LA-6458-P

Proposal

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A Proposal

for a

Tritium Systems Test Facility

at the

Los Alamos Scientific Laboratory

by

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Robert H. Sherman
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Contributors

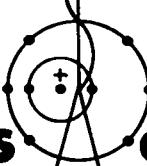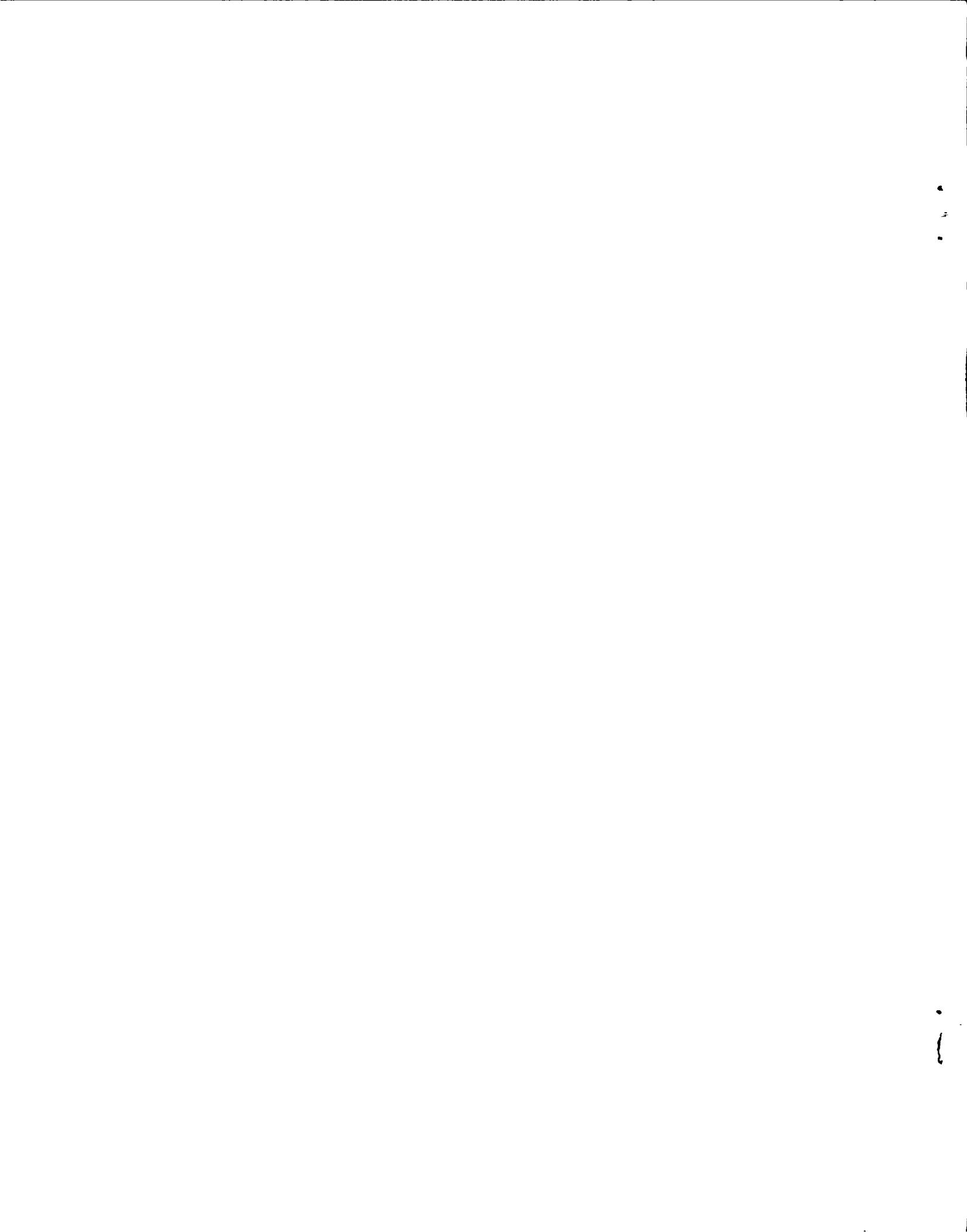|	
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A PROPOSAL

FOR A

TRITIUM SYSTEMS TEST FACILITY

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ABSTRACT

It is proposed that LASL be funded to design, construct and operate
a Tritium Systems Test Facility to develop and demonstrate the tritium
fuel cycle and environmental control systems for an Experimental Power
Reactor. This facility will include systems to demonstrate all of the
technologies necessary for the development of the fuel cycle. This includes
vacuum systems, fuel purification, hydrogen isotopic distillation systems,
gas analysis, transfer and mixing systems, as well as the necessary instru-
mentation, control, containment and cleanup systems. It is proposed that
this facility be housed in an existing building at LASL. The total cost
to design, construct, and operate the facility through FY-1981 is
estimated to be $\sim$ \$7.7M.

I. INTRODUCTION

1.1 Summary

It is proposed that the Los Alamos Scientific Laboratory (LASL) be funded to design, construct, and operate a Tritium Systems Test Facility (TSTF) to demonstrated the tritium fuel cycle and environmental control systems for an Experimental Power Reactor (EPR). (See artist's conception Fig. 1.1-1.)

The LASL is extremely well qualified for this task with existing expertise available in every major technical area to be covered in the TSTF. The existence of this experience at one Laboratory is deemed very important to the orderly planning, design, construction and operation of the TSTF.

Personnel to be associated with the TSTF have in excess of 40 man years of "hands-on" experience in tritium technology. These people have extensive experience in vacuum technology, gas analysis, cryogenic distillation, design and construction of tritium facilities, including environmental control systems, computer-control of large sophisticated systems, health physics and environmental sciences. Additionally there is a wide range of support personnel and facilities including engineering, shops personnel and facilities, fusion research groups and personnel working on the design and operation of the Intense Neutron Source (INS), and other fusion research programs.

The TSTF will be a national facility which will encourage and solicit exchange with other groups working in tritium and fusion technology. One of the major goals of the staff at the TSTF will be to inform industry on the developing requirements for tritium handling in large facilities and to encourage industry to work with the staff in developing components to meet these requirements. The TSTF will also serve as a training site for personnel from other laboratories who will be involved in tritium technology at other fusion facilities but who have no direct experience in tritium handling. The TSTF should develop a reservoir of personnel to staff other tritium facilities.

An existing building at LASL is available for this facility, but it must be extensively modified to best accomodate the TSTF. This building (TA-21-155) has equipment that will have to be removed prior to the start of the proposed modifications. The main room in the building has $\sim$ 3700 ft^2 and

a floor-to-ceiling height of 28 ft., making it ideally suited for the large components necessary to a TSTF. Included in the room is a large (2-ton) overhead crane which will be important during installation and maintenance on the system. An additional 4000 ft^2 is available as offices, laboratories and equipment rooms in this building.

One of the main components of the TSTF will be a large vacuum system. The system is scaled to be equal in size to 1/32 of the toroidal volume of the Tokamak EPR designed by Argonne National Lab.[1] This is one-half of a module size in the Argonne report and thus will be ideal for scaling to full size systems. The vacuum system will consist of a large ($\sim$ 22 m^3) tank where various types and combinations of vacuum pumps can be evaluated. The rest of the main gas loop will be capable of handling the projected full flow (540 moles/day)[1] DT gas stream. This gas loop includes purification systems to remove impurities from the exhaust gas, a cryogenic distillation system for hydrogen isotope separation, stations for evaluating and developing circulation pumps, a complete gas analysis system and a standard volume for preparing proper gas mixtures including the option of adding expected impurities in the gas mixture to simulate the exhaust gas. Included in the facility will be systems for the routine cleanup of effluents prior to their exhaust to the atmosphere and a large (1000 scfm) emergency cleanup system to recover tritium from the room air following a major accidental release.

The entire system will be designed for ultimate computer-control after a lengthy period of proof testing.

It is projected that if funding for the project is available at $\sim$ $500 K for FY-77 and additional funding as requested in section 6 is available, the system could be operational and yielding significant data by late FY-1980. The projected total cost for design, construction, testing, and operation of the system from FY-1977 through FY-1981 is $\sim$ $7.7 M.

Reference

1. "Conceptual Design of a Tokamak Experimental Reactor," Argonne Natl. Lab. Report ANL/CTR-75-2, June 1975.

CRYOSORPTION PUMPS

VACUUM TANK

ISOTOPE SEPARATION
SYSTEM

MACHINE SHOP

FUEL CLEANUP

CONTROL ROOM

TRITIUM WASTE
TREATMENT

FLOW LOOP

EMERGENCY TRITIUM
CLEANUP

N
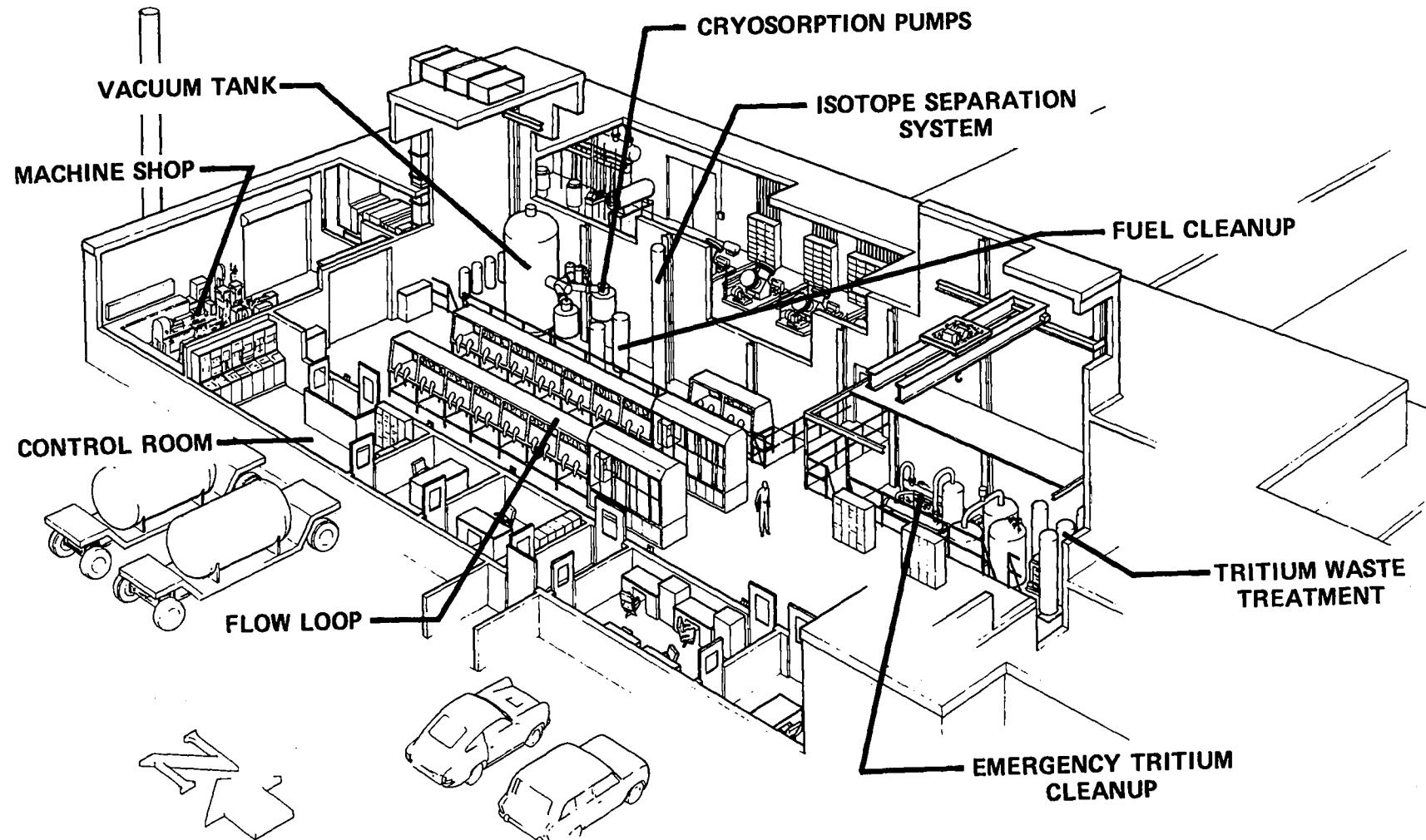
Fig. 1.1-1   Artist's Conception of the Los Alamos Tritium Systems Test Facility.

1.2 LASL's Qualifications

In the overall program to develop fusion reactors, the problem of handling large quantities of tritium must be addressed. Tritium has been handled in processing plants and in laboratories by physics experimentalists. Since the Los Alamos Scientific Laboratory has had significant and diversified experience in tritium technology LASL would be well qualified to house the proposed Tritium Systems Test Facility.

LASL's experience has been in the design, construction, testing and operation of systems for handling large quantities of tritium. Expertise includes handling tritium gas at pressures to 100 mPa and developing systems to handle large quantities (200 g) as reactive metal tritides. Design construction, testing and operation of a modern Tritium Waste Treatment System (TWT) which effectively removes tritium from the effluents generated at a major tritium facility have been performed at LASL. Section V of this proposal discusses in considerable detail LASL's experience and qualifications for handling large quantities of tritium.

Inventory

The LASL has a nominal tritium inventory of about 150 g. The addition of a 200-g inventory at the proposed TSTF would more than double LASL's tritium inventory. At the proposed facility site, the inventory would increase from about 50 g to about 250 g. While LASL has prior experience in safely handling the quantities of tritium projected for the TSTF, the new facility will undoubtedly pose new control and protection problems because of its experimental nature. However, health protection capabilities at existing LASL tritium facilities will provide a good base for coping with these problems in a manner that assures personnel exposures will be maintained as low as practicable and well within established standards.

Location

The Los Alamos Scientific Laboratory is located in the isolated community of Los Alamos, population 17,500, in north-central New Mexico (see Fig. 1.2-1). Santa Fe, the state capitol, is 40 km SE by air. Albuquerque, the state's largest city and site of an International Airport, is located 100 km SSE by

Santa Fe – Denver
road 386 miles
air 316 miles

Espanola
elevation 5766 ft

Los Alamos
elevation 7150 ft

Pojoaque

Road 34
air 20 miles

Santa Fe
elevation 6344 ft

Road 96 miles
air 69 miles

Road 62 miles
air 47 miles

North

Albuquerque

International airport
elevation 5352 ft
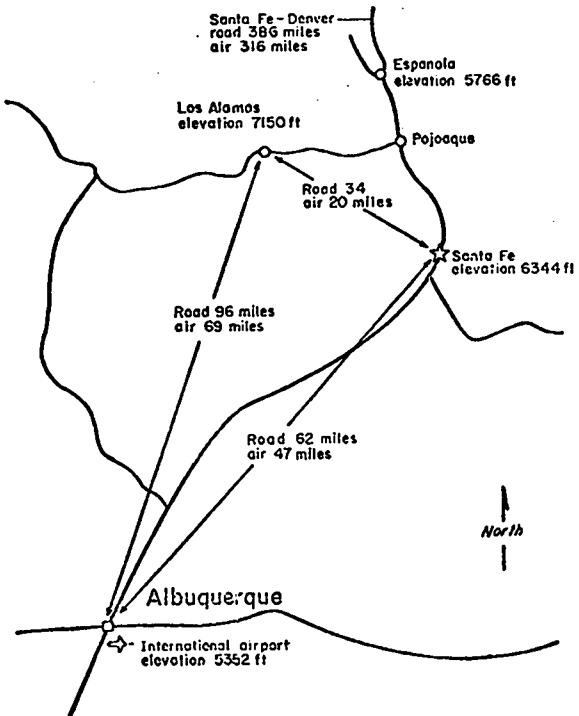
Fig. 1.2-1   Location of Los Alamos in North-Central New Mexico.

air. The LASL and its support community nestles in a forested area at an elevation of 2250 m, high on the side of the Jemez Mountain Range and at the base of the Sierra de los Valles. The nearest community of any size is Espanola, 20 km to the northeast, with a 1970 population of 4560.

The Los Alamos area possesses a known attraction for scientists throughout the world because of its climate, geography, beauty, and clean environment. These advantages assure a continuing source of talent and help to promote scientific exchanges.

Site Availability

LASL, fortunately, has an existing building that could be readily available for the Tritium Systems Test Facility (TSTF) with some modification. Located in a fenced technical area, the building is situated at the far east end of a finger of mesa with canyons on three sides. The nearest residence is 1 km away and the limited access airstrip is located across a canyon to the north on a parallel mesa. (See aerial photograph Fig. 1.2-2).
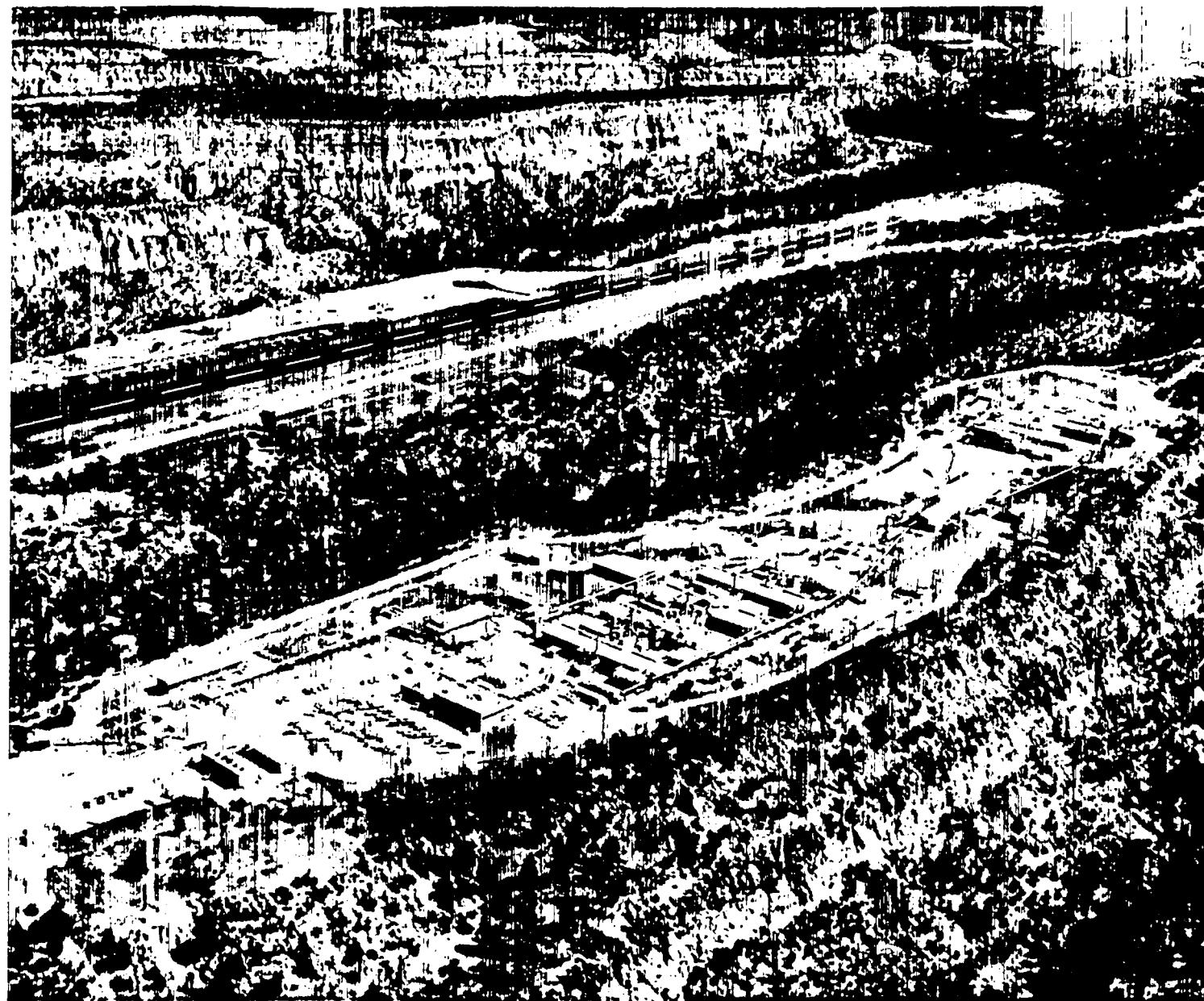
Fig. 1.2-2   Aerial Photograph Showing Proposed TSTF Site.

The building is part of a larger complex of buildings in a security-protected technical area. More than 7700 square feet would be dedicated to the TSTF including a large central area with a high bay and overhead crane, adjacent mechanical equipment room, laboratories, offices and change rooms. Access into the security area for the visiting scientist is easily arranged.

Support Facilities

The scope of the TSTF is large enough and sufficiently sophisticated to require sizable adjunct facilities for its efficient design and operation. Only at a large laboratory, such as Los Alamos, are such facilities available. LASL has the diversity, experience and interest required for accommodating the project and can do so without saturation of its adjunct facilities or creating an imbalance among existing or future programs. The project, in turn, will enhance future programs in the magnetic fusion energy field.

Handling of radioactive contaminated material as well as tritium and tritium-contaminated material has long been a specialty at Los Alamos. Although the safeguards for protecting the public are more than adequate, public awareness of environmental impact and ecological responses are sufficiently sensitized today that the location in a remote area near a scientific community such as Los Alamos should be an important consideration.

A National Facility

The anticipated major use of the TSTF will be in support of the nation's Magnetic Fusion Energy (MFE) research and development program. This experimental program will be a one-of-a-kind project and should serve the entire MFE community in the United States. In addition to an outstanding academic atmosphere in Los Alamos, the Laboratory has an effective and major program in CTR research and development and in CTR radiation-damage studies. Such close association is imperative to an active and viable research and development program to be expected from the TSTF project.

Scientific Personnel

The success of any project of this scope depends in a large part on the expertise available for design studies in each of many scientific fields involved. Fortunately, LASL has scientific talent in all of those areas relevant to the needs of the facility's design.

From LASL's pursuit of ion-source research and development for use in its tandem Van de Graaff and cyclotron accelerators and the establishment of an intense proton-source injector system for the Clinton P. Anderson Meson Physics Facility, experience has been gained with vacuum pumping, permeation, materials, and sophisticated instrumentation and controls. Experience in tritium handling and research extends from the late 1940's.

Relationship to the Intense Neutron Source (INS) Facility

The INS Facility is being constructed as part of the radiation damage assessment program for the Division of Magnetic Fusion Energy of the Energy Research and Development Administration. This Facility will have the capacity to produce 10^{15} neutrons per second from each of two sources, whose neutrons will be generated by the deuterium-tritium reaction resulting from the collision of a 300-keV 1-A tritium ion beam with a supersonic jet target of deuterium gas. This facility is scheduled to be operational early in FY-1980.

The required confinement of approximately 30 grams of tritium in the INS Facility requires the development of tritium handling technologies: hydrogen isotope separation (see Sec. 5.2.1), tritium-contaminated vacuum pumping systems, tritium-bearing gas compression, tritium transfer systems, inventory control and accountability, safety monitoring, maintenance, tritium chemistry, containment, and cleanup. The environmental impacts for both normal operational releases and accidental releases of tritium have been addressed in an environmental impact statement,[1] soon to be released in final form; however, the equipment development needed to reach these goals must be accomplished within the next few years. Although these problems are specific to the operation of the INS they will relate directly to similar but more severe requirements demanded by future development of fusion reactor devices.

The proposed schedule for developing the Tritium Systems Test Facility will be of direct benefit to the INS and later, of course, to the entire fusion program. The detailed similarity of tritium handling problems between the two facilities is strikingly clear and establishes a compelling justification for locating the tritium facility at Los Alamos. Many of the early results of the tritium facility program would be applied directly to the operation of the INS, which would then act as a proving ground for practical tritium handling systems. The tritium facility, by close coordination with INS, would further develop these systems into the more complicated and sophisticated systems

needed to handle considerably larger tritium inventories and different flow rates under more severe environmental constraints.

Reference

1. Final Environmental Statement, Intense Neutron Source Facility, LASL, U. S. Energy Research and Development Administration report ERDA-1548, (1976).

II. NEED FOR TRITIUM FACILITY

2.1 Tritium Handling Requirements for EPR

The U. S. Energy Research and Development Administration, Division of Magnetic Fusion Energy, (ERDA/MFE) proposes to build and operate an Experimental Power Reactor by the late 1980's. This reactor, EPR-I, will be an experimental Tokamak with the following principal objectives:

1. Operation at a few tens of megawatts of thermonuclear power;
2. Demonstration of the basic components and systems of a fusion power reactor;
3. Scalability to a sustained reactor grade plasma;
4. Capability for producing significant electrical power.

In order to meet the proposed schedule for the development and operation of EPR-I several major technological areas need significant additional research and development programs to assure that these technologies are available when the plasma physics and confinement systems studies are sufficiently advanced to allow design of EPR-I to proceed. A major subsystem which needs to be developed and demonstrated within this time scale is the tritium processing system.

