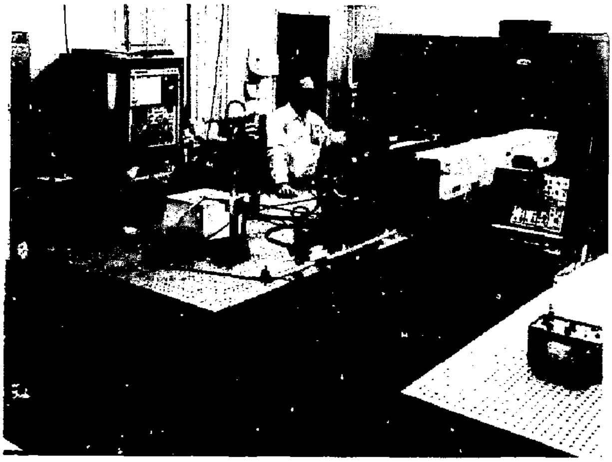


New system
(duration: 2 days)

Since resources for nuclear testing are limited, developing high-productivity methods for emplacing nuclear test systems is appropriate. The Cable Downhole System uses computer-controlled motor-driven tensioning units to guide and control the tension on electrical cables during the process of lowering the experiment to depths of 2000 ft.

Nuclear Testing

Optical laboratories are operated by our mechanical technicians



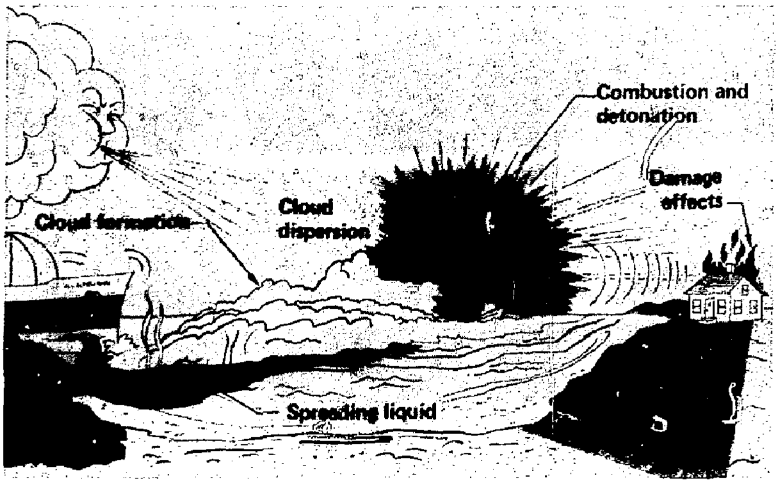
Fiber optics R&D laser laboratory

A recent development in nuclear testing technology is the use of optical fibers to transmit information from the device output sensors in the downhole diagnostics system to recording systems located on the surface. The nonconductive optical fibers do not transmit the noise that often degrades information that is transmitted electrically on metal cables. We are developing new methods in our optical laboratory to help design, install, connect, splice and protect optical fiber systems.

Energy

Our liquefied gaseous fuels program emphasizes liquefied natural gas safety

NTED



Unpredictable, devastating effects could result from serious liquefied natural gas (LNG) ship and storage tank accidents. LLNL scientists are developing and verifying models to predict and evaluate these effects. NTED people in the LGF group designed and built test instrumentation systems for use at a small spill test facility at China Lake, CA, and are now designing a large-scale spill test facility for future use in spill testing at the Nevada Test Site.

Energy

LGF program people are designing and building a spill test facility at NTS

500m³ test facility, NTS

The large-scale facility is designed to store and test liquefied natural gas, liquefied petroleum gas, liquefied ammonia and liquid hydrogen.