ERDA's weapons-related processing plants and laboratories, including the LASL, have had valuable experience in developing the technologies needed for handling significant quantities of tritium. Much of this experience, however, does not involve continuously operating systems or handling and recycling the large quantities of tritium involved in an EPR. Current design reports[1,2] indicate that the cumulative amount of tritium passing any point in the mainstream fuel cycle may reach 1000-2000 g per day. Public acceptance of the MFE program will require demonstration of a satisfactory handling and containment system for these quantities of tritium.

Of the 1000-2000 g per day flow of tritium through the reactor system, about 1% will actually be burned in a D-T reaction. The bulk of the tritium will be extracted from the reactor torus by means of a vacuum system, then purified, isotopically separated, and recycled or stored as necessary. In addition, an equal molar amount of deuterium will be continuously circulated through the same fuel cycle system. This means that the gas system will be handling some 1600-1300 g of a DT mixture each day. The gas extracted from the

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torus will contain significant quantities of impurities, such as hydrogen, oxygen, carbon, nitrogen, iron, vanadium and low molecular weight hydrocarbons and other compounds formed by reaction of the plasma with the walls of the reactor and the ^{1}H and ^{4}He reaction products (ash) formed in the plasma as well as unavoidable external leakage in volumes as large and complex as a Tokamak. These impurities must be removed from the gas prior to processing and reinjection of the fuel into the reactor.

The injector systems have not been clearly defined at this time, but high purity DT gas mixtures will have to be introduced into the torus before the initiation of the burn cycle. The plasma may be replenished by the addition of solid DT pellets during the burn cycle. Neutral beam injector systems will continuously add small quantities of pure D_2 gas during the burn cycle. The neutral beam is added to help achieve and maintain the necessary temperatures. The tritium facility must be versatile enough to provide a continuous, adequate supply of the appropriate gases to each of these feed systems. Figure 2.1-1 is a simplified flow diagram of the EPR plasma fuel and exhaust system.

Additionally, the tritium facility in an EPR must include adequate containment/cleanup systems to handle all routine and accidental releases so that personnel exposures and environmental releases are minimized.

TSTF as a Teaching Facility

In the future, there will be a great demand for staff and technicians who are experienced and knowledgeable in the problems of handling tritium, especially problems of a large flow facility with its many complexities. Future on-the-job training offers little opportunity for experimentation or for handling off-design or transient conditions.

The TSTF facility is well suited to provide training in tritium handling. The main flow loop, the developmental research stations, and the various recovery systems can be used in training programs for technicians and visiting scientists to develop broad practical experience with a large tritium system.

References

1. "Conceptual Design of a Tokamak Experimental Power Reactor," Argonne Nat'l Laboratory report, ANL CTR-75-2, June 1975.
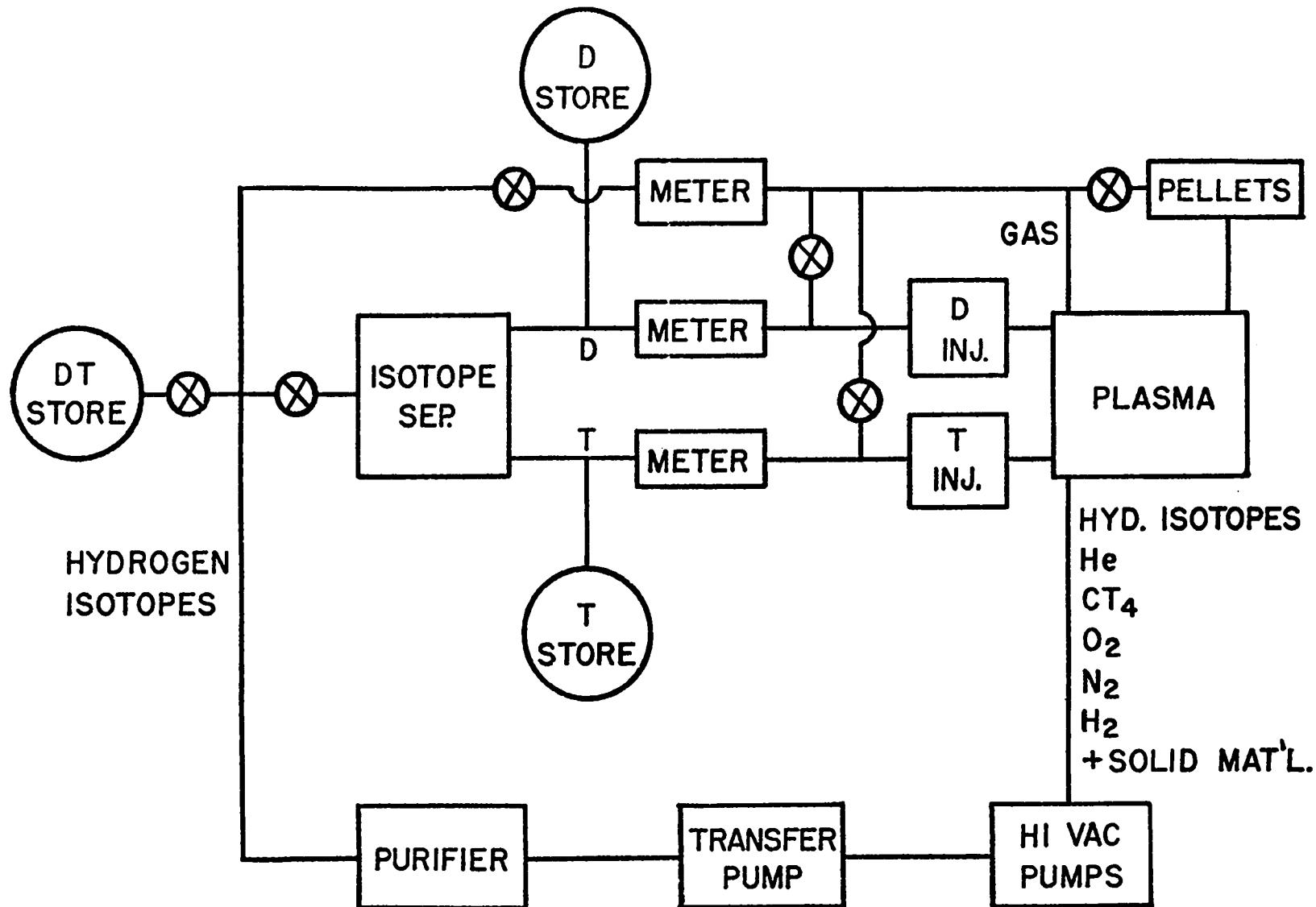
Fig. 2.1-1   Flow Diagram of EPR Fuel Cycle.

2.2 Technical Areas to be Addressed at the TSTF

Several subsystems in a tritium handling facility for EPR-I need considerable research, development and demonstration prior to the final design of EPR-I. The TSTF should be large and versatile enough to provide for the development and demonstration of all of these technologies as they are now perceived. Furthermore, the system will be versatile enough so that more experimental and development stations may be added as new ideas for tritium technology develop.

The major subsystems and technologies that need to be specifically addressed in the TSTF include the following:

1. The fueling and vacuum system must be studied. Gas and/or pellet injector systems as well as neutral beam vacuum systems and the associated instrumentation and controls have to be developed and shown to be reliable in a continuous operation mode;

2. Transfer and circulation pumps will have to be developed and shown to be capable of continuous operation at the required flow rates without adding additional contaminants to the gas stream;

3. Fuel-cleanup systems for removing ash and impurities from the gas stream before introduction of the gas to the isotope separation system will have to be developed and tested;

4. A continuously operating cryogenic distillation isotope separation system must be built and tested since this is an integral part of the fuel cycle;

5. There must be cleanup systems to remove tritium from gaseous effluents generated within the tritium facility. A large cleanup system to recover tritium from an accidental release into the bay must be designed, built and tested. Since such large systems have not yet been tested with tritium, much work needs to be done in this area. An integral part of this system will be a study of the

various levels of containment necessary for the fuel cycle components. This will include an assessment of various types of double- and triple- containment, such as gloveboxes, fume hoods, and double- jacketed piping. Part of this containment study will involve techniques for sealing off the TSTF bay and thereby isolating a tritium release until the cleanup system can reduce the concentration in the bay to acceptable levels.

6. Instrumentation and control systems, including gas analysis and radiation monitoring are necessary. Control of the flow through the fuel cycle and distillation columns will be a major area of development. In addition, instrumentation and controls to assure adequate safeguarding and accountability of the large tritium inventory will have to be developed. Radiation monitoring instrumentation to measure tritium in neutron-activated air and monitoring techniques to control start-up of the emergency tritium cleanup systems must be developed.

7. Techniques for the safe and secure storage of the large tritium and deuterium inventories will have to be demonstrated.

8. Techniques and equipment must be developed to insure personnel and environmental protection during operation and maintenance of the tritium system. A preventive maintenance program must be developed and emergency maintenance operating procedures and systems developed during the planning and construction of the TSTF. The general area of the plant safety, including a quality assessment program, for a facility handling these large quantities of hydrogen isotopes, must be addressed. The safe disposal of gaseous liquid and solid wastes is an area requiring additional research and development.

9. Facility operation and concurrent research will provide much of the necessary basis and information for the preparation of environmental statements of future fusion reactors.

10. The TSTF will provide an ideal facility for the extensive materials science research and development that must precede the design of EPR-I. The effects of tritium exposure and the resulting radiation damage coupled with continuous operation of the system will allow the testing of many materials and components, including valves, elastomers, and secondary containment systems. The facility will also be very useful in the development and testing of low-cost, easily fabricated metals and alloys having extremely low hydrogen-isotope permeabilities.

This is not an all inclusive listing of technical areas to be studied in the TSTF. It, however, covers the major systems and subsystems which must be developed and demonstrated within the EPR time scale.

III. TECHNICAL DESCRIPTION OF PROBLEM AREAS

3.1 Toroidal Vacuum System

Requirements

The toroidal vacuum system is the first subsystem in the process of re-
covering D and T from the EPR plasma. Descriptions of the toroidal vacuum
system are given in engineering studies.[1,2] In general, the toroidal vacuum
system must exhaust the products of a burn from an estimated volume of 711 m^3
over a period of 10 to 15 seconds. The fuel use rate is given as 540 moles
of DT per day, with 0.3 to 1 mol/cycle of DT (depending on cycle times which
vary from 50 to 200s) and possibly one percent each of He, O_2, CH_4 along with
traces of other gases and solids sputtered from the inner wall. This mixture
enters the pumping system near 550 K and must be pumped from 10^{-3} to 10^{-5} torr
during the exhaust period. The ultimate pressure the pumping system needs to
reach is 10^{-9} torr. Depending on what outgassing rates and pump line volumes
are assumed, the above requirements can be translated by standard vacuum
technology equations into system pump speeds of 0.5 to 1.5 x 10^6 ℓ/s. A
system pumping speed of 1 x 10^6 ℓ/s is used in estimating the needs of a test
facility.

Description

A pumping station is composed of a flapper valve at the inner wall, a
pump-out tube with a bend, a Y section, valves, heat exchangers, and pumps.
The flapper valve keeps the fuel from being drawn into the pumps during fueling
and provides some radiation shielding. The pump-out tube with the bend allows
the pumps to be placed outside of the blanket and main shielding. The bend in
the tube protects the pumps from direct radiation. The Y section and valves
allow two pumps to service each tube while the heat exchangers cool the exhaust
gas before entering the pumps. See, Figure 3.1-1.

The geometry of the EPR requires that 16 toroidal field magnets be placed
external to the shielding. Sixteen locations are available between these
magnets for the pumping stations. When pumping stations are located both near
the top and the bottom of the toroidal, 32 pumping stations may be applied. See
Figure 3.1-2.
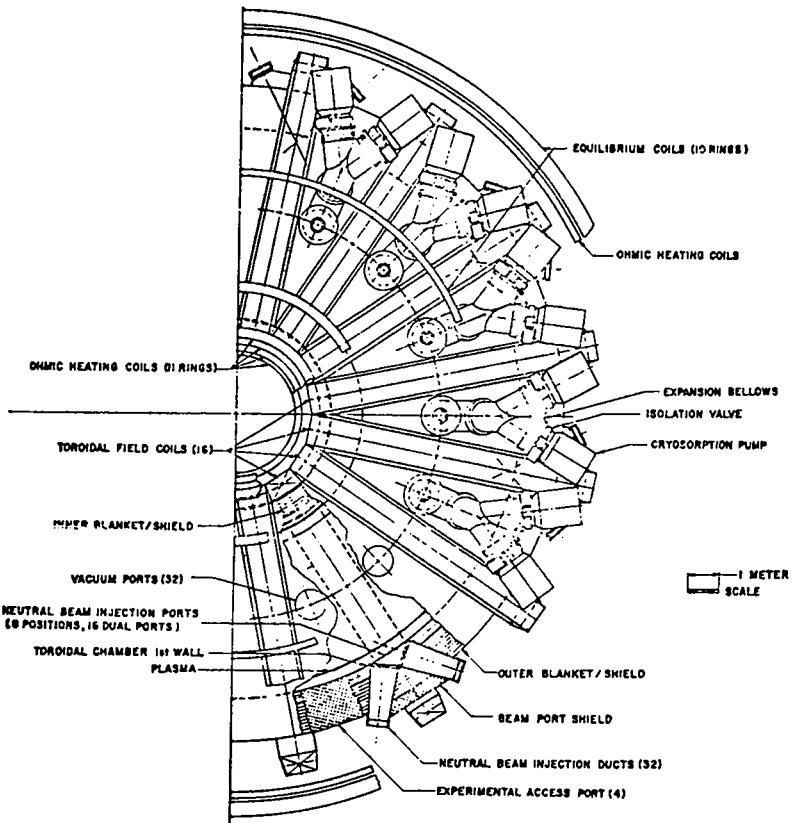
Fig. 3.1-1   EPR Horizontal Section View.
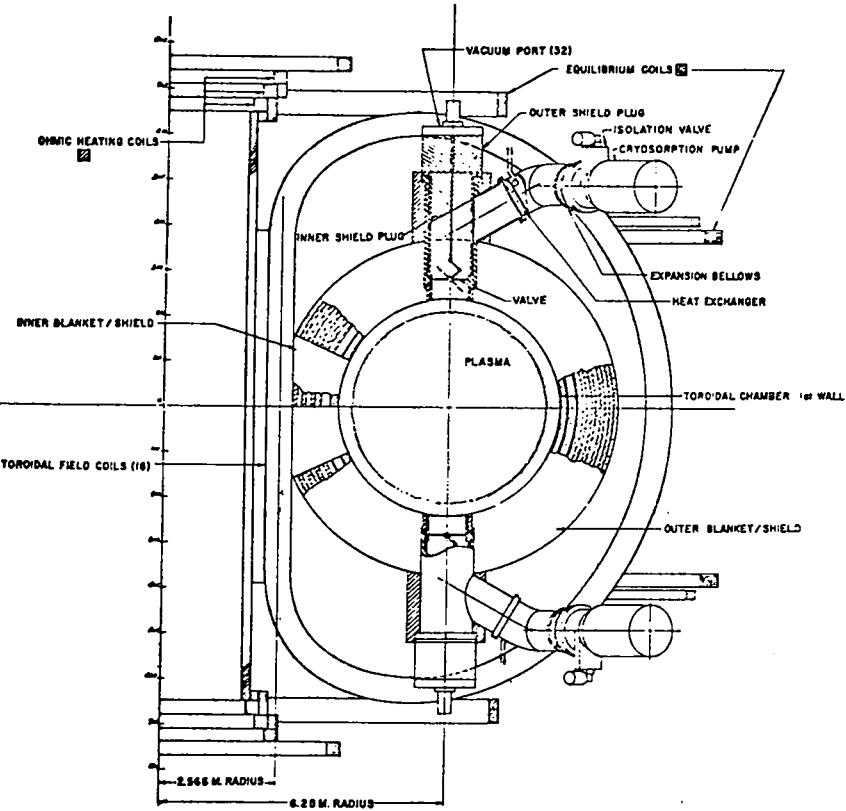
Fig. 3.1-2   EPR Vertical Section View.

Pumps

A full-scale pumping station would have a pumping speed of $1 \times 10^6/32 =$ 31,250 ℓ/s. There are no commercial pumps available with this speed; however, engineering studies indicate cryosorption pumps as their preference.[1,2] This is due to the ability to scale up this type of pump with reasonable confidence along with the ability to obtain a low ultimate pressure without the possibility of contamination of the system by the pump. Cryosorption pumps with speeds of 17,000 ℓ/s, have been built and tested on H_2 thus a full scale pumping station for the EPR requires a scale-up factor of about two.

Function of the Toroidal Vacuum System Test Facility

The engineering design study defines the need to test both large cryosorption pumps operating on DT and as a closed cycle for pumping, storing, and separating T_2 and D_2 from DT. It is the function of the toroidal vacuum system test facility to test the pumping station system defined above on such a scale that an EPR pumping system could be built with confidence.

Scaling

The use of 32 pumping stations reduces the effective pumping volume of each station to a volume of 22.2 m^3. If a spherical tank shape is used, the tank diameter is 3.5 m. This tank will hold 7×10^{-4} moles of DT when filled to a pressure of 10^{-3} torr. Thus, it is proposed to build a 1/32 scale EPR vacuum system which is a full scale EPR pumping station.

Facility Design Problems

The distillation column for separating D_2 and T_2 from DT does not scale as readily as the vacuum system. Reducing the column feed rate by a factor of 32 will result in an impractically small column. On the other hand, a single pumping station could not operate at a rate fast enough to provide an adequate DT feed for the column. Thus the deuterium-tritium handling system must be designed so the vacuum pumps and the column can operate separately.

Radiation from the EPR will subject the components of the pumping system to various neutron flux densities. Although the pumps under test are outside the radiation shield, and the pumping tubes include an angle, the pumps will be subject to some radiation that passes the shield and reflects through the

pump tube. It is not known what effect radiation has on the process of physical adsorption. The use of liquid nitrogen in a radiation environment sometimes results in explosions. This has been explained by the production of nitrogen oxides and ozone from the radiation of nitrogen and oxygen impurities; these in turn react with other impurities. A similar effect is possible in the adsorption beds if the exhaust gas has a high enough oxygen content and radiation intensity.

At this point there appears to be no definitive answer as to how much O_2, if any, there will be in the exhaust gas. In the event that concentrations of 0.01% or greater of O_2 occur in the exhaust, much greater local concentration can be expected within the adsorption beds in the pumps. These concentrations in the presence of hydrogen isotopes are a hazard if the system pressure is allowed to approach atmospheric. The catalytic removal of O_2 before the exhaust enters the pumps needs to be considered along with methods of keeping the pump pressure low while O_2 is present.

An attempt has been made to balance the mass feed rate into the EPR against the exhaust pump throughput from the data provided in engineering studies.[1,2] The 2700 g/day or 540 mol/day of DT and a cycle time of 74s results in a mass input of 0.46 mol/cycle. On the other hand, the moles exhausted from the torus in each cycle can be calculated from the ideal gas law. Using the data given as $P = 10^{-3}$ torr, $V = 711$ m^3, and $T = 550$ K, the results mean an exhaust rate of 0.02 mol/cycle. There is an order of magnitude discrepancy in the reactor mass balance, and it should be studied how this effects the tritium processing and containment.

In order to write a more specific proposal we need to know the following: 1. the radiation intensity at the pumps; 2. the exhaust gas composition; 3. the mass throughput. This proposal assumes that O_2 will be present in sufficient quantities to present a hazard and that the 10^6 ℓ/s system pumping speed and the 2700 g/day fuel rate are correct.

References

1. "Conceptual Design Report for a Tokamak EPR," Argonne National Laboratory report, ANL/CTR-75-2, June 1975.

2. Oak Ridge National Laboratory Reference Design, Contract W 7405-Eng-26.

3.2 Transfer Pumps

Secondary gas circulation (transfer) pumps will be employed to move gas through the test loop. These pumps must be capable of continuous pumping without introduction of contaminants and without loss of tritium. The TSTF will involve pressure ranges from 10^5 torr to ~ 1 atm. To cover this range, several pumping stages may be required. These pumps will have to be designed to use no moving shaft seals, use no organic fluids, and have no elastomer seals.

While cryopumps and cryosorption pumps appear to be good candidates for the main vacuum system, the intermediate pressure range, where the transfer pumps are needed, offers a less clear choice. Diaphragm and bellows pumps are possibilities, but generally have low throughputs, especially in the low pressure range. Vane pumps are currently used for transfer operations with tritium gas, but these pumps contain hydrocarbons and appear to be somewhat unreliable in intermittent service.[1] Wobble pumps have been developed for use in the nuclear industry and appear to be worth pursuing.[2] These pumps have relatively high speeds at low compression and are thus ideal for circulating pumps. By staging several of these in series some compression can be achieved. These need to be thoroughly tested, however, to determine their reliability and suitability for the EPR program. At present there is no well-tested, reliable pump for the 10^2-to 10-atm pressure range. A major effort at the TSTF will be the development and testing of such pumps.

References

1. L. J. Wittenberg et al., "Evaluation Study of the Tritium-Handling Requirements of a Tokamak Experimental Power Reactor," Mound Laboratory Report MLM-2259, Miamisburg, OH (Nov. 1975).

2. C. L. Folkers and V. P. Gede, "Transfer Operations with Tritium - A Review," Proc. of 23rd Conf. on Remote Systems Tech., San Francisco, CA, Nov. 1975, pp 55-63.

3.3 Fuel-Cleanup Systems

The exhaust from a fusion reactor chamber contains a wide variety of impurities. These arise through reaction, permeation, leakage, residual outgassing from walls, and erosion of walls. The impurities may include elemental forms and compounds containing nitrogen, oxygen, helium, hydrocarbons, iron, vanadium, tungsten, and others. These impurities are expected to occur in amounts of about a percent each for O, C and He. Total impurities will comprise 3-5% of the entire exhaust stream.

The impurities must be removed in the fuel recycling process for three reasons:

1. Effects detrimental to the burn cycle result if the impurities are present in the charge to the reaction chamber;

2. Deposition of solids and blockage of tubes and heat transfer surfaces can result if the the impurities are present in the feed to the cryogenic distillation section; and

3. Hazardous conditions may arise if impurities accumulate in uncontrolled places and amounts.

The level of cleanup required to avert these problems is a key consideration in the design of an EPR and therefore, of TSTF. Cleanup requirements in general for cryogenic processing are a much-studied subject.[1,2] Total impurity concentrations must be reduced to the range of 0.1-1 ppm to avert problems with long-term buildup in low temperature systems.

Helium represents a special impurity which, of course, will not cause plugging but can block heat transfer surfaces. The removal of helium prior to or in the distillation section is essential. The cleanup requirements imposed by the fusion reactor are less stringent than those imposed by the distillation columns.

Also a part of the TSTF fuel-cleanup system is an equilibrator for the hydrogen isotopic species. This will ensure the ratios of species will accurately simulate the species present in EPRs.

References

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2. Dodge, B. F., "Removal of Impurities from Gases to be Processed at Low Temperatures," Adv. Cry. Engr., Vol. 17, pp. 37-55, (1970).

3.4 Hydrogen Isotope Separation

The separation of hydrogen isotopes is an essential step in the fuel handling process of any magnetic fusion power reactor. In general, all six isotopic species (H_2, HD, HT, D_2, DT, and T_2) may be present in the exhaust from a fusion reactor. Out of this mixture, H_2 must be extracted and eliminated from the system; D_2 (and perhaps T_2) must be extracted to provide feed for the neutral beam injector, and D/T mole ratios must be brought appropriately close to 1:1 for recycling to the reaction chamber.

The problem of separating isotopes of hydrogen on a large scale has been studied several times previously by ERDA's predecessor, the AEC. In the late 1940's, the problem was the separation of D_2 from H_2 for making heavy water. From all succeeding studies[1,2,3,4] the conclusion is that continuous cryogenic fractional distillation is the best method of separation for hydrogen isotopes. Its advantages include low power consumption, high throughput, high-purity product streams, and operating flexibility.

References

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2. Murphy, G. M., ed., Production of Heavy Water, Chap. 4, McGraw-Hill, New York, NY, (1955).

3. London, H., Separation of Isotopes, Chap. 4, George Newnes Ltd., London (1961).

4. Damiani, M., R. Getraud, and A. Senn, "Tritium and Hydrogen Extraction Plants for Atomic Power Reactors," Sulzer Technical Review, Special Number 'Nuclex 72' (1972).

3.4.1 Duties of a Cryogenic Distillation System for TSTF

Three specific duties of the isotope separation system in TSTF can be defined. The first duty is to remove H_2 at the rate it is introduced as an impurity in the simulated fusion chamber exhaust. This rate is not well determined, but the quantity of H is known to be small (< 1%) relative to the

D and T portions. The H_2 product stream from the isotope separation system should be of high purity, with special importance on low tritium contamination so it can be dumped to the atmosphere with or without burning.

Secondly, the system must provide a small stream of high purity deuterium to simulate the required feed for a neutral beam injector. This stream would represent a few percent of the total deuterium in the Circulating Gas Loop (CGL). A high purity tritium stream may be needed also for the same purpose, as well as for adjusting the D/T mole ratio in the simulated fusion chamber feed.

Accumulated He must be removed from the CGL preceding the cryogenic distillation section. The best method of removing helium would be a subject of study in the TSTF.

3.4.2 Technical Studies

The isotopic equilibria

$$H_2 + D_2 = 2\ HD$$
$$H_2 + T_2 = 2\ HT$$
$$D_2 + T_2 = 2\ DT$$
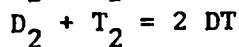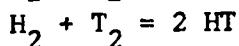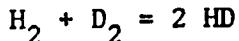
can be catalyzed at or above room temperature where the equilibrium constants all approach the limiting value of 4. The equilibrium constants are all temperature dependent and at temperatures near 20 K tend to favor the formation of the pure homonuclear species. If a suitable catalyst can be found to catalyze the reaction at low temperatures then the efficiency of the isotope separation system can be improved and the tritium content of the waste stream reduced.

Another aspect of developmental research is the selection of efficient column packing with special emphasis on low liquid holdup and hence reduced tritium inventory. Studies should also be directed at the most efficient method of removal of the radioactive decay heat of the tritium in the distillation columns. This heat load has a major effect on the design of the distillation columns and is discussed in section 4.3.3. These latter studies can be conducted with the test system available in Q-26 for development of the INS isotope separation system.

3.5 Instrumentation and Controls

Instrumentation and control systems overlay virtually every other area of study addressed by this proposal.

It is necessary to study tritium damage effects and determine long-term reliability of a wide variety of instrumentation such as temperature indicators, flowmeters, and pressure transducers.

The reconstitution of the fuel after isotope separation must be carried on in a completely automated mode which requires a flow control valve and automated, continuous gas analysis equipment. Similarly, regeneration of cryosorption pumps and cleanup beds should be automatic. Monitoring and control of the isotope separation system should be automatic and respond to transients but with a long time constant.

3.6 Containment and Cleanup of Routine and Accidental Tritium Releases

A major function of the TSTF will be the demonstration of environmental control systems for an Experimental Power Reactor. These systems will provide secondary and tertiary containment of tritium, together with adequate removal of tritium from contaminated gas before it is exhausted to the atmosphere.

Secondary containment will be provided by gloveboxes, and other enclosures that will be connected to a Tritium Waste Treatment system (TWT). The latter will treat relatively small volumes of air, with tritium contents of 1 Ci/m^3 or greater. The maximum processing rate will be 30 ℓ/s (60 CFM). The TWT system will be similar to several already in use in the United States, including one at LASL. The ability adequately to decontaminate small volumes of air containing a fraction of a megacurie of tritium will be another goal of TWT tests.

Tertiary containment will be effected by the TSTF building itself, with automatic isolation from the outside and with automatic actuation of a large Emergency Tritium Cleanup system (ETC) to process the building air. The ETC system would also serve as a backup to the TWT system under emergency conditions. Finally, it is intended that the ETC system be tested under conditions of simulated accidental release, using tritium-doped deuterium. The ETC system is matched to some degree with similar systems in nuclear reactor installations, but is different in detail and is largely untested.

Air flow in the system will be $\sim$ 500 ℓ/s (1000 CFM); it will provide a capability of a $\sim$ 3-h turnover time for the building atmosphere of the high bay area (Sec. 4.4).

The simplest method of cleaning such an enclosure is on a "oncethrough" basis with the exhaust of the ETC going directly to the building stack. In this case, however, the processing of 500 ℓ/s of air at $25^{\circ}C$ and 100% humidity would produce one ton of tritiated water per day with attendant water handling problems, frequent dryer regeneration, long dryer regeneration times, and a requirement for massive dryers. Accordingly, it is planned to recirculate the treated gas. A two-day cleanup time with a 500 ℓ/s dryer is the minimum time expected for a major tritium release in the TA-21 site.

In the event of an accidental tritium release, the building would be automatically isolated from the normal ventilation system, and the ETC system

would start processing the air. The air would be recycled until it met radiation protection standards. A small fraction of the ETC exhaust would be stacked on a once-through basis to provide a slight negative pressure in the building. Fail-safe operation of the detecting, alarming, recording, and actuating equipment during such emergencies as sabotage, accidental explosion, and power failure is clearly desirable.

Tritium removal in the TWT and ETC is based on the conversion of T_2 to T_2O in the air on a high surface area material impregnated with precious metal catalyst, dilution of the T_2O with H_2O as required, and removal of the tritiated water with one or more dryers, and H_2O addition between dryers. Most catalysts for the T_2-O_2 reaction are proprietary products formulated to give reproducibly high catalytic activity under selected conditions of temperature, pressure, and flow.

3.7 Environmental Surveillance

Well documented evidence of the environmental impact of the TSTF would provide a desired data base for future fusion test reactor reference. The Los Alamos Scientific Laboratory maintains a monitoring program as part of a continuing environmental investigation and documentation, including long-term programs on the effects of radiation and pollution on man and his environment. Environmental surveillance of Laboratory activities includes collection, analysis, and reporting results of a systematic sampling and measurement program for air, water, soil, and other environmental media.

Atmospheric radioactivity samples are collected at 26 continuously operating air sampling stations in Los Alamos County and vicinity. Station locations are shown in Fig. 3.7-1. During CY 1975, samples were collected over 2-wk periods for a total of 676 samples. "Hi-Vol" air pumps with flow rates of approximately 3 ℓ/s are used in the network. The atmospheric aerosol is collected on a 79-mm-diam polystyrene filter. A fraction of the total air flow (approximately 2 mℓ/s is passed in parallel through a cartridge containing silica gel adsorbent which collects atmospheric water vapor for tritium analysis. Air flow rates through both sampling cartridges are monitored with variable-area flow meters, and sampling times are recorded with electric clocks.

Silica gel cartridges from these 26 air sampling stations are analyzed biweekly for tritiated water. Water is distilled from each silica gel sample, giving a 2-wk average atmospheric water sample. A standard aliquot of the distillate is analyzed for tritium by liquid scintillation counting. The resultant tritium concentration is then multiplied by the measured absolute humidity to give the 2-wk average tritiated water vapor concentration in air. These results are reported annually by LASL.[1]

Ecological studies on tritium have been underway since 1972 in an effort to document ambient levels of HTO in the LASL environs and to provide data to assess biological pathways of this nuclide to humans. Studies with honeybee colonies (Hakonson and Bostick, 1976)[2] have shown that this insect rapidly reflects changes in the HTO content of surface water and vegetation indicating their potential worth as biological monitors for this nuclide. Colonies are presently located throughout the Laboratory area for potential use in tritium monitoring.

Since tritium is transferred to the honey within the hive, there is a potential for transfer to the general population. We are in a position to evaluate the importance of this pathway as a contribution to the human doses resulting from this facility.

References

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2. Hakonson, T. E. and K. V. Bostick, "The Availability of Environmental Radioactivity to Honeybee Colonies at Los Alamos," J. Environ. Qual. $\underline{3}$: (In Press), 1976.
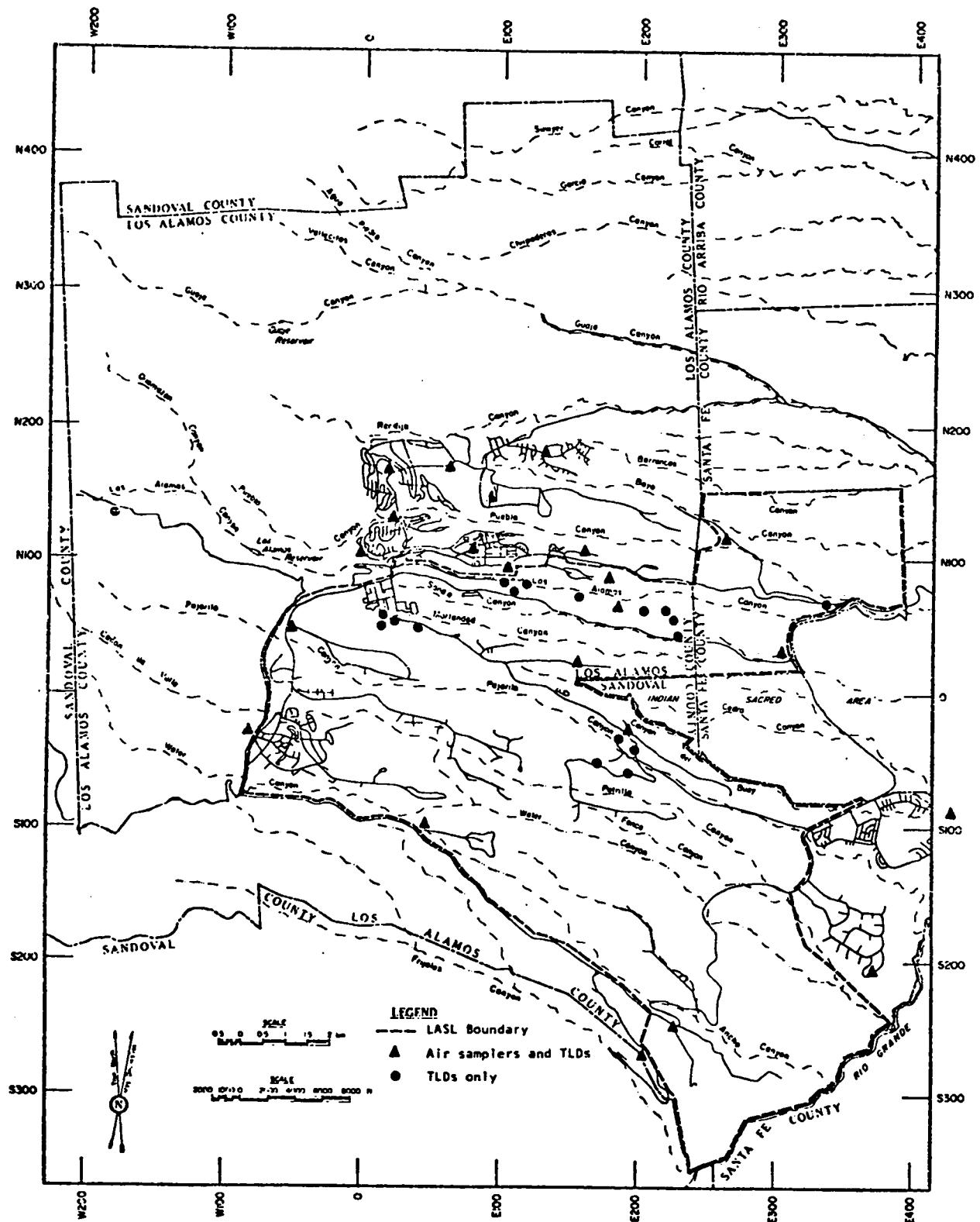
Fig. 3.7-1   TLD and Air Sampler Locations.

3.8 Maintenance, Safety, and Waste Management

Unique and difficult tritium control problems are anticipated at the TSTF since the proposed facility will test new systems and equipment items. Therefore, careful maintenance along with effective worker protection, waste management, and effluent control measures must be undertaken.

3.8.1 Maintenance

The entire TSTF will be designed with the goal of minimizing routine maintenance. For this reason organic materials will not be used in those sections of the system with which tritium might come in contact. The cryogenic pumping system will avoid the use of vacuum pump oils in the system and will provide a clean, fast, and efficient mode of evacuation.

Wherever possible the tritium lines will be of welded construction to eliminate as many joints as possible. Where it is necessary to have joints, the connectors or flanges used in the joints will have metal gaskets. Throughout the tritium system considerable redundancy will be incorporated into those major components that might present frequent maintenance problems. This procedure will be adopted so that a standby unit will always be available in event of a critical component failure. It also allows component maintenance to be performed and new components to be added without shutting down the system.

The components of the TSTF will be doubly contained wherever feasible. This double containment will include the use of many glove boxes surrounding the components and piping. These boxes will be designed so that during routine maintenance and component change-out, the air flowing through the hoods will go directly to the TWT cleanup system for removal of any released tritium before stacking. The air flow through the hoods will be from front to back pulling the air away from working personnel. The hoods will be relatively shallow so that a person working at the face of the hood can easily reach all components. Provision will be made at each hood for attachment of a flexible duct through which the air will be pulled to the cleanup system.

The tritium handling system will be designed so that all major components can be isolated by a set of valves. This procedure leads to the use of many valves but means greater personnel protection against tritium contamination

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while doing maintenance work. Each component in the tritium system will be joined to the remainder of the system by a double-valved, purge system as illustrated in Fig. 3.8-1. When a component has to be changed, valves V_1 and V_2 will be closed and valve V_3 opened to the auxiliary vacuum system. When the volume between V_1 and V_2 has been evacuated, this volume will be back-filled with clean argon. The same sequence of events will occur at all other joints leading into or out of the component. The joints can then be opened with a minimum hazard to personnel, and the maintenance and/or change-out can proceed. This procedure has the added advantage of keeping the remainder of the system isolated so that working vacuum or pressure can be maintained. After the maintenance is finished, the component can be easily rejoined to the system. The auxiliary vacuum system will then be used to evacuate the atmosphere from the volume defined by valves V_1 and V_2, after which valve V_3 will be closed, and valves V_1 and V_2 can be opened to bring the system back to operating condition. This purge system is being used in the LASL tritium facility with great success (reduced personnel exposure, tritium releases to the atmosphere, and maintenance times).
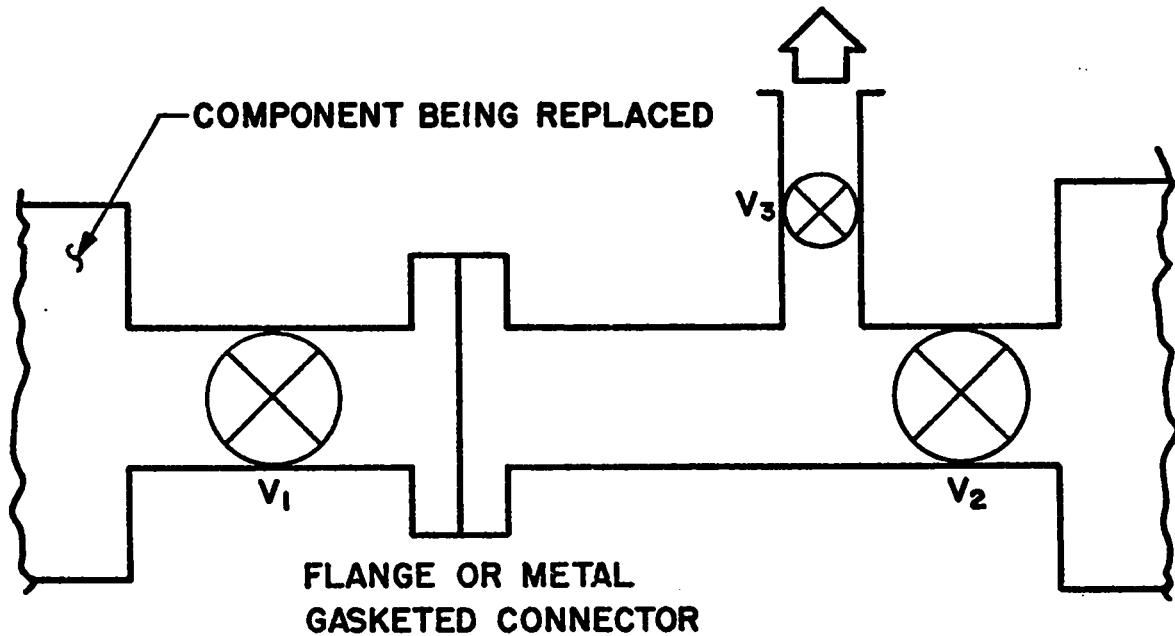
Fig. 3.8-1   Double-Valve and Purge System for TSTF.

3.8.2 Safety and Waste Management

Environmental health and safety research will improve worker and public protection and further the development of safety techniques and equipment associated with the TSTF and future EPR facilities. Necessary research in the areas of worker protection, decontamination and waste management should be conducted concurrently with operation of the proposed TSTF. These activities would be directed by appropriate Health Research Division personnel and might include the following:

Worker Protection Individuals involved in the operation and maintenance of tritium contaminated systems must be protected to avoid unnecessary tritium intake. Development of optimum protective clothing articles and temporary plastic enclosures for equipment is proposed along with development of techniques for fixing tritium contamination.

Decontamination. The proposed TSTF and future fusion reactors will generate contaminated equipment items that are excess to programmatic needs. Development of techniques for equipment decontamination is proposed. This is needed for the safe handling and disposal of highly contaminated equipment.

Waste Management. Operation of the proposed facility will generate both liquid and solid waste that is contaminated with tritium at levels that preclude uncontrolled release to the environment. Improved treatment and storage techniques will be developed to achieve optimum waste management capabilities for resulting waste.

3.9 Accountability and Storage of Large Tritium Inventories

Accounting for 200-250 g of tritium in an operating flow system is a major problem under the current requirements of 0.01 g as the reporting amount. This represents 1 part in 20,000 which surpasses currently available methods of assay.

Accurate P-V-T (pressure-volume-temperature) measurements and mass spectrometry can serve to determine the small amount of tritium in the transfer pumps and lines and the larger amounts transferred from gaseous storage to getter beds. The most significant problem areas are inventorying tritium in the cryo-pumps, cleanup system, and isotope separation system.

Almost 100 g of tritium will be contained mostly as liquid in the distillation columns. There are presently no measurements of liquid densities for D-T mixtures or of the P-V-T surface (equation-of-state) of pure T_2 or D-T mixtures. Research on these subjects is necessary for inventory control.

Tritium inventory methods based on the calorimetric procedures hold some promise.

For the present, accounting will derive from an initial P-V-T inventory of incoming T_2 and the use of integrating monitors to determine the sum of all losses.

The storage of large tritium inventories, either as gas or absorbed on a metal getter bed is a question to be addressed. This stored inventory must be safeguarded at all times, but must be stored in a manner so as to be readily available to the experimenter. Included in this general area of investigation will be techniques for the safe shipping and receiving of large quantities of tritium gas and tritium contaminated materials and components.

Part of the question of safe storage of tritium will be an investigation of the best design for metal getter beds. In many places in the TSTF gas loop these getter beds will be included as part of a surge volume to getter rapidly any tritium released in an accidental or emergency failure of other components. The getters should be capable of rapid and complete gettering of the gas under these conditions. The development of getter bed designs will be of prime importance.

3.10 Materials, Seals, Permeation Testing

The choice of construction material has long posed problems for tritium system designers. Not only does tritium cause hydrogen embrittlement in many materials, but there are in addition destructive effects from the radiation field and the ^{3}He formed by decay of tritium which has permeated the material. A portion of the TSTF loop will be designed to permit studies of permeation of tritium through various metals, alloys, and surface coatings and treatments.

Demountable joints must be sealed, often with polymeric elastomers, and these joints present a high failure potential. There is currently little information on the use and life of these materials. Studies of these materials are essential to the development of long-term reliability in a tritium flow system.

Rotary seals present an even greater problem and they, too, need exhaustive study.

3.11 Interface with Blanket Recovery Systems

Tritium recovered from a breeding blanket will most likely contain impurities which are not significantly different from those encountered in the exhaust fuel stream. Therefore a most logical interface would be directly to the fuel cleanup system. Between the cleanup system and the isotope separation system, the recovered tritium will be stripped of any foreign gases and ^{3}He buildup.

IV. PROPOSED FACILITY

4.1 General Description

The TSTF must have sufficient versatility for development and demonstration of all of the subsystems for the EPR tritium fuel cycle. An important factor in this proposal is that there already exists at LASL expertise in all of the necessary areas. It is felt that no additional research and development expenditures are necessary for LASL to accomplish initial design operation of a TSTF. The TSTF will be considered a national facility and the design team will solicit and expect input from other US groups involved in the MFE program. However, it will not be necessary to go outside LASL to secure the basic expertise necessary to design, construct, and begin operation of the facility.

The TSTF will consist of a large gas loop, Fig. 4.1-1, which can simulate the closed fuel cycle in an EPR. The loop, as shown, does not include any specific gas injection system, but will be sufficiently versatile so that systems can be added as the requirements for an EPR are better defined.

The gas loop will be housed in a large, high-bay room described in Section 4.4. The room will be equipped with an emergency tritium cleanup system (ETC) that will remove tritium from the room air in the event of a large accidental release. This ETC will be in the same room as the gas loop and will be an integral part of the facility. A smaller tritium waste treatment (TWT) system will be available to remove tritium from routine gaseous effluents prior to their release to the atmosphere. All components in the gas loop will be doubly contained where feasible. This double containment will be gloveboxes or fume hoods. The exhaust from these containment systems will be processed through the TWT prior to atmospheric release. These double containment systems will be designed so that specific areas in the gas loop can be isolated during periods of maintenance or equipment changeout. This will serve to keep the amount of effluent gas processed by the TWT to a minimum. A larger glovebox system will be available for off-line maintenance and assembly of components. The box line will be in the main cell area. Again, the exhaust from this volume will be processed by the TWT or ETC systems prior to its release to the atmosphere.

Site preparation for the TSTF will involve some modification to the existing structure, primarily, a new ventilation system, capable of providing
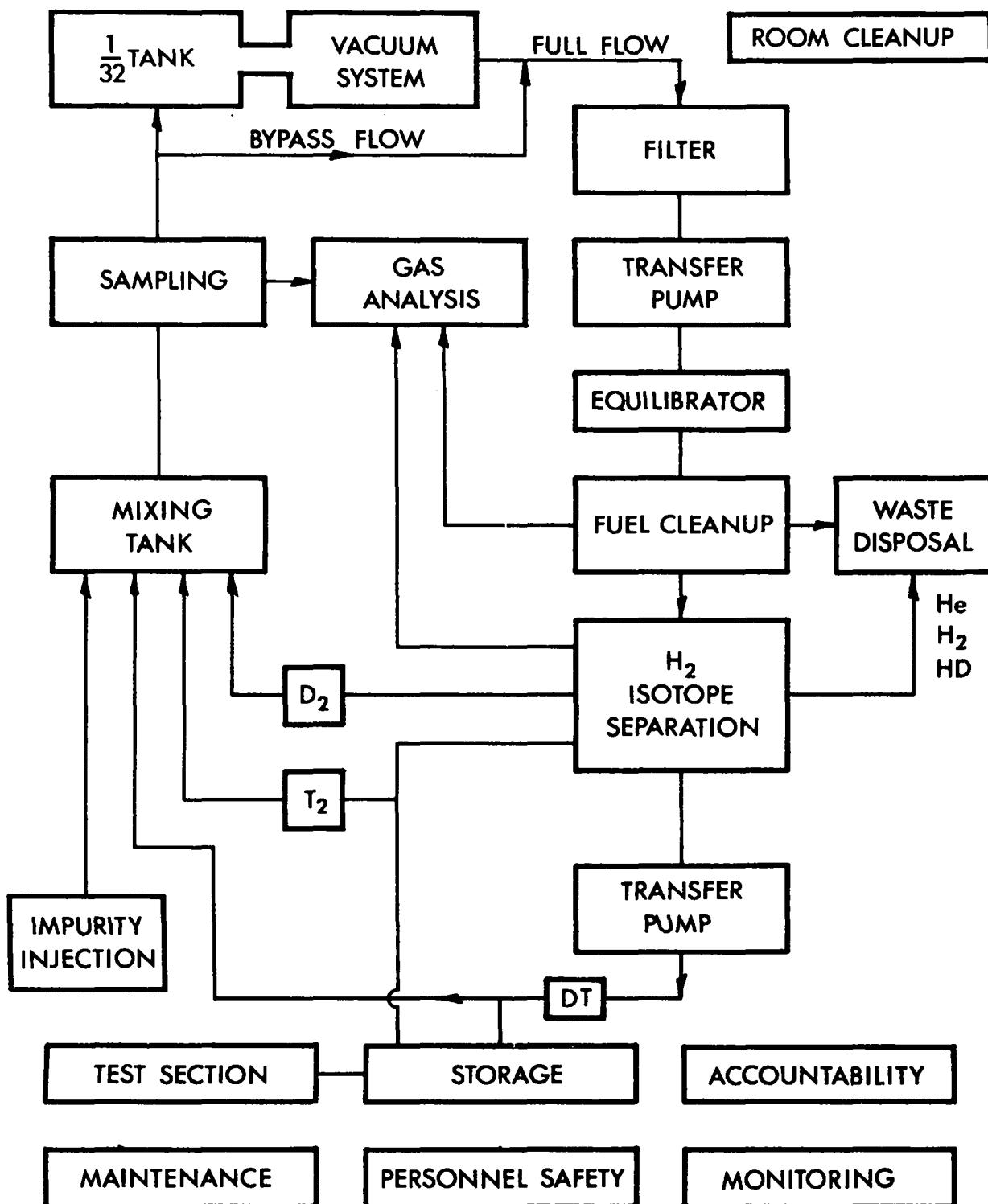
Fig. 4.1-1   Flow Diagram for TSTF Circulating Gas Loop (CGL).

seven changes per hour of filtered air to the TSTF. The system will exhaust through a 30-m stack to be installed. The ETC will be interfaced with the ventilation system; so that in the event of a tritium release to the cell, dampers will automatically close in the exhaust ducts, and the closed-cycle ETC system will be actuated. The ventilation must be balanced so there is a flow of air from the "cold" to the "hot" areas of the facility. Doors into the facility will be airlock type doors sealed so as to prevent air leakage. Thus a tritium spill in the hot areas can be contained there with minimal contamination of the office and equipment room areas. The initial design study will include an evaluation of possible coatings for floors, walls and ceiling surfaces to insure low permeabilities of tritium through these surfaces and to provide surfaces that can be easily decontaminated.