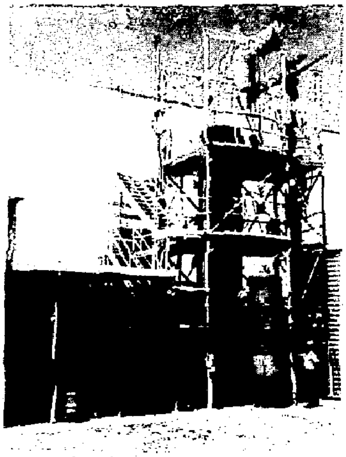
Energy

Technical personnel assemble and install LNG sensor systems

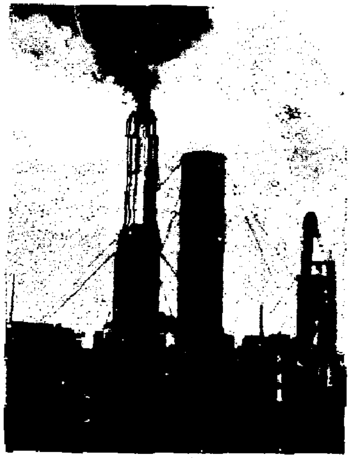
The sensors, 40-ft and 11-ft towers, designed, built and installed by our LGF people, have been used at China Lake for three years of tests with no failures (right). Methods for forcing LNG through pipes at high velocity are being developed at LLNL. The 1/8-scale (left) and 1/4-scale models are to proof test our designs for the full-scale 500 m^3 spill test facility.

Energy

The energy group supports fossil energy research



Oil shale retort project

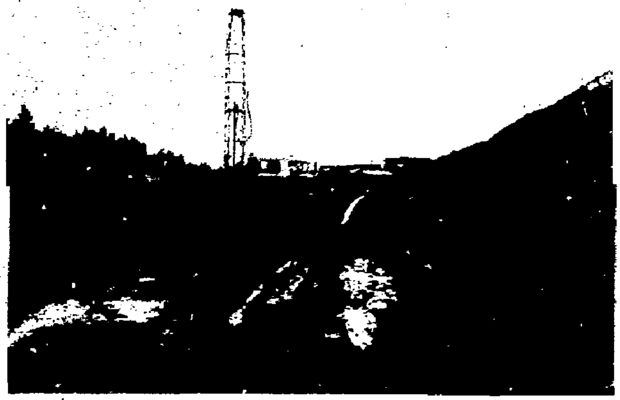


Coal gasification project

Oil shale program work includes designing and operating retort systems. The experiments involve the pyrolysis of oil shale and are designed to produce data for mathematical modeling for in situ and surface retorting processes.

Energy

Technical personnel test hydrology and permeability in a coal seam outcrop

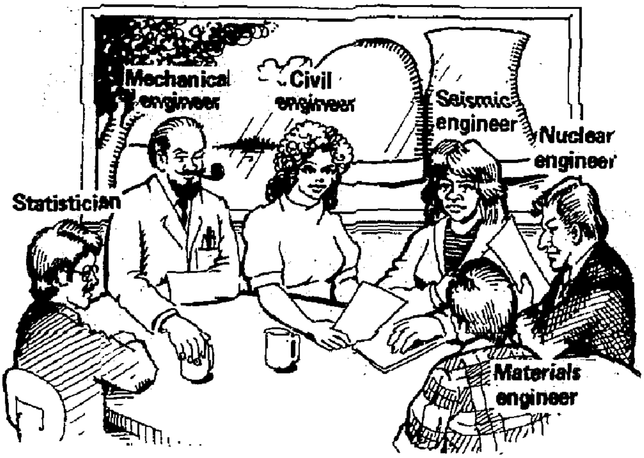


Centralia, Washington

The underground coal gasification project is part of the DOE program to extract economical energy from coal without mining. The basic goal is to develop a process for producing medium-heating-value gas that can be upgraded economically to pipeline quality or used as a chemical feedstock. To this end, we provide the mechanical engineering support for both laboratory experiments and large field tests. LLNL does the laboratory work so as to understand the chemical processes involved in converting the coal to gas. This scientific knowledge is then applied to gasifying the actual underground coal resource during <u>in situ</u> field tests.

Reactor Safety

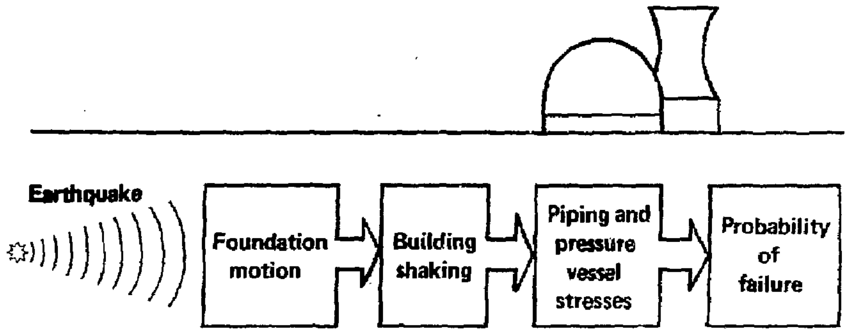
Our engineering mechanics people provide multidisciplinary support to reactor safety projects



We perform most of our nuclear system safety work in support of the NRC, in three basic areas related to reactor safety: seismic engineering, applied mechanics, and systems and risk analyses. The major concern of the NRC in these areas is the safety of nuclear power plants and associated facilities. Through our Engineering Mechanics Section, we provide technical advice and data on which the NRC can base licensing decisions and develop assessment tools to assure the protection of the public health and safety.