A large set of doors (10 ft. x 10 ft.) will provide truck access to the main cell area so large, heavy components can be easily taken into and removed from the facility. The two-ton overhead crane is on tracks that allow coverage of the entire main cell area. This can be extremely important when removing large tritium contaminated components. With both existing crane and the large doors, considerable flexibility is available in developing systems and techniques for disposal of large, contaminated materials and components.

Several major safety and safety-related systems will be required at the TSTF. These auxiliary systems are necessary to insure proper personnel protection, effluent treatment and control and waste management. A breathing air supply and distribution system will be required to supply high quality air for routine and emergency use with air supplied suits. The system will include a supply compressor, surge tank, airline distribution manifold with connection points in locations near expected use sites, and appropriate air quality instrumentation.

A liquid waste collection and handling system will be included. Contaminated liquid wastes will be collected in a tank in or near the main experimental area for controlled disposal.

A solid waste collection and treatment system will be included. A room with a large fume hood or glovebox will be available for packaging solid wastes prior to transport to the existing LASL disposal area. This disposal includes the solid forms generated in the liquid waste systems.

An extensive air monitoring system will be provided with zone monitoring of the components of the gas loop, the TWT, and ETC systems. An exhaust air monitoring system will be included. These systems will be continuously operated and have alarming and recording capabilities.

A change room for the issue and collection of protective anticontaminant clothing will be provided adjacent to the TSTF cell. This facility will be in the adjacent rest room and shower facilities. As part of the facility design, an automated urine analysis sampling system will be considered. This could provide continuous data on tritium levels in the workers' urine. A continuing and ongoing bioassay program at LASL will provide guidance as to the advisability and practicality of such a system. If such an automated system is not included, an acceptable bioassay program will be adopted at the TSTF.

4.2 Description of Gas Loop

In scoping and sizing a TSTF for this proposal, the ANL Conceptual Design Report for a Tokamak EPR[1] was the primary reference. This design calls for a modular construction with 16 modules in the machine. Each module will be equipped with two pumping stations each of which will probably have two pumps, one will be in operation while the second is being regenerated. The modular design of the system is easily scaled to duplicate one of the 32 pumping ducts for full scale pumping, therefore the vacuum system will be completely scaled to 1/32 size. The effective pumping volume and the gas load will be scaled proportionately. For this scaled system the pumping volume will be reduced to $\sim 25,000$ ℓ which can be pumped from 10^{-3} torr to 10^{-5} torr in 15s with a pumping speed of $\sim 34,000$ ℓ/s. For this system we propose to use existing liquid-helium cooled cryosorption pumps, with some modifications, available from a commercial source. To achieve the necessary pumping speeds several existing pumps will have to be plumbed in parallel. The system will be designed so that as new and larger pumps become commercially available these new pumps can be placed in the TSTF gas loop for evaluation. This will entail much cooperation as information gained at the TSTF is channeled to industry to influence and guide their pump design and manufacture. A very important study will be to determine the amount of radiation degradation of zeolites in cryosorption pumps used for tritium pumping. It has been estimated that as much as two percent oxygen could be released per day from the degradation

of zeolites in this proposed pump. This has extremely serious implications in terms of pump lifetime and safety consideration. It will be absolutely necessary to avoid having an explosive mixture of oxygen and tritium. This study itself could indeed be as important as any to be undertaken at the TSTF.

A pump or series of pumps will be the next major item in the gas loop, Fig. 4.1-1. These will be used for regeneration of the cryosorption pumps and as gas circulation pumps to move the exhaust gas through the loop. Provisions will be made so that several ports are available so that a number of pumps can be on line ready for use. This will allow testing of several pump designs in the course of an experimental period. A fuel cleanup system is required to remove all impurities except ^{1}H and possibly He from the gas stream prior to the inlet to the cryogenic distillation columns. Total impurity content must be reduced to the range of 0.1 - 1 ppm to avert problems with long-term buildup in the cryogenic still. One essential responsibility of the TSTF will be to determine the desirability of removing the helium prior to the distillation columns. The system must therefore have the versatility of testing various techniques for removing helium prior to and in the distillation columns.

The distillation columns do not scale to one thirty-second size as easily as the vacuum system. Reducing the column feed rate by a factor of 32 will result in an impractically small column. Likewise, a single pumping station does not operate at a rate fast enough to provide adequate DT fuel for the column. Thus the TSTF gas loop must be designed so that the vacuum pumps and the columns can operate separately. Consequently, the gas loop in the test facility will contain a bypass line so that a closed loop, bypassing the vacuum tank and cryosorption pumps, can be continuously operated. With a total tritium inventory of 200 g at the TSTF this portion of the gas loop will be a full flow system, i.e. capable of continuous operation at a flow rate of 540 moles DT (STP) per day. The three-column distillation system will handle the full flow and the remaining components in the system will be compatible with this flow rate. The three-column distillation system can remove ^{1}H from the gas and provide a $\sim$ 99% pure DT stream, a $\sim$ 96% pure D_2 stream, and a $\sim$ 99% pure T_2 stream. Helium removal can also be accomplished in the distillation system.

Additional circulating pumps are then required to transfer the gas streams from the distillation columns to the appropriate banks in the gas

loop. A mixing tank, where appropriate amounts of impurities can be added to simulate the EPR exhaust gas composition, will be necessary. A high resolution mass spectrometer system will be interfaced throughout the gas loop so that gas compositions can be adequately monitored. Gas flow into and out of the mixing tank will be continuously monitored and adjusted by the addition of D_2 and T_2 to provide the desired gas composition. This system will permit the development of gas injection systems, including the evaluation of various gas and/or mass flow meters to regulate and measure gas quantities.

The flow through the entire loop will be computer controlled to demonstrate that continuous automatic operation is possible. The control system will include a large number of pressure, flow, and thermal monitors with appropriate readout and alarm systems. The control system will be properly programmed so that proper routine and emergency shutdown of the gas loop can be demonstrated and evaluated. An auxiliary power supply system will be installed to permit the operation of critical components and control equipment in the event of a power failure. This will allow safe and orderly standby and shutdown procedures to be followed.

Reference

1. "Conceptual Design Report for a Tokamak EPR," Argonne Nat'l. Laboratory report, ANL/CTR-75-2, June 1975.

4.3   Components

4.3.1 Pump Facility

Figure 4.3.1-1 shows a schematic diagram of the vacuum pump facility.
Central to the facility is a vacuum tank of $\sim$22 m^3 filled with a mixture of DT
and other gases to a pressure of 10^{-3} torr to simulate the gas load on an EPR
pumping station. A mass of 0.0037 g of DT will fill the tank at this
pressure. Heaters need to be attached to the surface or installed in the tank
to raise the gas mixture to 550 K. The tank will be thermally insulated. A
double-walled gas feed line and valve allow the mixture to enter the tank.
Helium purge, gas sampling, vacuum, and instrumentation lines also enter the
tank.
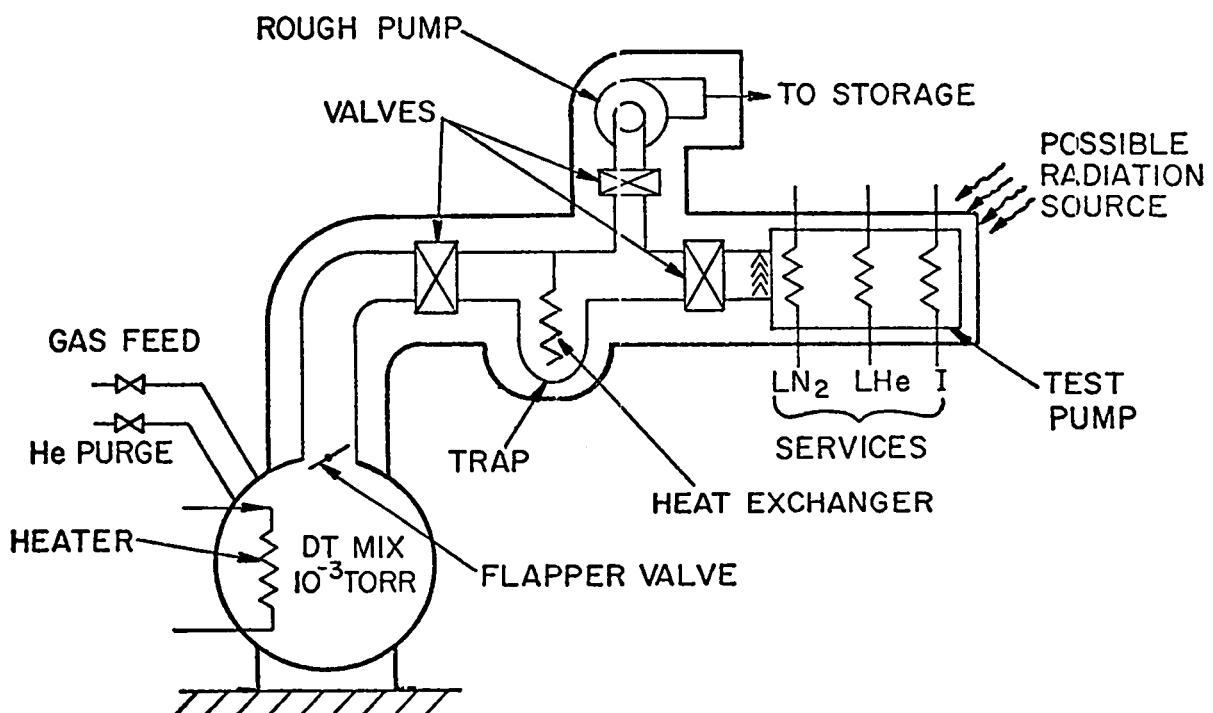
Fig. 4.3.1-1   Schematic Diagram of TSTF Vacuum Pump Facility.

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The main pumping line, with an inside diameter of 75 cm, exits from the top (or bottom of the tank), rises 2 m to simulate passing through the blanket and shielding of the EPR, and makes a 90° bend. A flapper valve is located at the exits of the tank and a gate valve is located at top after the bend. A straight section passes through a particulate matter trap and heat exchanger to help remove solids sputtered from the inner wall of the EPR and to reduce the exhaust gas temperature. A nickel catalyst is attached to the surface of the heat exchanger to remove O_2. Next, a T-section with valves on all sides allows the connection to a rough pump and to the cryosorption or another type of pump under test.

Consideration should be given to the addition of a radiation source at the pumps under test so that the effect of radiation on physical adsorption may be evaluated.

An integral part of the vacuum facility is the regeneration system for cryosorption pumps. The system described is similar to one which will be used for the INS.

As one pump becomes loaded with DT, it is valved out of the system after valving in the recently rejuvenated pump. The adsorbent surface of the loaded pump is warmed to around 50 K to release the DT which is pumped by an Edwards 2M4B mercury vapor pump backed by a Pressure Products 1165 V2 diaphragm pump. The 2M4B can operate with a starting pressure of 35 torr and a maximum back pressure of 40 torr and has an unbaffled pumping speed of 70 ℓ/s. The 1165 V2 diaphragm pump is oil free and has an ultimate pressure of 40 torr and can pressurize up to 50 psi.

It may be necessary to interpose a small doubly-contained bellows pump between the 2M4B and the 1165 V2 pumps. All of these proposed pumps have seen extensive service in tritium applications. Redundant traps are used on each side of the mercury vapor pump to insure that no mercury gets into the system. A closed cycle refrigerated trap would stop the mercury vapor if an automatically filled liquid N_2 trap should run dry. This double-trapping of the mercury is considered necessary to provide fail-safe operation. Suitable valving around the liquid N_2 trap will allow pump-out of water vapor or other condensates when the trap is warmed. Warm-up and pump-out of the DT should take a fraction of an hour per regeneration cycle.

4.3.2 Transfer Pump

Several modified commercial pump designs have been demonstrated to be
suitable for transferring tritium gas. The transfer pump section of the TSTF,
Fig. 4.3.2-1, will contain a manifold comprising three to six parallel
transfer pumps of different designs, both to establish reliability,
serviceability, and endurance in continuous operation with tritium. Ease of
maintenance and secondary containment problems peculiar to each design can
also be evaluated.

No hydrocarbons will be used; instead there will be only mercury or
flexible metal-membrane pumps. The first transfer pumps to be tested will be
a commercial welded-diaphragm pump and a commercial metal-bellows pump which
have been modified at LASL for use with tritium. The only organic material
wetted by the tritium is a small amount of polyimide plastic used for check
valve seals and seats. This material has very good radiation resistance. All
fluorocarbons will be scrupulously avoided.

The parallel pump concept will permit repair or replacement of one pump
while another is running under evaluation. Appropriate flowmeters and
differential pressure gauges will monitor efficiency of the pump being tested.
The parallel arrangement will also permit testing of special pumps of new or
unusual design (such as the nutating bellows or "wobble-movement" pumps). The
failure of an untested pump after a few hours will not close down the facility
because one of the parallel standby pumps can be valved—in within a few
minutes.

Each pump with its associated valves will be installed in a separate
secondary containment box that can be isolated for maintenance. Double valves
on suction and discharge sides will provide for evacuation of lines before
disconnecting the pump for any necessary maintenance. The premaintenance
evacuation pump will be of the sorption or nonevaporable-getter type to
provide a delay in introducing the evacuated gas back into the process line.
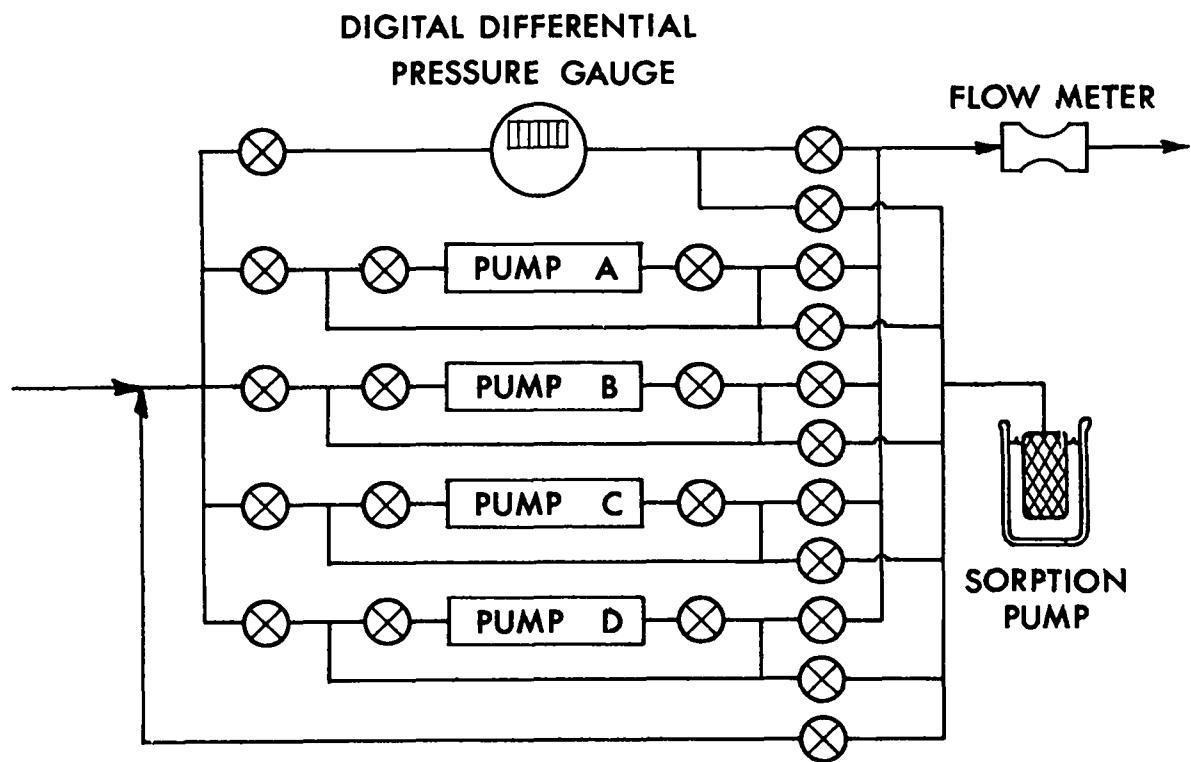
Fig. 4.3.2-1 Transfer Pump System.

4.3.3 Fuel Cleanup Systems

There are two important objectives in developing chemical impurity and helium separation systems for TSTF. First, the solidification of gaseous impurities in the fuel stream should be controlled while cooling it down to the temperature of the cryogenic distillation columns so as to eliminate plant blockages from the growth of solid deposits and particles transported by gas streams. Secondly, it is important that all the gaseous impurities and the helium be discharged to the environment with an acceptably low content of tritium.

4.3.3.1 Chemical Impurity Removal

Cryogenic cleanup systems fit in well with the proposed distillation system for the separation of the H isotope. Solutions of the first objective have been attained with past British research in hydrogen distillation for deuterium production. A British experimental plant was satisfactorily operated down to 20 K with key impurities such as H_2O, CO_2, CH_4, CO and N_2 up to 1% levels, using the freezing principle in both reversing and dual switched heat exchangers.[1] The special problem, peculiar to hydrogen, of the supersaturation of impurities and the consequent formation of gas borne crystals of impurities was investigated and solved theoretically and experimentally. Because the impurities are re-evaporated into the outgoing hydrogen stream, this system does not solve the further problem of releases to the environment. However, this latter problem has been dealt with in the helium cleanup plant[2] developed for the Dragon high temperature helium cooled nuclear reactor. (The Dragon reactor and the supporting R&D program was a joint European project and was built in Britain.) The system chosen used freezing, rather than adsorption, to avoid co-adsorption of the radioactive gases, and thus comply with the objectives of acceptable releases. Also, equipment was developed to permit very long periods (months) between regeneration and discharge of the impurities to the environment. Experience gained from the pilot plant suggests one approach to the cleanup for the TSTF. Special TSTF cleanup requirements necessitate additional study. These studies are expected to identify the need for additional low temperature phase

equilibria and adsorption isotherm data for specific impurities. The selection of heat exchange and adsorption equipment to provide the required safe containment of tritium under all operating conditions needs to be carefully considered.

After prior chemical removal of bulk oxygen, the behavior of oxygen in amounts of a few ppm (by volume) in the H isotope separation system is a vital safety topic. This has already received attention for deuterium production by distillation, but it should be re-evaluated for TSTF.

4.3.3.2 Helium Removal

Separation of helium with a sufficiently low tritium content is a problem because helium is the product of the D-T fusion reaction and is produced at a larger rate than the H isotope is in the much less probable D-D fusion reaction. Thus concentrations of 1-2% of helium will need to be removed from the main fuel stream in TSTF to simulate corresponding fuel burn-ups. Several options for separating and purifying the helium need to be studied; the following comments refer mainly to cryogenic options:

(a) Thermodynamically, efficient helium/tritium separation could be achieved at liquid helium temperatures in the primary cryopump with the hydrogens condensing on a helium-cooled panel and practically pure helium passing to a helium cooled adsorber. The adsorber would be regenerated on a relatively long time cycle. The special mass transfer and "cryo-trapping" limitations on the helium/hydrogen separation efficiency that could be achieved at these low pressures need to be investigated experimentally.

(b) Diffusion through a palladium-silver alloy at about 400°C and pressures approaching 1,000 psia, could conveniently remove the helium before distillation, but would not by itself provide a sufficiently pure helium stream without using a number of stages and incorporating a high vacuum on the low pressure side of the alloy "membrane."[3]

(c) Limited amounts of helium can and must be removed from the condenser at the top of the column. The condenser can be designed to do this and the vented helium can be passed to a final cryogenic purification stage for tritium removal before disposal. The TSTF application can be quantitatively evaluated from the following three points of view. First,

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the vapor flow rate in the primary column (which is set mainly by the required recovery of the H isotope from the feed) must be sufficiently large that the resulting partial pressure of helium in the column is low enough not to reduce significantly the isotope separation performance. Secondly, for 1-2% helium concentrations and the liquid and vapor flow rates in the primary column expected under TSTF conditions, the primary condenser will need to be cooled to near the freezing point of the "hydrogen" mixture. Thirdly, the vented helium and tritium-rich "hydrogen" mixture must then be passed through a special cryogenic separator. It needs to be developed to handle solid or adsorbed "hydrogen" and recycle this "hydrogen" mixture back to the top of the column as liquid reflux. Provision for a small amount of helium venting is necessary anyway; the simplest solution will be to remove the bulk of the helium prior to distillation.

(d) A normal pressure helium/hydrogen cryogenic separator is currently being evaluated at AERE, Harwell for the U.K. fusion laboratory at Culham.[4] The object is to provide practically complete separation of the helium from an otherwise pure 50/50 D-T vapor feed to the primary distillation column and to discard the helium practically free of tritium without employing subatmospheric pressures. An integrated system incorporates liquefaction, freezing and/or adsorption down to near 5 K and the removal of dissolved helium from the liquefied D-T, with "cold recovery" by feed compression to no more than about 50 psia, if required.

Cryogenic freezing and/or adsorption is a very attractive technique to develop both for the final removal and recovery of tritium from the helium before it is discharged. Because the vapor pressures of HT, DT and T_2 at their triple points exceed 100 torr, systems should be developed for hold-up and recovery of appreciable amounts of solid or adsorbed tritium, with refrigeration to handle the variable heat load due to the associated β particle heating. For a 1 GW D+T reactor, about one gram of tritium would be held up for every hour which elapses between regenerations.

References

1. "Purification of Hydrogen for Distillation," W. H. Denton, B. Shaw, and D. E. Ward, Trans. Inst. Chem. Engrs., 1958, 36, 179 and W. H. Denton, B. Shaw, R. Gayler, and P. Saeger, Trans. Inst. Chem. Engrs., 1959, 37, 277.

2. "Designing for Low Temperatures, Radioactivity, and Extreme Gas Purity in a Helium Coolant Purification Plant for a Nuclear Reactor," W. H. Denton, S. B. Hosegood, and F. C. Wood, A. I. Ch. E-I. Chem. E. Joint Meeting on "Chemical Engineering Under Extreme Conditions," London, 1965.

3. "A Model for Predicting the Permeation of Hydrogen-Deuterium Inert Gas Mixtures Through Palladium Tubes," Ind. Eng. Chem. Fundam., Vol. 11, No. 3, 1972, F. J. Akerman and G. J. Koskinas, Lawrence Livermore Lab., University of California. 4.

4. Private communication with Denton, AERE, Harwell.

4.3.4 Isotope Separation System

The isotope separation will be effected by a system of cascaded cryogenic distillation columns. In order to keep the H_2 level small, it was decided to process the entire fuel stream. Also, if only a small fraction of the full flow were processed, column diameters would be impractically small. The separation can be easily accomplished by 3 interlinked columns as shown in Figure 4.3.4-1. Various column design parameters are also given. These have been calculated using the sophisticated computer codes adapted by LASL for the INS distillation system. Experimentally determined equilibrium data were used in the design, and this significantly affects the physical parameters for the columns (i.e., height, diameter, power).[1] Figure 4.3.4-2 shows a typical computer plot of the composition of each isotopic species throughout the first distillation column. All other pertinent parameters are calculated including optimum feed location, number of stages, vapor and liquid flows, heater and condenser loads, column height, diameter, and tritium inventory. By means of these computer codes, distillation can be designed to accomplish almost any desired separation of isotopes. However, after a given set of design parameters has been used to construct a real system, a more limited degree of flexibility exists.

Column 1 is designed to strip the feed stream almost entirely of DT and T_2 yielding a distillate which consists of 92% D_2 and all of the H bearing molecules (H_2, HD, HT). This distillate stream is then passed over a catalyst bed to bring about equilibration of intermolecular species. By having an enriched D_2 system depleted in DT, the equilibrium

$$HT + D_2 \rightleftharpoons HD + DT$$
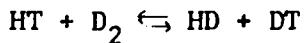
is forced to the right. Computer codes at LASL permit evaluation of the complete H-D-T system equilibrium without simplifying assumptions.

Column 2 is designed to effect a high degree of separation of H_2 and HD from the feed stream. The HT is reduced to 10^{-6} mole, which is equivalent to 100 Ci/y. The reboiler product is 96% D_2 and 4% DT.

Column 3 is designed to produce a high degree of separation of DT from T_2. In an operating Tokamak system such a high degree of separation would not be necessary, but in a demonstration system where the fuel must be reconstituted it is desirable. The extra refrigerant load required is negligible, well within the capacity of the refrigerator required for the entire system. An

additional advantage of the high separation is that very pure T_2 will be available for the developmental portions of the TSTF project.

The columns will be filled with packing materials which have proven to work well in hydrogen service and have relatively low holdup. All important streams will be monitored by scanning quadrupole mass spectrometers whose output can be used for automatic control.

An advantage of the configuration of columns described here is the great flexibility. For example, if at some future date it is found desirable to provide large flows of D_2 and T_2 streams then it is only necessary to redirect the distillate stream of Column 3 through an equilibration bed and back to the feed stream of Column 1.

The refrigeration requirements indicated in Fig. 4.3.4-1 are a few hundred watts at 20 K. Cryogenic refrigerators with this capacity are commercially available and cost about $140,000.

It will be important to remove most of the helium isotopes before the distillation systems. The flows in the first column are large enough to be not materially affected by a small helium impurity. However, with H_2 + HD impurities at a 0.1 to 1% level, the composition at the top of the second column can become mostly helium which will drastically reduce the efficiency of the column. One possible solution is to flood the feed to Column 2 with H_2, thus increasing the flows in the upper part of the column.

An important aspect of the computer code is that it permits the design of a distillation column with a composition dependent heat load on each stage. The heat produced by the radioactive decay of tritium significantly affects the design of columns which are rich in tritium.

Some suggestions have been made that it may be necessary to cool the reboiler to permit the accumulation of liquid at the bottom of the still. This can be shown to be an inadequate solution to the problem. Column 1, for example, can be made to operate by increasing the reflux ratio from 32 to 97, while at the same time increasing the tritium inventory from 44 to 105 grams and the condenser heat load from 65 to 194 watts. Figures 4.3.4-3 and 4.3.4-4 show the calculated vapor and liquid flows and the heat load for such a column. It can be seen that the lower portion of the column almost runs dry due to the tritium heat. The effects of this type of heat load on the third column are even more drastic.

Input (top left, 27% stream):
- .0005
- .039
- .035
- .921
- .005
- 7.0×10^{-9}

Equilibrator

#2
13.2' x 0.39"
6 W*
0.08 gm
L/D = 47.8

HD (1.9%)
- .024
- .976
- 1.8×10^{-6}
- 3.0×10^{-9}
- $<10^{-10}$
- $<10^{-10}$

(27%)

Intermediate stream:
- .0017
- .0704
- ----
- .0013
- .889
- .037
- .0004

Feed to **#1**:
- H_2 .00014
- HD .010
- HT .0093
- D_2 .248
- ----
- DT .484
- T_2 .248

#1
16.3' x 1.22"
65 W*
44 gm
L/D = 31.6

D_2 (24.7%)
- $<10^{-10}$
- .0008
- .0014
- .957
- .040
- .0004

(73%)

#3
12.7' x 1.05"
50 W*
56 gm
L/D = 11.8

DT (48.6%)
- $<10^{-10}$
- $<10^{-10}$
- 3.0×10^{-8}
- .0050
- .990
- .0051

Bottom intermediate stream (into #3):
- $<10^{-10}$
- $<10^{-10}$
- 2.0×10^{-8}
- .0034
- .659
- ----
- .338

T_2 (24.8%)
- $<10^{-10}$
- $<10^{-10}$
- $<10^{-10}$
- 6.0×10^{-8}
- .0097
- .990

*Exclusive of Tritium self-heating.

Fig. 4.3.4-1   Cryogenic Distillation System.

A more adequate solution is to provide for programmed cooling along the length of the columns to extract the heat as it is produced. This will require only a small additional refrigeration load and significantly reduce the tritium inventory.

Reference

1. Sherman, R. H., J. R. Bartlit, and R. A. Briesmeister, "Relative Volatilities for the Isotopic System Deuterium-Deuterium Tritide-Tritium," Cryogenics, accepted for publication.

TSTF — 1

MOLE FRACTION

LEGEND
□ = H2
○ = HD
△ = HT
+ = D2
× = DT
◇ = T2
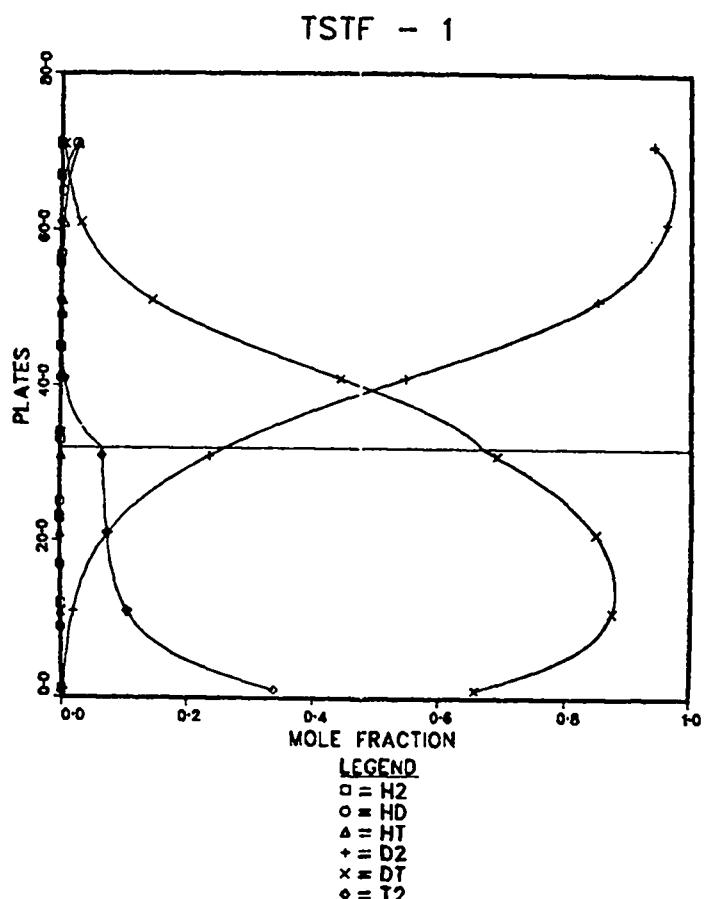
Fig. 4.3.4-2

Composition of Hydrogen Isotopic Species in First Distillation Column.

TSTF — 1Q
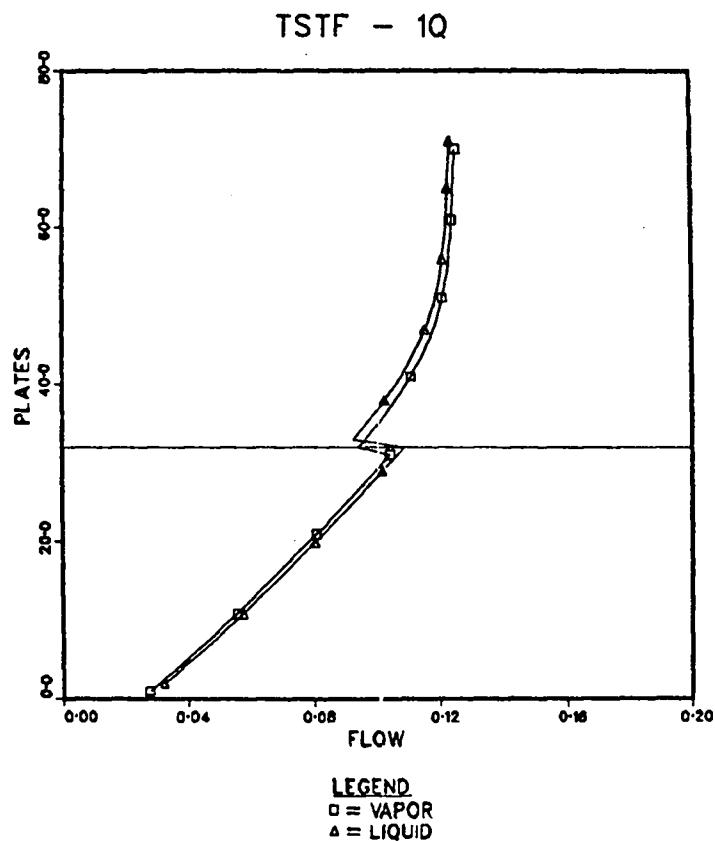
Fig. 4.3.4-3   Liquid and Vapor Flows in Distillation Column.

TSTF — 1Q
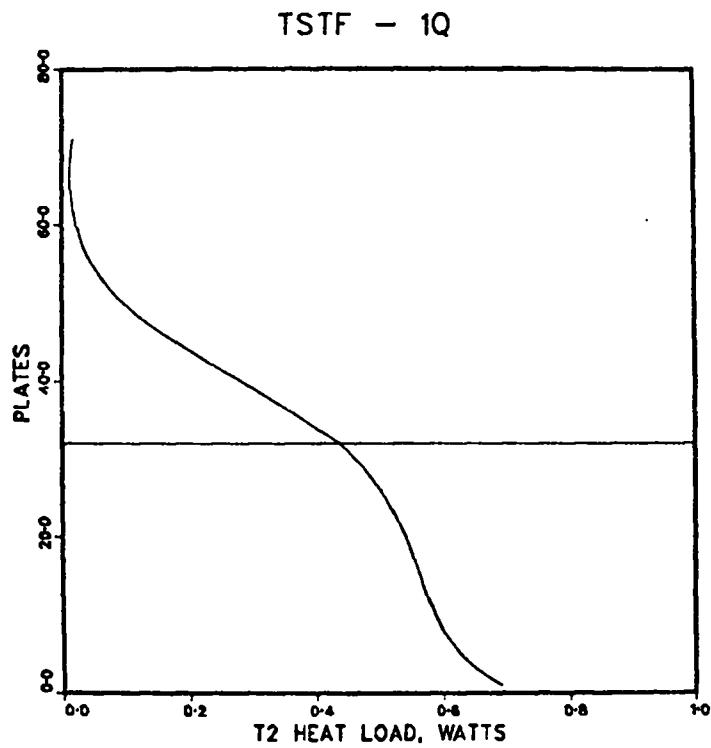
Fig. 4.3.4-4   Heat Production from Tritium Decay Along Distillation Column.

4.3.5 Tritium Waste Treatment and Emergency Tritium Cleanup Systems

The development and refinement of equipment and procedures for the TWT and ETC will constitute a major element in the research, development, and testing endeavor at the TSTF. Further, a large fraction of the area of the facility will be devoted to these systems, particularly to the ETC system. Finally, the capital cost and construction of these systems dictate a careful selection of equipment for the initial installation.

Because the selection of components for these systems is most important, it will be instructive to consider an example of such a system. This will not only illustrate such features as redundancy of equipment for safety and testing but also emphasize some of the problems associated with tritium handling.

An example of a design for the TWT and ETC is given by K. I. Thomassen et al.[1] The TWT is similar to several already in use in facilities in the USA, including one at LASL. The ETC system is matched to some degree in similar facilities at nuclear reactor installations but is different in detail and largely untested. A brief description of these systems follows.

The TWT system is an automatically actuated tritium removal system based on a previous metal catalytic recombiner which converts all hydrogen isotopes in air to water, and organic materials to water and carbon dioxide. The water is then adsorbed on molecular sieve drying towers. Gas from vacuum systems, analytical systems, gloveboxes (which may have separate processing systems), hoods during tritium spills or maintenance, and purge systems will be processed in the TWT system. Gas from those various sources will first flow into a large storage and ballast tank. The oxygen, hydrogen isotope, and water concentrations in the tank air will be continuously monitored and maintained at a level sufficient to provide enough oxygen to convert catalytically all of the hydrogen isotopes to water; the oxygen and hydrogen are controlled to levels below the explosive limits; and the water is kept to 2.5% relative humidity, minimum, to effect dilution of the $(D,T)_2O$ without unnecessary loading of the dryer with water. When the pressure in the tank reaches a present upper limit the valves will open and the circulation blower on the system will come on and pull gas out of the tank through the TWT. The gas flow through the TWT will continue until the pressure in the ballast tank falls to the lower pressure limit at which time the automatic valve on the tank closes and the 60 ℓ/s blower is turned off.

Built-in redundancy of equipment and lines will characterize the cleanup systems. In the case of the TWT dryers, duplication is necessary to permit regeneration of a saturated dryer while the TWT continues to operate with a second processing line. The adsorbent is regenerated by heating it to 450 K and flowing a dry purge gas over the sieve bed. The evolved water is condensed and collected for eventual disposal or tritium recovery.

The ETC system is similar to the TWT system. A schematic drawing of it is shown in Fig. 4.3.5-1. The ETC system will differ somewhat in operation because of the size and weight of the equipment and since its eventual function is to serve in case of emergency. Redundancy of equipment will be required for testing and development. Equipment sizes will be large, with the dryer beds having diameters and lengths on the order of 1.2 m (four feet) or more to accommodate at least 910 kg (one ton) of dryer. The latter will have a water capacity of about 113 kg (250 lb.). (This is the amount of water in 100% R H , 25°C air in the TA-21 facility.) Two of the dryers might be throw-away dryers since they will see little or no use. In this case, no provision for regeneration would be made. Other features of the system are that no ballast tank will be required, and a modest oversizing of one recombiner to allow low-temperature, stand-by operation will be considered.

Finally, plenum-type ventilation inlet and exhaust systems might be considered to allow rapid "once-through" or single-pass operation of the ETC. Assuming a ceiling inlet, the fresh air would require heating to minimize convection.

Evaluation of technical problems associated with the cleanup systems will be part of the TSTF program. Such studies are directly related to the selection of components. Some of these problems are the following:

1. Tritiated water exchange. In the dryers, exchange of tritiated water off an adsorbent bed with water vapor left in the air could limit operational conditions. For example, saturation of a dryer with uncontaminated water followed by regeneration might be required for a highly contaminated dryer.

2. Tritium exchange. Exchange of hydrogen with adsorbed or dissolved tritium on or in a recombiner catalyst might require addition of hydrogen for tritium cleanup of the catalyst.
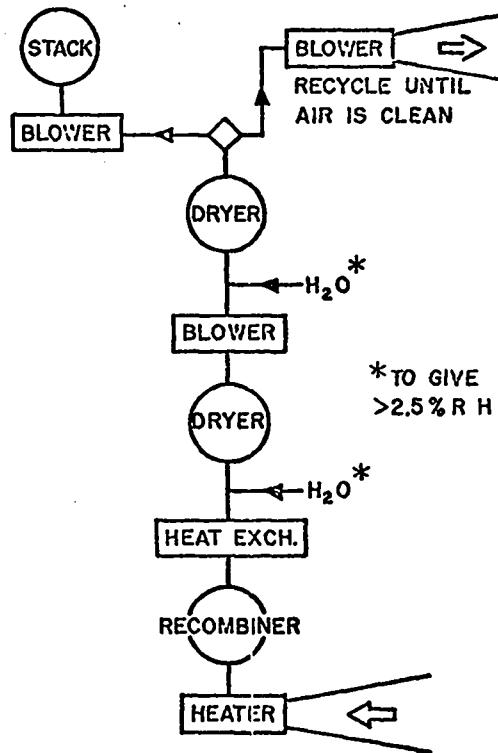
Fig. 4.3.5-1   Emergency Tritium Cleanup (ETC) System.

3. Heating methods. Methods of heating dryers (for regeneration) and recombiners, such as electrical vs hot gas, will be studied.

4. Room temperature operation of recombiners. Because ETC recombiners will be used in the EPR for emergencies only, room temperature operation would be desirable. The possibility of such use will be examined.

5. Throw-away dryers. The possible use of throw-away dryers needs evaluation.

6. Tritiated water disposal. Related to the dryers is the collection and disposal of large quantities of tritium-contaminated water.

7. Tritium recovery from tritiated water. Such recovery might be economical, particularly for TWT water.

8. Dryer regeneration frequency. Minimization of tritiated water inventory is of importance.

9. Helium collection. Cryosorption pumps might be used for transferring waste to the TWT system. Collection of helium for

helium-3 recovery might be desirable because of the ease of separation.

10. Hydrogen explosions. Procedures will be developed for avoiding H_2-O_2 explosive mixtures in the TWT.

11. Tritiated hydrocarbons. If graphite or silicon carbide first-wall coatings are used in the Tokamak reactor, the handling of tritiated hydrocarbons might be particularly important. A study of the formation of such compounds by the action of atomic hydrogen on graphite would be desirable. The need for a study of the processing of appreciable quantities of tritiated hydrocarbons in the TWT also follows.

12. Tritium monitoring. A study of tritium monitoring of air containing other radiogases would be desirable, particularly at tritium concentrations that are low with respect to those of the contaminants.

13. Tritium accountability procedures.

14. Life tests of gaskets, valves, and welds in tritium environments.

15. Dusting and decomposition of zeolite in cryosorption pumps in tritium environments. Serious degradation in the presence of tritium betas might be expected for zeolite-type materials.

16. Leak-tight or enclosed compressors.

17. Water-injection techniques and gas mixing.

18. Contaminated equipment repair and replacement.

Reference

1. K. I. Thomassen, compiler, "Conceptual Design Study of a Scyllac Fusion Test Reactor," Los Alamos Scientific Laboratory report LA-6024 (January 1976).

4.3.6 Building Ventilation System

The TA-21-155 building structure will provide the final barrier for containment of the TSTF tritium inventory. By the use of secondary containment systems around the primary tritium handling equipment, the concentration of tritium within the building atmosphere will be maintained at levels low enough to allow the ventilation air to be exhausted directly to the stack. To assure detection and containment of possible tritium leaks to the building atmosphere, the building will be divided into ventilation zones based on the probability of tritium contamination. The areas of the TSTF from which tritium operations will be excluded (offices, equipment room, and cold labs) will be classed as Zone I. Areas in which the tritium experiments are taking place (hot labs and the experimental area) will be classed as Zone II and will interface with Zone I via air locks. The ventilation system will be designed such that the Zone I areas will be held at a pressure slightly exceeding the environment and the Zone II areas at a pressure slightly negative to the environment. This mode will minimize both infiltration of dust into the building and possible diffusion of tritium from the Zone II areas.

As shown in the schematic air flow diagram for the building, Figure 4.3.6-1, inlet air to the Zone II areas will be the Zone I exhaust air with makeup air from the outside. Both Zone I and Zone II will be provided with seven air changes per hour. Since tritium will be the only contaminant of concern, the only exhaust air treatment will be to pass it through heat transfer equipment to preheat the inlet air. All Zone II inlet air will pass through filters designed to remove particles as small as 2 µ in diameter in order to provide a clean Zone II environment for makeup of leaktight connections between the tritium handling components.

Instrumentation

Operation of the ventilation system will be monitored with the aid of the usual instrumentation: pressure and differential pressure transducers, temperature sensors, flow switches, and valve position indicators. Conventional control systems will regulate temperatures and maintain the pressure differentials.

Air in the Zone I areas will be monitored for tritium concentration as needed with portable or semiportable table air monitors. The Zone II areas

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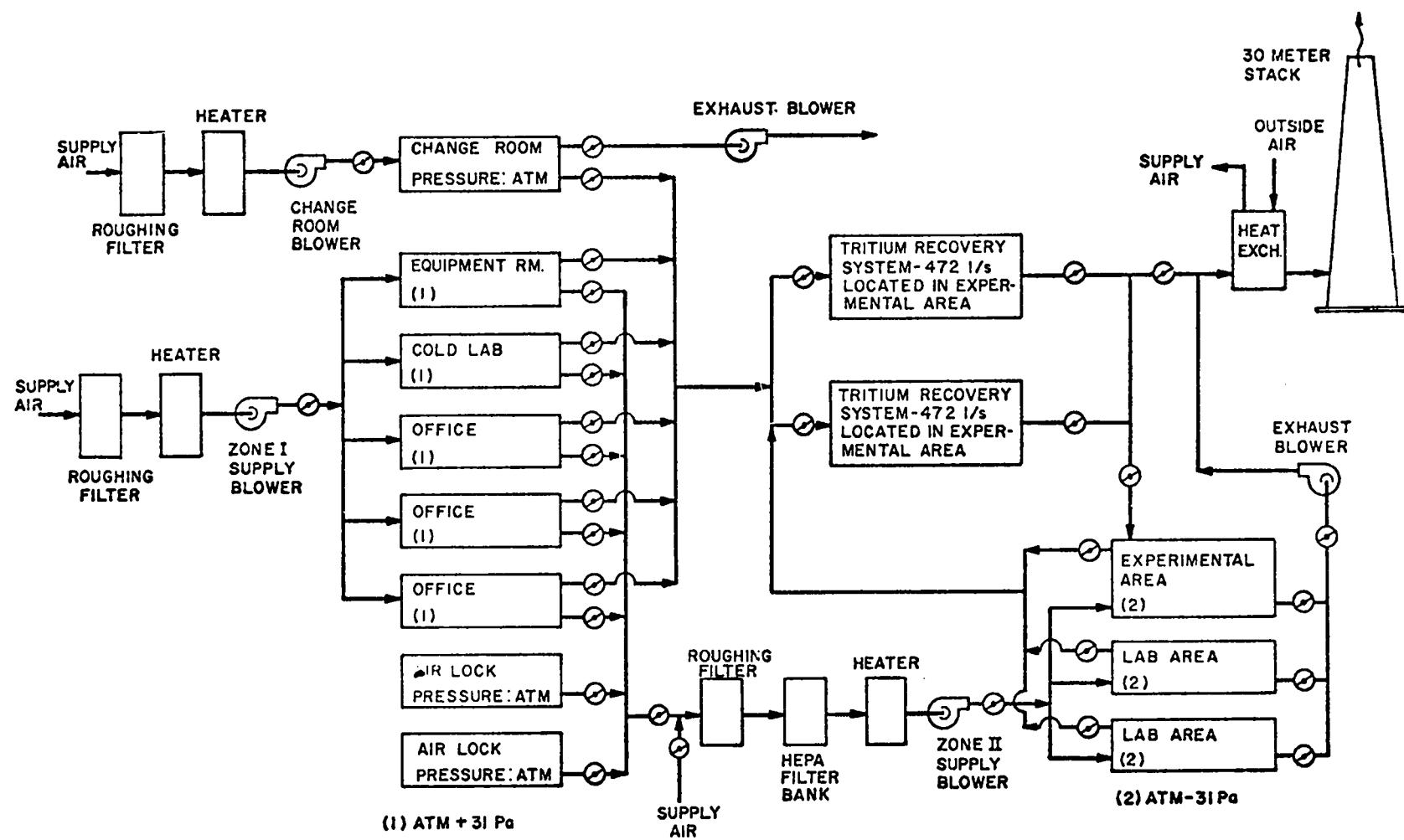
Fig. 4.3.6-1   Schematic Air Flow Diagram for TSTF.

will be continuously monitored by ionization-chamber-type integrating air monitors strategically located to rapidly detect a tritium release. In addition, the Zone II exhaust air will be continuously monitored by other integrating monitors to assure that the concentration in the stack is kept below the maximum permissible concentration of tritium in air. The monitors will have a detection range of 1 to 20,000 $\mu Ci/m^3$. Each monitor will have a local digital readout and a two-level alarm system which flashes a yellow light when the lower set point is exceeded and flashes a red light and sounds an audible alarm when the upper set point is exceeded.

Interface to Emergency Tritium Cleanup System

The Emergency Tritium Cleanup System (ETC) will be an automatically actuated room air detritiation system based on a precious metal catalytic recombiner and molecular sieve drying towers. The characteristics and components of the ETC are described in section 4.3.5. A contaminated gas header will connect the ETC to each potential contamination source. Individual areas will be tied into the system by activation of a contaminated gas header valving on a signal from the tritium monitors. Valves will also be provided in the contaminated gas header to permit isolation of compartmented areas of the building including Zone I areas. These valves will be activated from a central control station. Multiple rooms may be tied into the ETC, although the ability to maintain negative pressure and confinement will be compromised dependent on room volumes and leak tightness.

Clean gas from the ETC will be discharged to the experimental area to minimize the amount of fresh air (and thus clean water vapor) which must be processed. A portion of the clean gas will be discharged to the stack to maintain a slight negative pressure in the contaminated area.

The accidental release that would be most difficult to handle would be a massive rupture of a primary tritium handling component which resulted in tritium release to the experimental area. In this event the following actions would occur: (1) audio and visual alarms would be activated by the tritium monitors; (2) power to the Zone II supply and exhaust blowers would be stopped; (3) the pneumatically controlled shut-off dampers in the supply and exhaust ducts would be closed; (4) the isolation valves for the experimental area in the contaminated gas header would be opened; and, (5) the ETC would come on line and start processing the room air at a rate of 472 ℓ/s.

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The ETC would continue to process the room air until the room air tritium concentrations returned to a safe operating level. The released tritium would be contained on the molecular sieve beds in the oxide form.

Technical Studies

A major tritium release in the experimental area would require that the room air be processed through the ETC for up to 48 hours if ambient air currents kept the room well mixed. If "plug flow" of the air could be maintained, this processing time could be cut considerably and the quantities of tritiated water to be disposed of would also be reduced. Experiments aimed at studying this aspect of room detritiation could be carried out under controlled conditions in isolated enclosures connected to the ETC. Other studies related to the TSTF cleanup systems are delineated in section 4.3.5.

4.3.7 Getter Beds

Reactive metal beds will be used extensively in the TSTF. They will be used for the surge volumes shown in the main gas loop, Fig. 4.1-1. They will also store large tritium inventories and will be used in the transport and disposal of tritium.