Reactor Safety

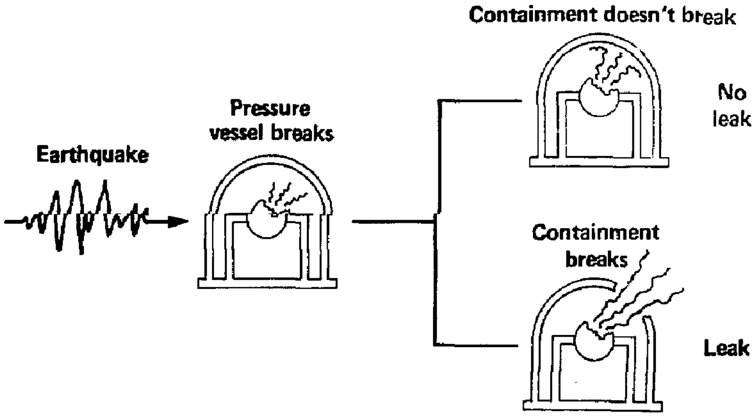
Our people contribute to analyzing reactor response to an earthquake



Allowing for earthquake stresses is a major part of nuclear power plant design. The ultimate questions we must examine are how well can commercial nuclear facilities withstand earthquakes and how high is the earthquake-related risk of a radiation release from nuclear plants. To do this, we case-review specific plants and sites for seismic vulnerability; evaluate seismic-engineering approaches that are being used for nuclear facility design; and develop, over the long term, a new probability-based seismic-engineering approach.

Reactor Safety

Nuclear systems engineers perform risk assessments for reactor safety systems

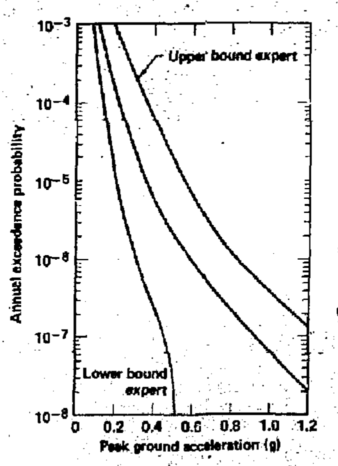


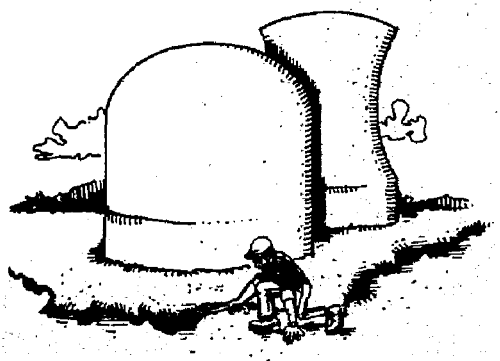
Fault Tree Analysis

The quantification of risk is done by our nuclear systems engineers using such methods as fault-tree analyses. Identifying high-risk systems is a first step towards prevention of reactor accidents.

Reactor Safety

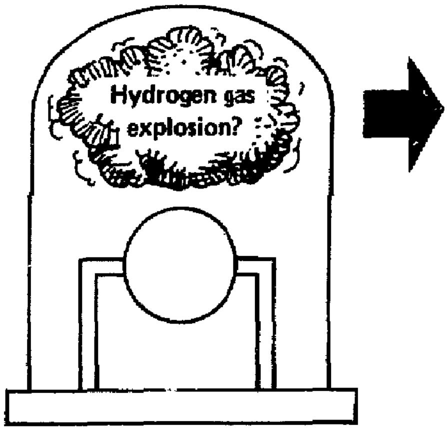
Seismic engineers provide seismic predictions for risk studies at reactor sites





Our seismic engineers assess information about the location of faults and their activity around reactor sites. Using this information and predictive earth mechanics models, they calculate the expected ground motion at ·eactor sites.