Each of these proposed uses has rather specific requirements in terms of the amount and purity of the tritium involved, operating pressure and temperature ranges, continuous or intermittent operation, interfacing with other gas loop components and expected lifetimes. Because of these specific requirements, various getter materials will be considered for each situation. Three main areas to be considered in choosing metal getter beds are the following: (1) Thermodynamic properties from pressure-composition-temperature studies. (2) Kinetics of hydriding-dehydriding and effects of particle size, tritium pressure, surface properties and temperature on the process. (3) Stability of the resulting tritides including radiation damage effects, effects of contamination or equilibrium and kinetic properties, the long-term stability of materials for disposal and the effects of many hydride-dehydriding cycles on the material.

Materials proposed for studies as getter and storage beds include uranium, titanium, palladium, vanadium, aluminum-zirconium alloys and lanthanum-nickel intermetallic compounds. Multiple applications for a single metal tritide would be extremely desirable. If the same metal bed could serve as a surge tank, storage, shipping, and purification bed, then the use of this material would be quite attractive.

A study of possible materials for getter beds and the design of these beds, including secondary containment, will be a major effort at the TSTF. At this time it is proposed to use a uranium bed as the surge tank, for storage of tritium inventories, and as a possible means of separating oxygen and nitrogen contaminants from the tritium gas. A LASL design of such a uranium bed is given in Carstens' paper.[1] Additional LASL expertise in this area is cited in references 2 and 3.

References

1.   D. H. W. Carstens, "A Gas Handling System for Tritium-Contaminated Materials," Proc. 23rd Conf. on Remote Syst. Tech., San Francisco, CA (Nov. 1975) pp 6976.

2. J. L. Anderson et al., "Hydrogen Absorption by AB_5 Compounds," Los Alamos Scientific Laboratory report LA-5320-MS (July 1973).

3. T. P. Seitz, R. Woods, M. Wallis and R. L. Henkel, "The Safe Handling of Large Quantities of Tritium Gas at the Los Alamos Tandem Accelerator Facility," Nucl. Inst. Methods, 93, 125-129 (1971).

4.3.8 Materials of Construction

All structural materials used in the TSTF must be relatively impermeable to hydrogen isotopes, must be absolutely free from hydrogen embrittlement and must be relatively stable to radiation damage from the tritium beta particle. The materials used in construction of the tritium handling components of the TSTF will include only those components known to be reliable in tritium service. Copper tubing and type 316 stainless steel will be the primary materials used in the system. Type 316 stainless is a very stable austenitic steel, weldable, resistant to hydrogen embrittlement, and not subject to gross martensitic transformation when thermally cycled or plastically strained at cryogenic temperatures. Type 304L stainless steel is rejected because it frequently contains such small quantities of austenitic stabilizing elements (Ni, Mn, N and C) that exposing it to cryogenic temperatures is very dangerous.

Copper is acceptable for use in low pressure systems, particularly if thermal cycling over large temperature ranges is not anticipated. There is virtually no solubility of tritium in copper so that permeation of tritium through copper is not a problem.

Gas lines in the TSTF will be joined by soldering or welding where practical. Because of the experimental nature of the facility, many joints will have to be frequently opened for maintenance and component change-out. These joints will be made using a compression seal against a metal gasket. A Cajon-VCR fitting or similar type fitting, will be used where possible. Special flanges, with metal gaskets, will have to be specially fabricated in many situations. The use of elastomer gaskets will be avoided wherever possible. The average tritium beta particle (6 keV) has several orders of magnitude more energy than any chemical bond in the elastomeric material; thus radiation induced thermal decomposition is a serious problem. Equally detrimental is the rapid exchange of the active tritium with the normal hydrogen in the elastomers resulting in an accelerating of the decomposition of the elastomer. Where the resiliency or friction of a plastic is absolutely required, as in high pressure valve seats and packings on soft-seat check-valves, the best elastomer is polyimide.[1]

All welded, stainless steel (316) construction bellows valves will be specified in critical components. Where it is necessary to use valves

containing elastomer seats and/or packing, the use of polyimide will be specified.

Double containment will of course be a requirement in all critical areas of the TSTF. The double containment will generally be stainless steel gloveboxes, equipped with removable safety glass faces so that easy access to contaminated equipment is possible during periods of maintenance and changeout.

Reference

1. "Tritium Operating Safety Seminar, July 30, 1975," Los Alamos Scientific Laboratory report LA-6307-C (May 1976) pp. 10-14.

4.3.9 Instrumentation and Control

Gas Analysis

An important aspect of the operation of the flow loop and all develop-
mental research will be the availability of instruments for precise gas
analysis. On-line mass spectrometry will serve for the control of the dis-
tillation columns and the reconstitution of fuel streams. These spectrometers
should be backed up by a mass spectrometer specifically designed for the analysis
of hydrogen isotopes and other low molecular weight gases. Negotiations by a
committee from ERDA laboratories for a contract to develop such an instrument
are now in progress, and it should be available in several years.

Instrumentation will also be necessary for the rapid, routine deter-
mination of trace impurities from the fuel cleanup system. Detection of the
order of 0.01 ppm of O_2, H_2O, CO, and CH_4 will be necessary. Gas chromatog-
raphy will be adequate for this service (with the exception of H_2O). There
are other types of detection systems such as oxygen fuel cells which may not
be compatible with hydrogen or tritium.

Clearly this is an area for development to permit continuous, automated
monitoring of a continuous flow system.

Control System

The purpose of the control system is to provide for the proper operation
and recovery of the TSTF. The control system could be a completely analog
system or a completely computer-controlled system. While an analog system
has a lower initial cost than a computer-controlled system, it would not be
as flexible.

The advantage of a computer-controlled system is the complete automation
of all actions with the greatly reduced probability of error and the high
degree of flexibility inherent in computer systems. The disadvantage is the
effort required in defining all control functions, in programming of the
computer, the documentation, and maintenance effort required.

For the TSTF, the computer-controlled system is similar to that proposed
for the Scyllac Fusion Test Reactor (SFTR).[1] This control system will be
designed so that it can control flow through the primary gas loop and provide
continuous on-line monitoring of pressure, flow and temperature throughout
the loop. All radiation monitors in the TSTF will be interfaced to the

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control system. In the event of an accidental release of tritium into the main cell, the control system will automatically switch the air flow out of the main ventilation system and into the automatically activated ETC.

The control system will be interfaced with many control valves in the gas loop, the TWT, and the ETC, so that the system is able to achieve a smooth and orderly shutdown under both normal and emergency conditions.

The control system will be designed to allow the systematic testing of the various subcomponents of the machine to aid in the location of malfunctioning components. This will decrease the time required to locate and repair a malfunction.

An important consideration in this type of design is to define carefully the interface standard between the various subcomponents. The interface proposed for the TSTF will be the CAMAC standard now in existence. Use of the CAMAC standard will allow the use of already developed equipment and will also allow devices developed for this system to be used in other systems. Also, component and software development can proceed independently of the actual computer system used.

The control system will be a completely redundant system, as shown in Fig. 4.3.9-1, so that failure of one component will lead to an automatic activating of a similar piece of equipment.

The basic design of the control system consists of a main control computer (mini) and a back-up computer plus two smaller mini-computers used for data capture. Included are two large disks (90MB), two small disks (10MB), two line printers, five CRT back-up power units, CAMAC equipment, and control hardware.

An additional option of this system will be a stand-by emergency power supply. This could be a gas-fired motor generator which would be automatically activated during a power failure. The power supply would, at least, be large enough to permit the computer-control system to achieve an orderly and safe shutdown of the system. Conceivably, this power supply could, at a small cost differential, be sufficiently large (~ 400 KW) to power all of the main components in the TSTF during short periods of power outage.

Reference

1. K. I. Thomassen et al., "Conceptual Design Study of a Scyllac Fusion Test
    Reactor," Los Alamos Scientific Laboratory report, LA-6024 (January 1976)
    pp. 138-145.
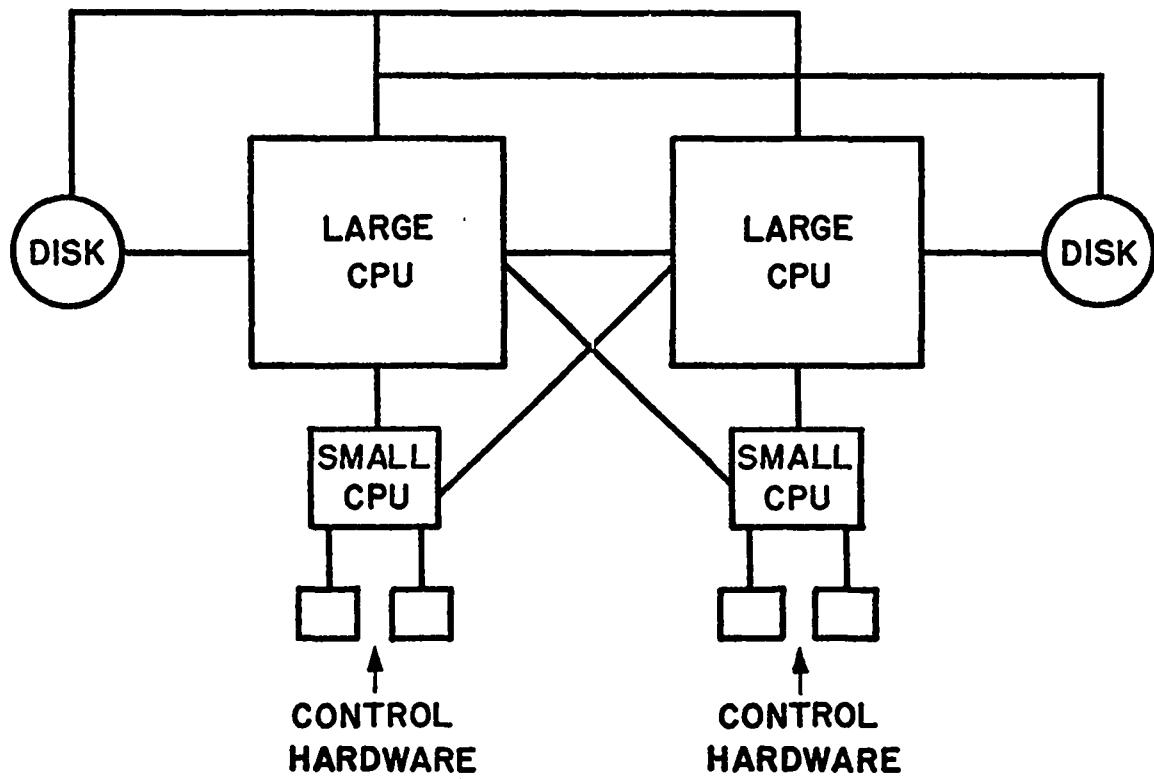
Fig. 4.3.9-1 Schematic of Computer-Control System.

4.4 Possible LASL Facilities to House the TSTF

Five buildings were identified as possible sites for the TSTF. Figure 4.4-1 shows the location of these buildings within the larger site boundaries of the Los Alamos Scientific Laboratory.

4.4.1 DP East Technical Area

The most favorable site for the TSTF is in Building TA-21-155, 2.5 km east of the townsite. The building is part of the DP-East complex (see Fig. 4.4.1-1) and lies within the DP-Site security area. It was the location of the Fuel Element Coating Facility for the Rover program. Currently some research and development is being conducted on chemical vapor deposition of superconducting materials, but this activity can be relocated.

Building Description. The building was constructed in two increments in 1964 and 1965 as an addition to the original structure 155. Figure 4.4.1-2 shows the floor plan; Figs. 4.4.1-3 and -4 show elevations; and Fig. 4.4.1-5 shows an exterior view of the building.

The walls are concrete masonry units with joint reinforced concrete every other course. Steel framing was used for building and crane-rail support. The vertical members of the steel frame are 356-mm (14-in.)-wide flange, 134-kg (61-lb) I-beams. Horizontal members consist of 152-mm (6-in.) and 203-mm (8-in.) I-beams. The ceiling over the high-bay area (Room 5501-North) is supported by 356-mm (14-in.)-wide flange, 134-kg (61-lb) beams. The roof structure consists of #2140 bulb tees with 76-mm (3-in.) tectum plank grouted in a 4-ply built-up roof, consisting of tar and gravel, 2-ply 0.41-m (16-in.) wide felt at the edge over gravel stop. One hundred two-mm (4-in.)-thick pressed fiber insulation panels are attached to the under side of the tectum planks.

This is the proposed experimental area. Figure 4.4.1-6 shows an interior view of this room which has a high-bay area, 12-m x 29-m (39-ft x 95-ft), with a floor-to-ceiling height of 8.5 m (28 ft). The floor area is 344 m^2 (3,700 ft^2), and a crane traverses the full length of the room. The floor-to-crane track clearance is 6.4 m (21 ft). Along the east wall of the room, there are two 1.5-m (5-ft)-deep pits which are 4.6 m (15 ft) wide, and 9.1 m (30 ft) and

RESIDENTIAL AREA

TA-3 ADMIN.BLDG

TA 21

TA 9

EAST RD.

EAST JEMEZ RD.

PAJARITO RD

TA 53

STATE ROAD 4

TA 33

N

0   1   2   3
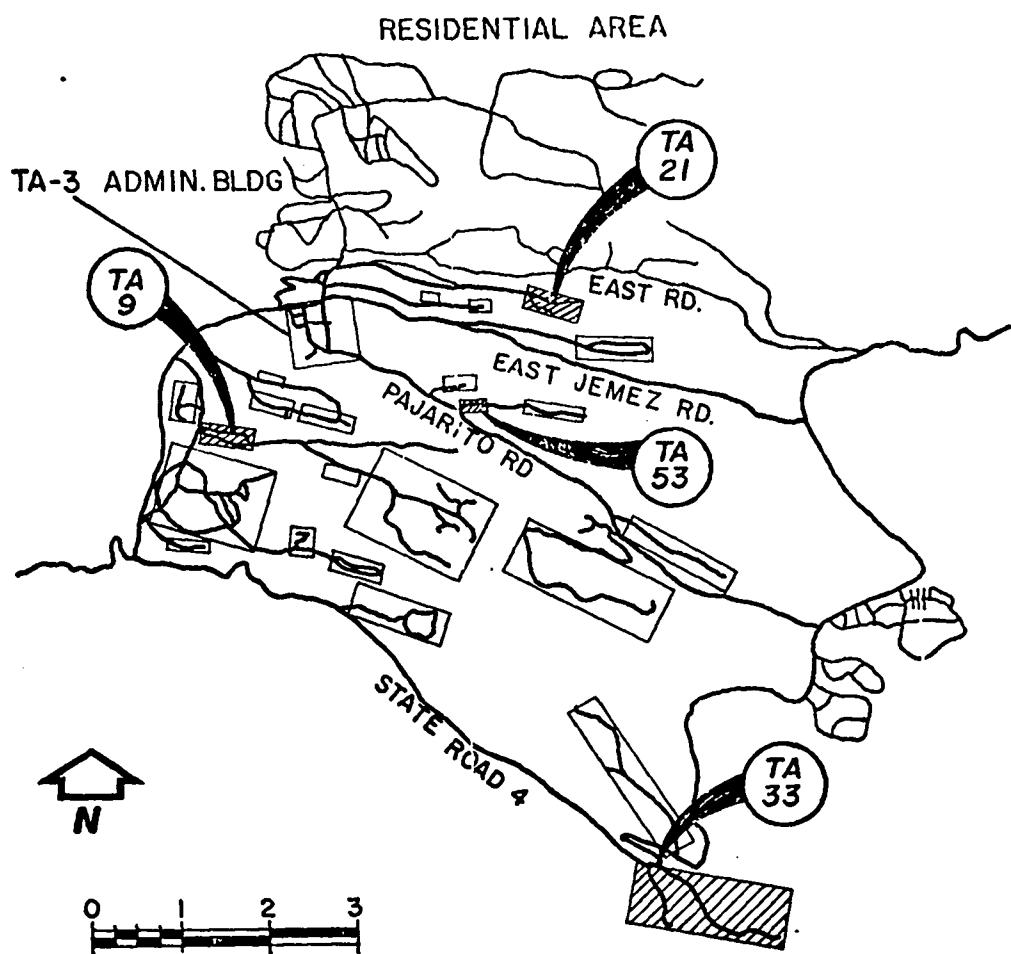
Fig. 4.4-1 Location Map of Facilities Considered for Housing the TSTF.

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17.7 m (58 ft) long, respectively. The height from the pit floor to the crane track is 7.9 m (26 ft).

Room 5513 is the mechanical equipment room. The floor area is 191 m^2 (2,060 ft^2), and the volume is 779 m^3 (27,500 ft^3). This room houses the ventilation equipment, pumps and heat exchanger for the process cooling water, power distribution center, and a battery room for emergency lighting.

Rooms 5507, 5508, 5509, 5510, 5511, and 5512 are office and lab spaces.

Change rooms are located between Room 5513 and Building 152. The walls and floors are tiled and the rooms have their own ventilating and heating system. Showers, toilets, and lockers are available for both men and women.

If the operational needs require that the building which is within the DP-Site security area be treated as an open area, it would be possible to use an existing gravel-surfaced road that lies north of the fenced area for a controlled access. (See Fig. 4.4.1-1.) Further, the TSTF could be physically separated from the rest of the Site by appropriate barriers. Access by cleared personnel to the rest of DP-East Site could be controlled by a manned security station located in the hall between Buildings 155 and 152.

Existing Utilities and Services.

Telephone service is installed and an intercom system is connected with the rest of the DP-East Site.

DP-East Site is serviced by a 13.2-kV electrical line and has 2,500 kVA of power available. There are existing electrical distribution centers in Rooms 5513 and 5501-North which provide 1,000-kVA power, 480/208Y/120V service to the rooms.

Adequate ceiling-mounted fluorescent lighting fixtures exist for general interior lighting. An exit and emergency lighting system is installed and connected to a battery power source with automatic transfer switch and charging unit in Room 5513A. There is adequate exterior lighting for safe access to and from the building after dark.

Adequate lightning protection for all structures and exposed equipment exists.

A 152-mm (6-in.), 0.68-MPa (100-psi) steam line services DP-East Site and is adequate for heating requirements.

A process water system for removing excess process heat is installed. The system is a closed loop which rejects heat through a heat exchanger to a

GUARD STATION

DISTANCE TO GUARD GATE
FROM TRITIUM TEST FACILITY
IS 1/4 MILE

TRITIUM TEST FACILITY

CHANGE ROOM AND
HEALTH PHYSICS OFFICE

EXISTING TRITIUM FACILITY

ROAD TO DP-EAST

SECURITY FENCE

N

100 0   200   400

TA-21 DPE SITE
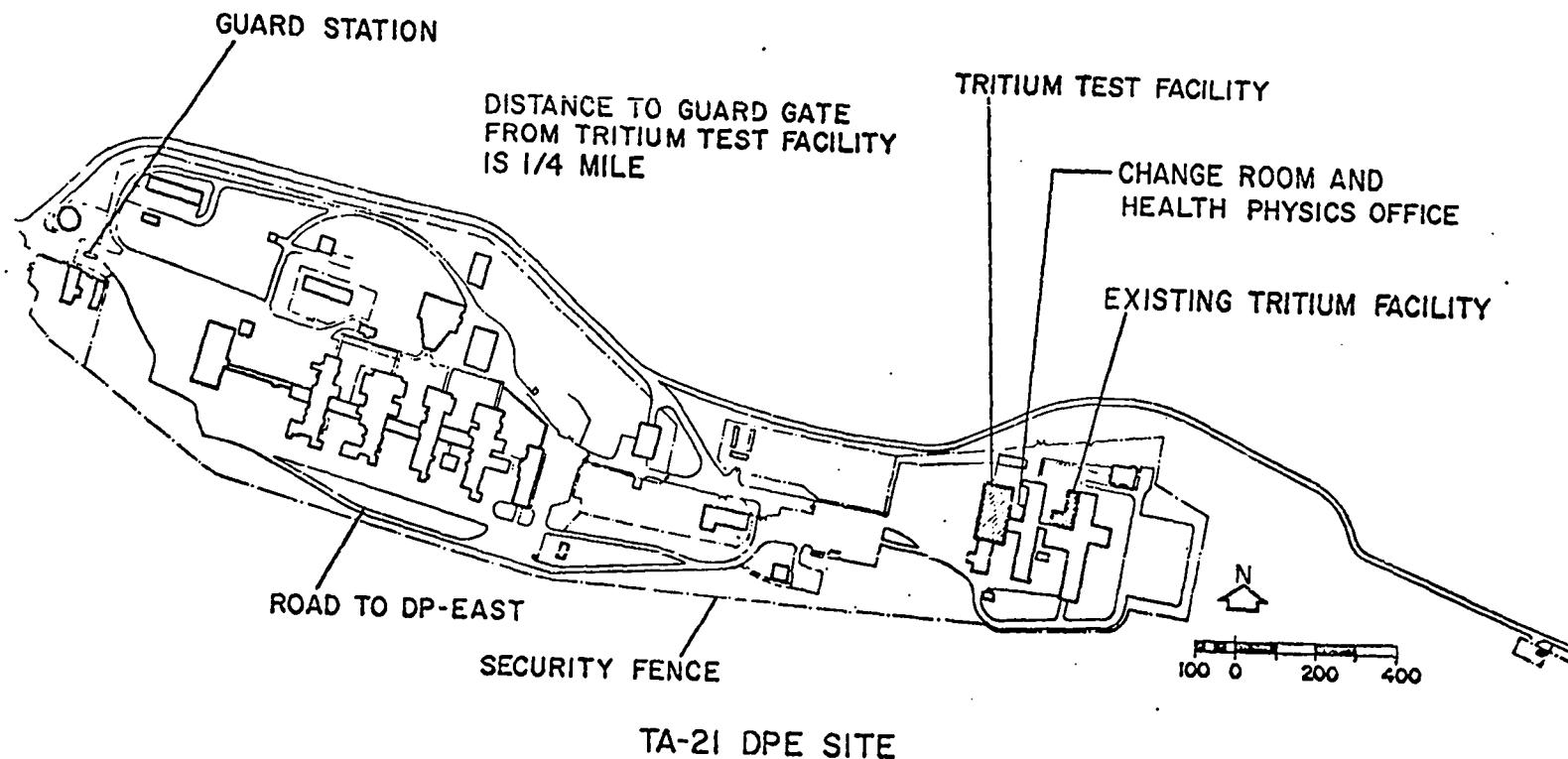
Fig. 4.4.1-1 Site Plan Showing the Location of Building Ta-21-155
in the DP-East Complex

cooling-tower water system. The cooling tower is located at the northwest corner of Building 155. The pumps, filters, water treatment system, and heat exchanger are located in Room 5513. The system is designed to provide 800 kW of cooling, at 0.063 m^3/s (1000 gpm). There are parallel pumps in the loop which may be alternated to provide continuous service. Each has a 480-VAC, 3ϕ, 40-kW motor. The process water system will be shared with other activities in the south end of Building 155 outside of the TSTF.

A heating and ventilation system is located in Room 5513 which provides 7.08 m^3/s (16,000 SCFM) of heated air to Rooms 5501-North, 5509, 5510, 5511, and 5512.

An industrial (acid) waste drain line runs from Building 155 to a waste treatment plant at the western side of DP-Site.

Fire Protection

Fire protection service water is available from a 203-m (8-in.) combined domestic/fire loop that is supplied from the new TA-21 east elevated (100,000 gal) storage tank. The 100,000 gal TA-21 west elevated tank is a strong secondary source of water to the TA-21 east loop and hydrants.

The water loop is connected through an electrically supervised post indicator valve (PIV) to a preaction (pneumatic) automatic sprinkler system with ordinary and intermediate rated heads. This 6-in. valve, riser, and system protects the concrete and concrete block main section of the building. A 4-in. wet-pipe automatic sprinkler system protects the south metal-on-metal portion of the buildings. The present construction of the building lends itself to fire-rated cut-offs around the proposed test area.

The sprinkler systems are connected to the Los Alamos Alarm Center, Station 100, LAAO. The manual alarm boxes are also connected to the LAAC. Standard fire hydrants are located north and west of the building connected to the aforementioned 8-in. loop. A five-man company and two 1000-gal pumps of the ERDA/Los Alamos Fire Department are located west of the site on DP Road 1.7 km (1 mile) away, with approximately 3-1/2 min running time.

Preparation of Building for Modifications.

During the course of the Fuel Element Coating program, some 50,000 ^{235}U enriched, fuel elements were processed. The program was terminated in January

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1973. Since that time the equipment has been maintained, but there has not been any production activity.
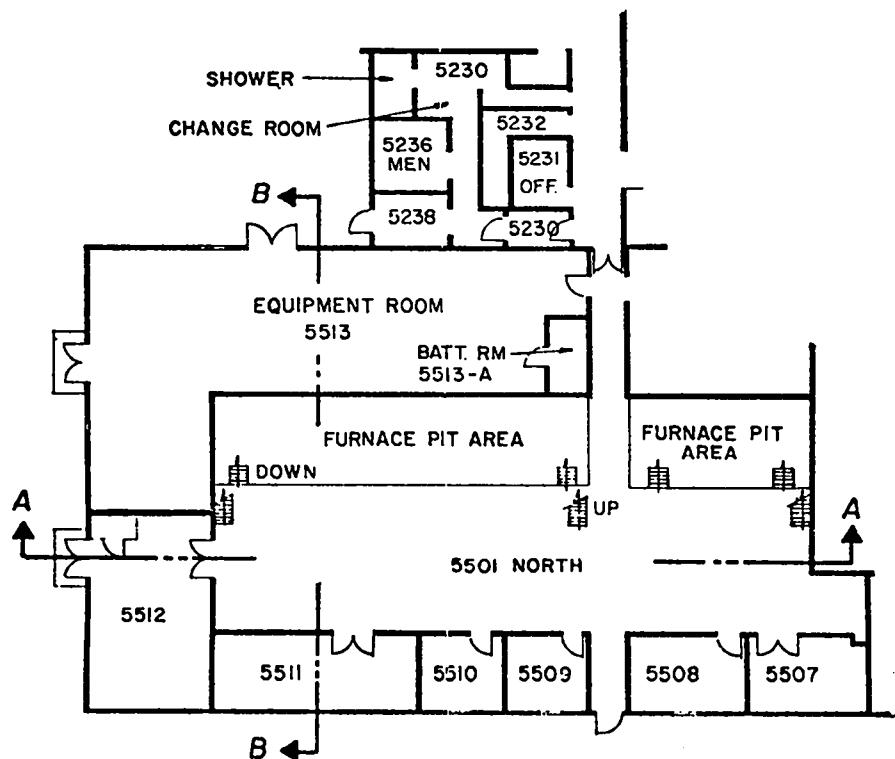
Fig. 4.4.1-2 Floor Plan of Building TA-21-155.

Section *B-B*
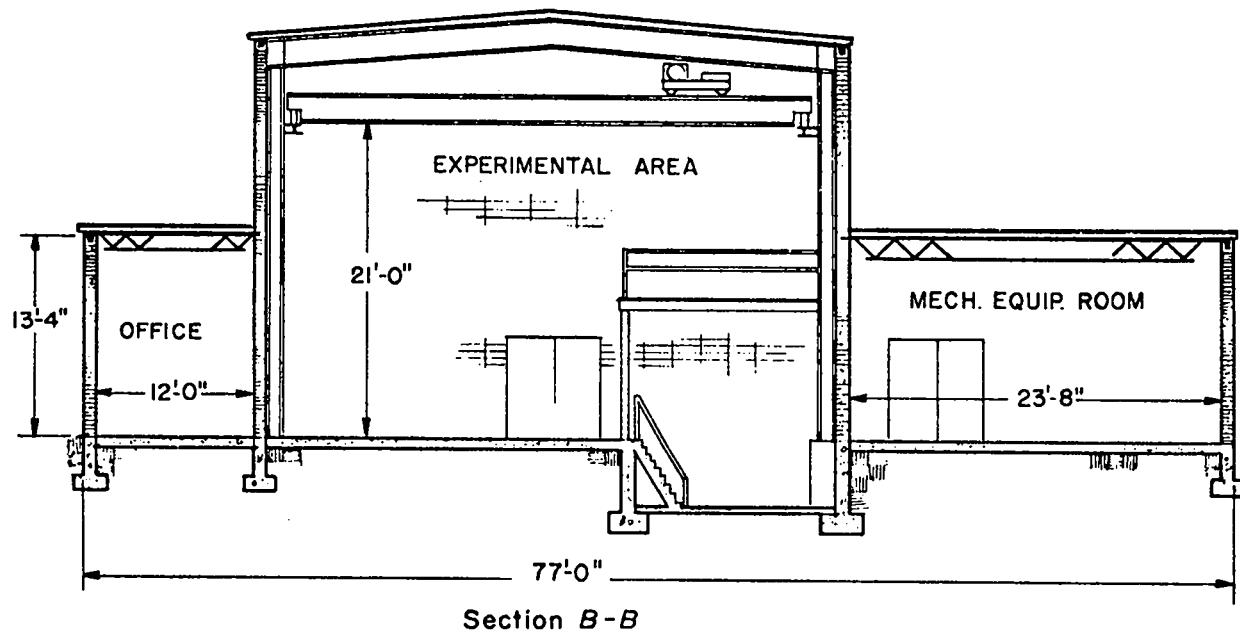
Fig. 4.4.1-3 North-South Elevation of Building TA-21-155.

Section *A-A*
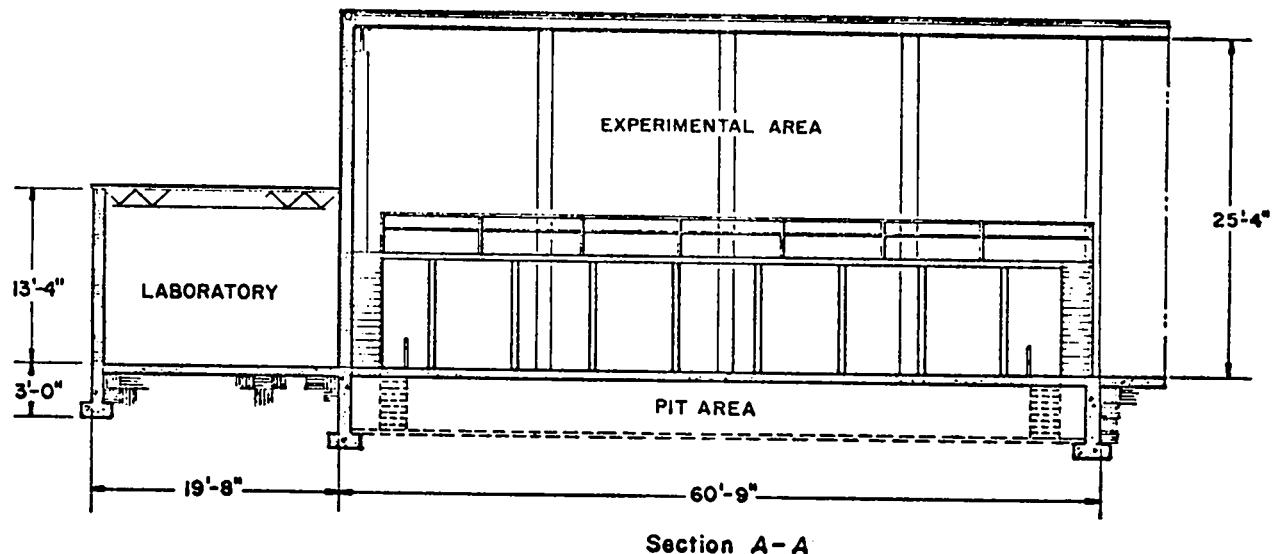
Fig. 4.4.1-4 East-West Elevation of Building TA-21-155.
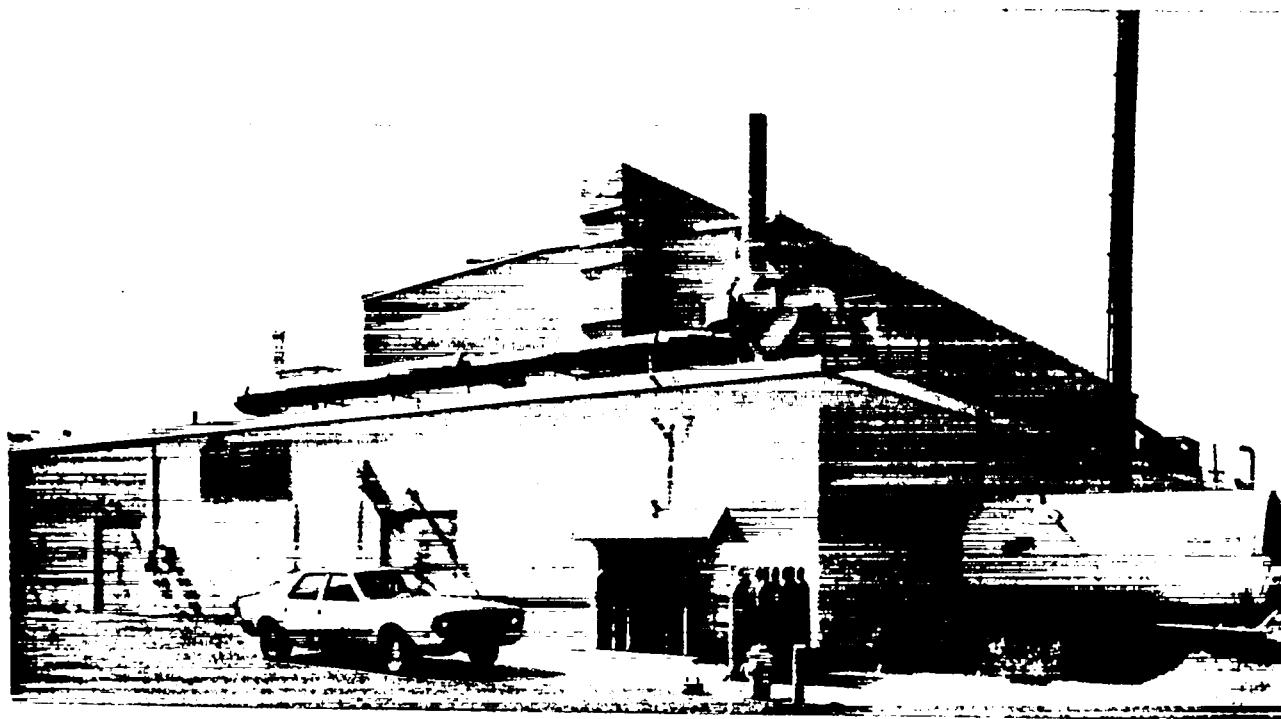
Fig. 4.4.1-5   Exterior View of Building-155.
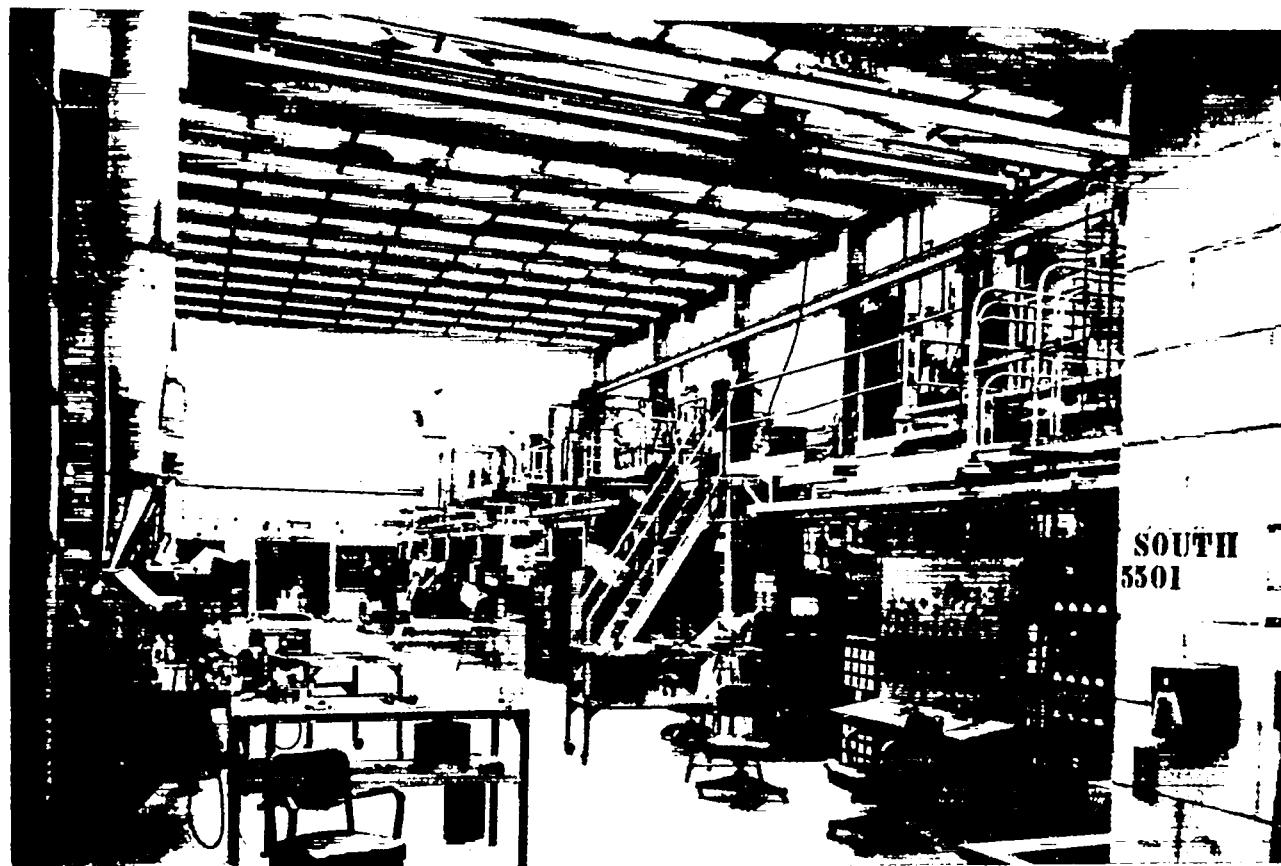
Fig. 4.4.1-6   Interior View of Building-155.

The major cost in preparing the building for subsequent modifications will be the disassembly and disposal of the process equipment and ventilation system. Major items include: six coating furnaces, associated control equipment, and connecting lines; two motor generator sets; portions of the steel decked floor; and the existing ventilation system.

Air samples have been taken routinely for the past two years and the analysis of the samples has shown that the amount of airborne ^{235}U has always been less than the applicable concentration guide. The floor of Room 5501-North and ancillary rooms are free of detectable contamination.

4.4.2 Alternative Sites

A building (TA-9-37) used for chemical processing and located within a security area 5.2 km WSW from the townsite, was considered as a possible site. It has reinforced concrete construction and a contained area of 129 m^2 (1385 ft^2) with a blow-out wall on the south side. This building was removed from further consideration because of insufficient working area.

In the same security area, Building TA-9-46 is located approximately 0.2 km west of TA-9-37. Of reinforced concrete construction, the building has a combined work area of 145 m^2 (1557 ft^2) with a blow-out wall on the south side. There is a one-ton capacity overhead crane in Room 101. Some chemical process equipment would have to be removed. Again, this building has insufficient working area.

At TA-33 12.8 km southeast of the townsite and 1.5 km east of the campground at Bandelier National Monument, building HP-86 houses activities for the purification of tritium used for experimental purposes in various parts of the Laboratory and for work in support of the geosciences. The building is reinforced concrete and masonry construction, contains a total area of 563 m^2 (6,063 ft^2), and is within a controlled access area. There is a high-bay ceiling 6.1 m (20 ft) high, over Rooms 1, 9, 10, and 11 with a separating wall between Rooms 10 and 11. The floor space under this high ceiling area is 409 m^2 (4,400 ft^2). Approximately 134 m^2 (1,440 ft^2) could be used for the experimental area of the TSTF. An overhead crane traverses Rooms 1 and 11. This building was eliminated from further consideration because of insufficient

room (both floor space and ceiling to floor distance) for the TSTF experimental area.

The Reactor Development Site contains a building, TA-52-1, 3.0 km SSE of the townsite in a controlled access area. This building was the location of an ultrahigh-temperature reactor experiment, now deactivated. A limited amount of laser research is currently conducted here. The reinforced concrete containment portion of the building has a volume of 5100-m^2 (2,600 ft^2) at ground level. With careful utilization of labyrinthine structure, this area might be increased to 418 m^2 (4,500 ft^2). There would be adequate height for the distillation columns in the structure. The ancillary floor space surrounding the containment building has 679 m^2 (7,500 ft^2) at ground level and contains a ventilation equipment room, boiler room, electrical equipment room, and an exhaust filter room; the first subfloor has 483 m^2 (5,200 ft^2) which includes office space, control room, cell operation room, toilets and change rooms; the second subfloor has 353 m^2 (3,800 ft^2) which includes office space, mechanical equipment room and a toilet.

Comparing the accessibility of the experimental area (containment building) with that at TA-21-155 (the preferred area, see Sec. 4.4.1), there is 27% less floor space which could be easily served by the overhead crane. The additional 177 m^2 (1,900 ft^2) in the building is covered by a removable floor at ground level; and if used, it would put restrictions on the layout of the experimental systems to assure that everything did not have to be disassembled when changes were made on the subfloor levels.

The major problem associated with the utilization of TA-52-1 is the cost to dispose and remove the contaminated equipment in the containment building. In particular, the integral removal of the reactor shell will require that a knock-out portion of the south wall in the containment building be removed, a portion of the remaining wall structure be broken out to accomodate the spherical shape of the shell, extensive rigging to remove the shell from the building onto a trailer and then transport it to a nearby burial area. Estimates of the cost for this operation are from $375,000 to $800,000.

Even though TA-52-1 has the greatest overall building space, it was removed from further consideration because the easily accessible experimental area is less and equipment removal costs to prepare the building for modifications are greater than those for the DP-East, TA-21-155 site. Also,

the somewhat excessive building volume at TA-52-1 for TSTF would unnecessarily increase expenditures for the ETC system.

4.5 Hazard Assessment

The use of an existing building located at the DP East technical area will substantially reduce the additional impact of the proposed facility on the environment. Existing electrical, water, and sanitary sewer lines are adequate and will be used. The only major addition to the exterior of the structure will be a 30-m stack for discharging gaseous effluents that may contain tritium.

Tritium is expected to be the only major environmental pollutant to be released from the facility. Under normal operations, small amounts, about 100 Ci/y, of tritium gas and water vapor are expected to be released up the stack from plumbing leaks, permeation through temporary plastic or rubber barriers, and from the exhaust of the tritium cleanup systems (TWT and ETC). In addition, during normal operations, there are expected to be modest amounts of liquid waste (pump oils and water) and solid waste (contaminated plumbing and other components, and water fixed in molecular sieve cartridges from the cleanup systems). Small volumes of liquid waste will be fixed on absorbent material or in a solid material before burial at the LASL waste disposal grounds. Larger volumes will be collected in the holdup tank for controlled disposal.

Two types of tritium stack releases are identified: a) chronic releases of gas and water vapor, which are expected to total about 100 Ci/y; and b) large accidental releases which, though highly improbable, must nevertheless be considered credible and addressed at this stage.

The nearest public access point is State Road 4, approximately 0.4 km north of the proposed site. Contaminant plumes in the north/south direction (across the "grain" of the canyon-mesa topography) normally encounter more mechanical turbulence than they would in the absence of the terrain effect. However, the particular feature of crossed airflow from DP East to the airport is very shallow and would be unlikely to induce major turbulence effects. The general ambient turbulence levels in the vicinity are high for cross-mesa flow, precluding the occurrence of the very limited mixing regimes.

4.5.1 Chronic Releases.

Annual average isopleths (X/Q in s/m^3) were calculated for the proposed
TSTF site based on wind and other atmospheric data compiled for that site.
These data are plotted in Fig. 4.5-1 for a 30-m stack height. No allowance was
made for terrain features which would interrupt the normal flow toward the
population centers.

From the isopleths, the annual doses to persons persistently exposed to
tritium being chronically released at the rate of 100 Ci/y were calculated and
transferred to the same isopleth curves (Fig. 4.5-2). The tritium was assumed
to be completely oxidized and absorption through the skin was included. On the
basis of these calculations, no member of the public would receive over 1
mrem/y.

Using current demographic data and the results in Fig. 4.5-2, the annual
population dose resulting from the same chronic release rate was found to be
approximately 0.13 man-rem.

4.5.2 Accidental Releases.

The tritium loop and the tritium storage containers will be confined to
the experimental building. Approximately 50 g will be kept in reserve storage
in a room that is vented continuously and directly to the 30-m stack. The
rema⸱ ⸱⸱r, ∿150 g, will be normally found in various components of the tritium
loop with the largest amount in the distillation columns (∿125 g). Each of the
components will be isolated when possible in separate gloveboxes or by other
secondary containments to facilitate recovery should a major leak occur. (See
Section 4.1.)

In case of the highly unlikely double failure of any of the primary and
secondary containments coupled with failure of the tritium cleanup systems,
gram quantities of tritium gas could escape to the environment. Should such a
release be accompanied by fire or explosion, all or part of the gas could be
converted to the oxide. The result would be significantly higher doses or
potential doses than would result from a release of an equal quantity of
tritium gas.

For such releases, calculations were made to estimate the personnel
exposure outside the building, assuming that all tritium is in the form of HTO.
Three standard meteorological conditions, a release height of 30 m and a wind
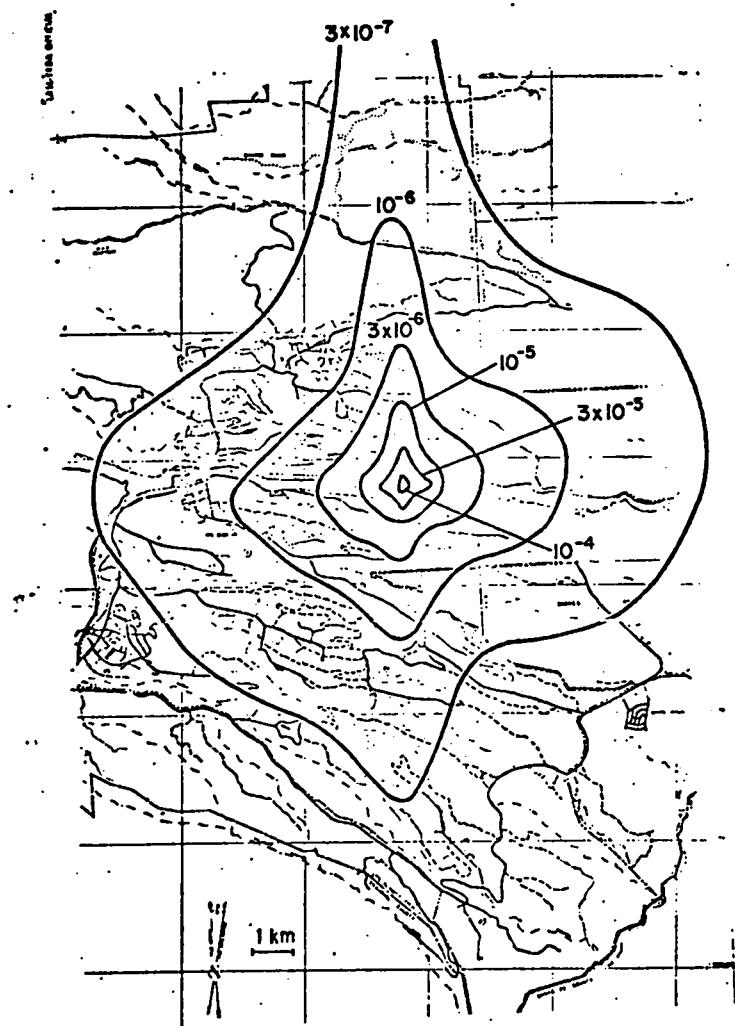
Fig. 4.5-1   Annual Average χ/Q (S/M^3) for TSTF source   Fig. 4.5-2   Chronic Tritium Whole Body Isodose Curves
at 30-m stack height.   for TSTF tritium release from a 30-m stack.
(mrem/yr)
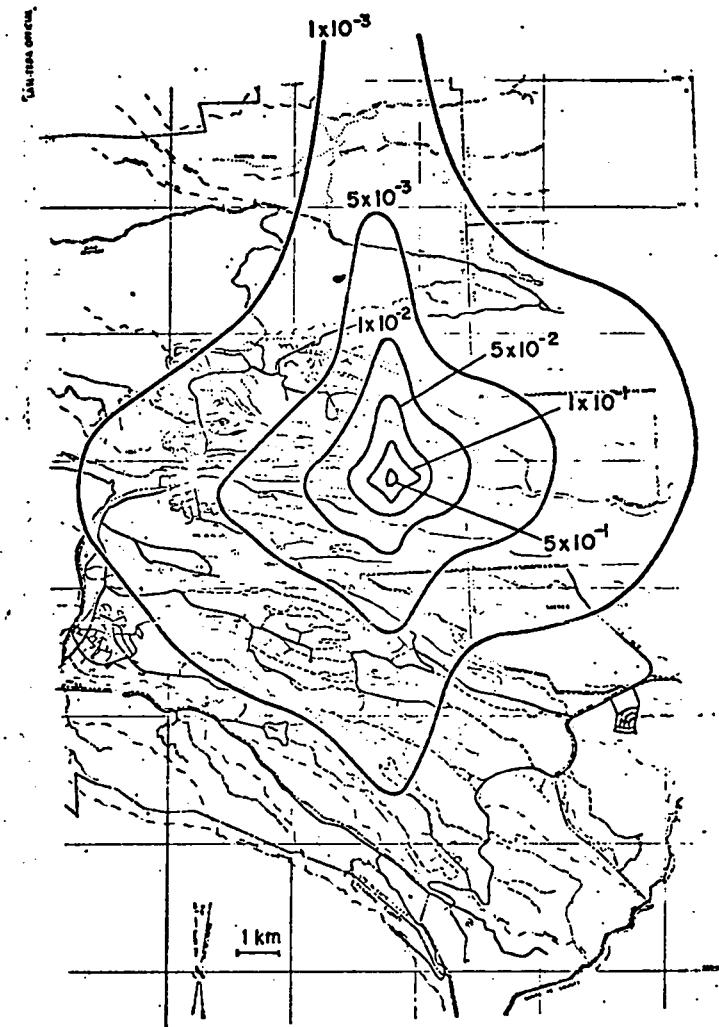
speed of 1 m/s were used. The result is plotted in Fig. 4.5-3. In the case of
a release of tritium gas, the resultant whole body doses, as read in Fig.
4.5-3, would be diminished by a factor of $\sim 10^3$ or more.