We study thermo-fluid processes affecting reactor containment

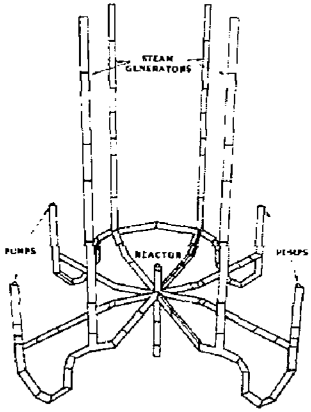


Our study was prompted by the Three Mile Island *incident*

A critical NRC safety issue is the control of hydrogen gas generated inside a reactor containment during a loss of coolant accident (LOCA). One proposed test system would burn, under controlled conditions, the hydrogen gas in a way that would prevent the gas-air mixture from reaching a detonable composition. Thermal igniters (glow plugs) used in this system were tested under varying concentrations of air, hydrogen, and steam in a pressure vessel at LLNL's Site 300, about 15 miles southeast of Livermore. These functionability tests assist the NRC in evaluating this and other hydrogen management schemes.

Reactor Safety

Mechanical engineers analyze and assess mechanical system reliability

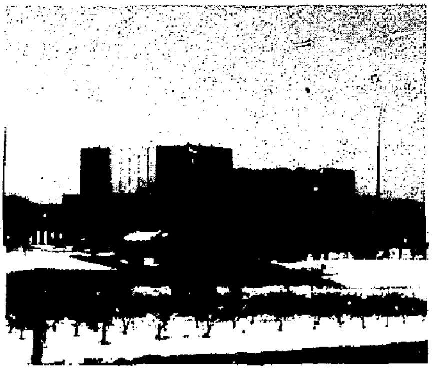


Another major NRC-sponsored program is the Load Combinations Program. This program addresses the various loads that are associated with the design of nuclear power plants, and the appropriate methods of combining the loads.

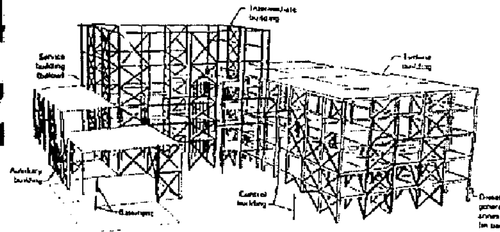
Reactor Safety

Civil engineers analyze nuclear reactors and conventional buildings

UNITED



Robert E. Ginna nuclear power plant, Rochester, NY

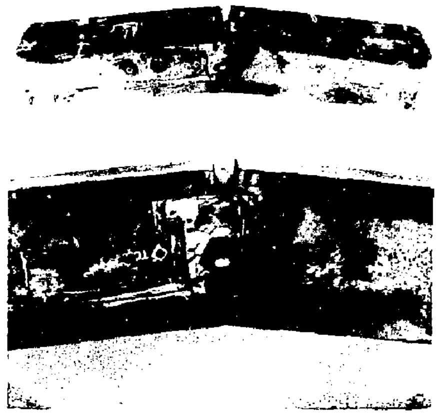


3-D computer analysis

In our analysis of the Robert E. Ginna nuclear power plant near Rochester, NY, we created a 3-dimensional representation of the interconnected building complex to analyze the plant's seismic response.

NTED's quality assurance program assures safe and reliable system performance

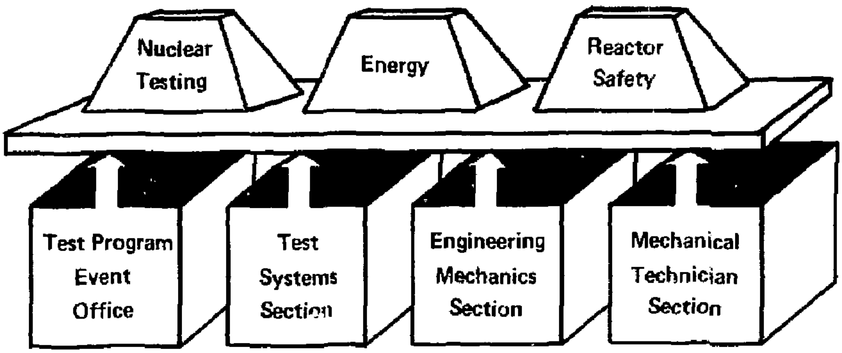
Safe



Reliable

To reduce the probability of serious accidents to a minimal level, NTED develops and carries out quality assurance plans and procedures. Faithfully following these procedures takes time, but does produce good results. The ability of a cracked part to bend (right) instead of breaking if overloaded is an example of one of the desirable characteristics of our high-reliability systems.

We have four major organizational groups supporting LLNL programs



We play a key role in the successes of these LLNL programs by providing high quality, responsive, technical and managerial support.

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