The maximum population dose resulting from a one-gram release of tritium
as HTO/T_2O in the direction of the Los Alamos townsite under neutral conditions
(see Fig. 4.5-3) is approximately 30 man-rem. The corresponding population
dose from an identical release in the direction of Santa Fe (40 km away) is
about 4 man-rem.
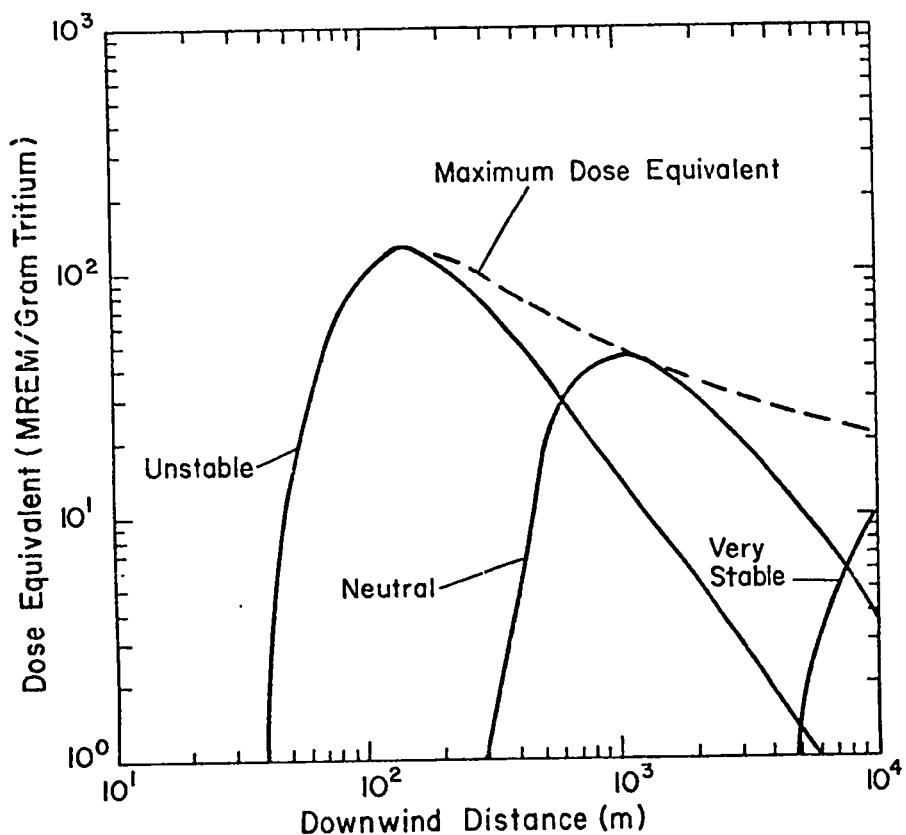
Fig. 4.5-3 Dose equivalent downwind from an instantaneous release of T
as HTO as a function of distance for three meteorological con-
ditions, a 1-m/s wind speed, and a 30-m stack height.

V. EXPERIENCE AT LASL WITH TRITIUM

5.1 Chemical/Materials Science Division (CMB)

5.1.1 Programs

An active program in tritium technology has been carried on by CMB-3 since
1950. Primarily, they have undertaken a study of the lithium-tritium system,
including an intensive investigation of the radiation effects resulting from
tritium decay.[1,2,3,4] LASL, to a large extent, pioneered in this field,
although similar work is now being done elsewhere. A great number of people
have benefitted from CMB-3 training in the handling of large quantities (up to
100 g) of tritium.

Currently, CMB-3 is synthesizing, processing and chemically analyzing
metal tritides. Investigation of the radiation effects resulting from the
tritium decay and the migration of the resulting ^{3}He in the solid tritium is an
important aspect of these studies.[5] In another program, scientists are
developing techniques for filling targets used in the laser fusion and
electron-beam fusion experimental programs. It involves the routine filling of
targets with $(D,T)_2$ gas mixtures at pressures from 33 kPa to 100 MPa, as well
as a continuing effort in the development of techniques for filling new target
designs and development of methods for verifying parameters used in
gas-filling.[6]

Studies of tritium chemistry associated with the lithium blanket and
container materials are being undertaken by CMB-3 for the LASL CTR program
funded by the Division of Physical Research/ERDA. New techniques are being
studied for separating tritium from the lithium blanket in a fusion reactor.
Under investigation is a liquid-liquid extraction technique using liquid-metal
getters and permeable membranes to achieve the lithium-tritium separation.
Also being studied is the phenomenon of hydrogen isotope permeation through
liquid lithium as well as through possible container and membrane materials.[7,8]
The forementioned program is quite pertinent to the TSTF.

For the past two years, the group has been involved in design studies for
the Scyllac Fusion Test Reactor.[9,10] They have contributed conceptual design
work in a tritium system equally complex to the one proposed for TSTF.

LASL's extensive background in tritium technology is indicated in the
"Proceedings of the 23rd Conference on Remote Systems Technology." Of eight
papers presented at the tritium handling session, four of these were presented
by LASL personnel.[11,12,13,14]

References

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12. J. L. Anderson, F. A. Damiano, and J. E. Nasise, "Tritium Handling Facilities at the Los Alamos Scientific Laboratory," ibid., p. 77-88.

13. R. A. Jalbert, "A Monitor for Tritium in Air Containing Other Beta Emitters," ibid., p. 89-93.

14. M. L. Wheeler and J. L. Warren, "Tritium Containment After Burial of Contaminated Solid Waste," ibid., p. 100-106.

5.1.2 Present Facilities

The LASL has recently activated a new facility designed to handle large quantities of tritium in the form of metal tritides or as gas.[1] This system includes an 11.5-m^3 drybox and associated Gas Purification System (GPS) and a Tritium Waste Treatment System (TWT). The building containing the system is interconnected to the proposed TSTF and is therefore, readily accessible to the TSTF. It is envisioned that many operations and experiments that are part of the TSTF can be done in the existing facility.

At the DP-East Tritium facility, the drybox gas is helium which is continually circulated through the GPS at $\sim$ 94 ℓ/s. In addition to the GPS, the circulation system contains a heated titanium bed which can getter tritium (at $\sim$ 770 K) or nitrogen (at $\sim$ 1120 K), and a catalytic recombiner which combines tritium and oxygen forming tritiated water that is then removed in the drytrain. This system maintains water concentrations at < 1 ppm, oxygen at < 10 ppm and tritium concentrations at < 0.5 ppm (1.3 Ci/m^3). Included in the drybox line are 200-ton and 20-ton hydraulic presses for compaction of metal tritide powders, a milling machine for machining reactive materials and an inert gas welding facility.

A vacuum system has been installed inside the drybox. This system includes a uranium bed for storage and purification of tritium,[2] a reactor for synthesis of metal tritides, standard volumes, and gages for measuring gas volumes, also a two-stage vane transfer pump and a lower capacity metal-bellows transfer pump for transferring gas within the system. Included in the system is a vanadium-vanadium tritide bed used for boosting small quantities of tritium gas to high pressures ($\sim$ 100 MPa). The vacuum system is interfaced with a mass spectrometer which is used for gas analysis.

A small ($\sim$0.3 m^3) vacuum drybox has been installed adjacent to the large drybox system. This smaller box is used for decontamination of material coming out of the main drybox. Material is introduced into the decontamination box, the box evacuated and back-filled with helium, and the material then decontaminated by washing with the appropriate solvents. The box is then evacuated once more, back-filled with clean gas and the material removed to the fume hood. All effluents from this decontamination box exhaust directly into the TWT.

All vacuum lines and all experimental stations associated with the drybox are interfaced with a TWT which scrubs tritium from the effluents prior to release to the environment. The TWT operates primarily by the catalytic conversion of tritium to tritiated water which is collected on molecular sieve drying towers. This system, which has a maximum capacity of 7 ℓ/s, is a completely redundant system so that the loss of any single component does not close down the facility. The system was designed and built to minimize release of tritium to the environment and to minimize personnel exposure to tritium. Recognizing that maintenance on such a system will be necessary, many precautions have been included to provide protection for maintenance personnel. All components are connected to the system through a double-valve purge system so that they can be removed with minimum exposure of a contaminated surface. All vacuum pumps in the system have been modified to allow the safe, clean, contamination-free changing of pump oil. The system includes only a minimum of materials susceptible to radiation damage. It is, as far as possible, an all-metal system with most joints being soldered or welded. Cajon fittings, with metal gaskets, were used for those joints which might have to be opened periodically for maintenance.

Included in the facility are supplied breathing-air stations for use with "bubble suits" during periods of maintenance on contaminated components. Room monitoring equipment as well as continuous stack monitoring are included. No provisions exist for cleanup of tritium spills into the room air.

There is a significant amount of experience gained in the design, construction, testing, and operation of this facility which will be vital to the TSTF. The personnel involved in these phases of the existing facility are currently employed in CMB-Division and therefore available to the TSTF program.

The operation of the existing facility adequately demonstrates LASL's ability to deal successfully with the questions of tritium handling, containment, personnel protection, and effluent cleanup.

During the past 20 months some 1.5 megacuries of tritium have been processed through this facility. Over this period some 370 curies have been released to the atmosphere, and there have been no significant personnel exposures. By careful attention to good housekeeping and safety procedures, it has been possible to maintain tritium levels in the working space adjacent to the drybox at $\sim 1 \times 10^{-7}$ μ Ci/cm^3 while the gas in the drybox is consistently

at 1 - 1.5 mCi/cm^3. This decontamination factor of 10^7 across the face of the drybox demonstrates the ability to provide adequate personnel protection. An advantage of maintaining this tritium-free working area is that personnel are not required to wear protective clothing, other than lab jackets, while working in this area. Every effort will be made to insure that the air in the TSTF cell is kept equally clean, thus providing superior working conditions.

References

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2. D. H. W. Carstens, "A Gas-Handling System for Studies of Tritium Containing Materials," Proc. 23rd Conf. on Remote System Technology, San Francisco, CA, 1975, pp. 69-76.

5.2 WX Division

5.2.1 Staff Experience

The continuous operation of a tritium gas processing system has been carried on within the Division since 1955. The system serves to evacuate, transfer, and compress tritium to the 100-MPa level. It also precisely measures pressure, volume, and temperature, along with providing isotopic mass spectrometry.

By means of this system, scientists are able to purify and separate tritium from other gases by palladium diffusion and selective adsorption.

Material development and tritium-compatibility studies have been performed within the group. They have selected, designed, and fabricated packless, remote-operated valves, pumps and fittings suitable for tritium. The WX group also designs and lays out graphic-panel remote-control systems.

Within the group, one staff member has worked with the system continuously since 1955. A total of 15 man-years experience with the system has been accumulated between six staff members. Eight staff members have from one to twenty years of design experience for vessels and hardware used for tritium, to make a total of 20 man years.

Published work can be found in the list of references.[1,2,3,4,5,6]

References

1. Don O. Coffin, "High-Pressure Gas-to-Liquid Transducer," R. Scientific Instruments, 29, No. 10, 896, (Oct., 1958).

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5. "Tritium Control Technology," Mound Laboratory report, WASH-1269, pp. 32-38, 123-127, 217, 256.

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5.2.2 Present Capabilities

At this facility, a variety of operations with large quantities of tritium gas are performed routinely. These operations include transfer and packaging over a wide pressure range. Accurate pressure/volume/ temperature measurements can be made over this pressure range, and isotopic analysis is performed by mass spectrometry and other analytical methods. Tritium is mixed with other gases, and non-isotopic impurities can be removed by a high-capacity palladium diffuser or by selective adsorption on a cryogenic charcoal trap. The capacity of this system is about one ℓ/s for transfer and several cm^3/s for purification. Many kilograms of tritium have been processed here since 1956.

5.3 Cryogenics Group (Q Division)

LASL's Cryogenics Group, Q-26, has a long history of operations involving tritium which dates back to 1950. Tritium was handled and cryogenically pumped prior to the establishment of the Savannah River Plant and the LASL facility in Group WX-5. Much of the subsequent research with tritium has been directed at fundamental properties measurements such as vapor pressures and liquid densities. Thin-walled liquid tritium targets have also been designed and constructed for neutron scattering and pion capture experiments. Of direct bearing on this proposal are the present research facilities described in the following section.

Group Q-26 has about 50 staff members and support personnel doing research and development in a broad range of cryogenic problems. Research is being conducted in DC Superconducting Power Transmission, Superconducting Magnetic Energy Storage and Laser fusion targets. A number of supporting or allied research projects are also carried on.

5.3.1 Present Facilities

Apparatus for measuring the solubilities of ^{3}He and ^{4}He in liquid deuterium and tritium has been used in the LASL Cryogenics Group (Group Q-26) for four years. This apparatus (pictured in Fig. 5.3-1 as the leftmost of the three main units) comprises a thermally shielded and refrigerated (20 K)
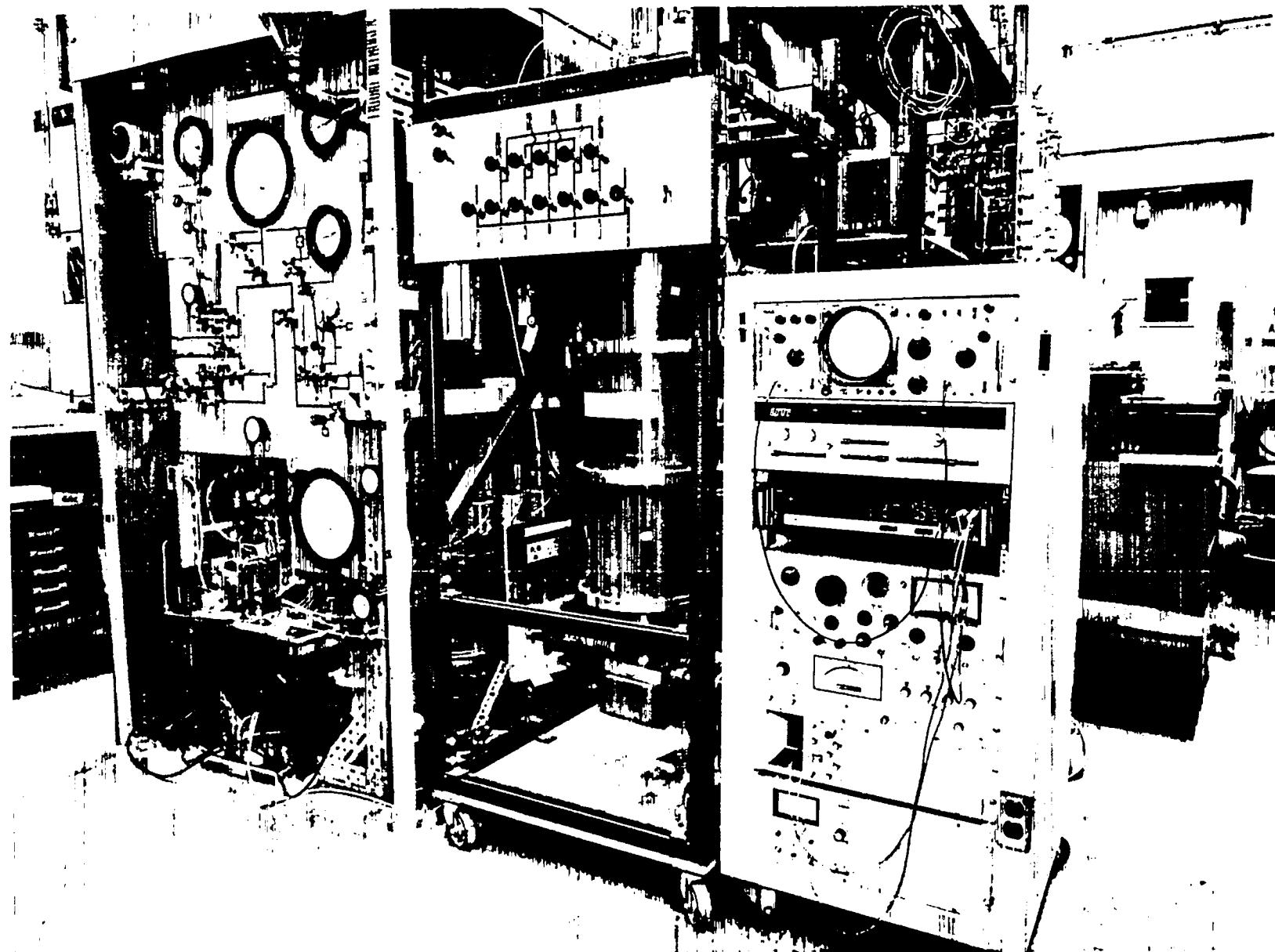
Fig. 5.3-1 Prototype Distillation Column for the Intense Neutron Source

equilibration cell of 20 cm^3 volume, together with associated transfer pumps, uranium getter beds, storage tanks, valving, gauges, liquid and vapor sampling equipment, and gas analysis equipment. Tritium in quantities up to eight grams has been handled in this apparatus. In addition to analysis by a small, on-line quadrupole mass spectrometer, a high-precision, 90° magnetic-sector mass spectrometer is also available. The tritium apparatus is enclosed in a hood equipped with automatic tritium monitoring equipment. A small, hooded, maintenance and repair area is available.

5.3.2 Present Distillation Work for INS Applicable to TSTF

There is in Q-26 an ongoing project for the INS program to develop a process of cryogenic fractional distillation for separating T_2 from a D_2 stream (2 SCFM) containing 0.1 mol % DT. This will require a system of three interlinked (cascaded) packed columns, of about 15 feet in height and 0.3 to 3-1/2 inches in diameter, and will include a 480-watt, 20 K cryogenic refrigerator.

Progress to date has included the following: the review of pertinent literature; the development of computer codes for designing interlinked, multi-feed multicomponent columns; the measurement and publication[1] of pertinent physical properties of tritium; and the fabrication, instrumentation, and installation of a prototype tritium distillation column. Figure 5.3-1 is a photograph of the prototype column showing the gas handling equipment (which was also the equipment used for measuring physical properties), the vacuum-jacketed distillation column, and the control console for an on-line mass spectrometer used for gas analysis.

The INS distillation team presently consists of four people. These are: Dr. John Bartlit, chemical engineer, Dr. Robert Sherman, physical chemist, Richard Briesmeister, chemical-mechanical technician and proposed chief operator of the system, and William Denton, visiting scientist from AERE Harwell.

Reference

1. Sherman, R. H., J. R. Bartlit, and R. A. Briesmeister, "Relative Volatilities for the Isotopic System Deuterium-Deuterium Tritide-Tritium," Cryogenics, accepted for publication.

5.4 Physics Division

Two electrostatic accelerators of the Van de Graaff type are used by group
P-9. A large vertical, single-ended accelerator was designed by the LASL in
the late 1940's and presently operates up to 7 MV on terminal. The second
accelerator is a commercial tandem unit purchased in the early 1960's and
presently operating at a maximum terminal voltage of 8.75 MV. Tritium is used
in two ways: (1) as a source gas to produce tritons for acceleration, (2) in
a target cell to produce neutrons for various nuclear experiments.

As a source gas the tritium is delivered in 2.5-liter containers at a
pressure of several atmospheres. Submerged in the bottle is a thin nickel
tube which, when heated by an integral heater, passes tritium through the wall
of the tube. The tritium flow-rates into the ion sources vary from 5-30 cm^3/h.
The gas flows through an ion source where 1% or less is used to create the
triton beam. The residual gas passes through various vacuum systems until the
tritium is finally adsorbed in a container of activated charcoal at the
temperature of liquid nitrogen (-196°C). Warmed up, these containers release
90% of the adsorbed tritium, and the tritium can then be pumped off and
recycled back into the supply containers. The accelerators have been using
tritium in this way since 1965 with the average use being 80,000 Ci/y.

The tritium gas targets store the tritium in a small container filled with
uranium chips. The container is heated by an external heater which releases
the tritium into the target chamber (0.05-5.0 cm^3) at pressures up to 400 kPa
(4 atm). These targets have been in use for over 20 years at LASL.

The large amounts of tritium used over the years have led to the
development of many techniques for handling the tritium contaminated vacuum

pumping systems. This ranges from vacuums of 10^{-7} torr up to atmospheric pressure.

5.5 Intense Neutron Source

The TSTF and the Intense Neutron Source Facility could interface directly and be of great mutual benefit. With the INS scheduled to be operational early in FY1980, the TSTF could be on line before and contributing to the INS. The detailed similarity of tritium handling problems between the two facilities is notable. The INS will require confinement of approximately 30 g of tritium. Many of the early results of the TSTF may be applied directly to the operation of the INS, which would then act as a proving ground for practical tritium handling systems. The TSTF, by close coordination with INS, could further develop these systems into more sophisticated systems to handle even larger tritium inventories.

Experience with the model isotope separator will benefit both research facility objectives. The development of the deuterium-tritium isotope separation system for INS with an as-low-as-practical tritium inventory is well underway with a prototype model now being readied for trial operation. A similar isotope separator, but with different flow rates, D-T concentrations, and contaminants, will be required by fusion devices and thus used in the TSTF.

5.6. Health, Safety, and Environmental Support Capabilities

The Health Research Division of LASL maintains a comprehensive laboratory support program in the areas of health physics, industrial hygiene, industrial safety, fire protection, waste management, environmental studies, and industrial medicine besides active research programs in many of these fields.

The special capabilities developed by the Health Division are available to support the design and operation of the proposed TSTF. The Division is uniquely prepared to meet these needs because of its involvement with all of the tritium programs at Los Alamos over the past 30 y and in particular because of recent experience gained in contributing to the Conceptual Design Study for the Scyllac Test Reactor, the Environmental Impact Statement and the Conceptual Design Report of the Intense Neutron Source Facility.

A staff of experienced professional health physicists and technicians has accumulated considerable experience in tritium monitoring and worker protection

involving tritium handling. They regularly review procedures and designs related to radiation safety and advise users of tritium regarding its safe handling.

A group of safety and fire protection engineers review building and experiment designs and continually monitor laboratory sites for industrial safety and fire protection.

The staff of the industrial hygiene group has extensive experience in tritium bioassay. They also develop and test respiratory protective equipment, and assist with the design testing and reviewing of ventilation and air cleaning equipment and systems.

In the field of waste management, there is extensive experience at LASL in liquid and solid waste treatment and disposal of tritium. The waste management group maintains an ongoing research program in radioactive solid and liquid waste management.

The environmental studies group documents and evaluates the environmental effects of the Laboratory's activities at Los Alamos. This group maintains an environmental surveillance program by systematic sampling of air, water, soil and other environmental media in addition to active research programs in related fields. Their capabilities, including predictive evaluation for routine and accidental tritium releases, are provided by a staff of qualified professionals in the fields of chemistry, health physics, biology, meteorology and other environmental sciences.

Special committees bringing together expertise from several divisions within the Laboratory review specific problems and will provide support for the proposed facility. Two of these committees are the Committee for Specialized (Research) Pressure Vessels and Piping and the Liquid Hydrogen Safety Committee.

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VI. SCHEDULES, ORGANIZATION, COSTS

6.1 Organization

It is anticipated that the TSTF staff will be organized across Division and Group lines within the existing LASL organization. Figure 6.1-1 shows the proposed organization chart for the facility. The people listed in the chart will, for the most part, continue as members of their listed groups. However, their responsibilities and involvement in the TSTF will be extensive.

The TSTF project will be under the general supervision of the LASL Controlled Thermonuclear Research (CTR) Division with Drs. F. L. Ribe and K. I. Thomassen listed as project supervisors. This contact will assure that the TSTF staff has a continuing awareness of the developments in the MFE program and an appreciation of how these developments impact on the TSTF.

Administratively, the TSTF will operate within Group CMB-3 which is part of the Chemistry-Materials Science (CMB) Division at LASL. Dr. J. L. Anderson (CMB-3) will be the project manager and Dr. R. H. Sherman (Q-26) the alternate project manager. These individuals will have the prime responsibility for overseeing the design, construction and operation of the TSTF.

The scope of the TSTF project is sufficiently large that a minimum of four sections will be required to coordinate the design and construction phases of the project. These four sections will then have responsibility for operation, maintenance and upgrading of the various components falling within their general areas of responsibility. These sections will also coordinate the R&D studies that will be an integral part of the ongoing effort at the TSTF.

The section leaders listed in Fig. 6.1-1 will probably remain affiliated with their present groups at LASL, but will undoubtedly have supervisory responsibility over staff members and technicians who are affiliated with CMB-3. These section leaders will also have prime responsibility for the training and education of the TSTF staff in the operation of the TSTF. The use of the TSTF as a training facility for technicians and visiting scientists will be coordinated through this same organization curriculum. Vitae for the individuals listed in the organization chart are included in Appendix B.

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                    ┌─────────────────────────┐
                    │        PROJECT          │
                    │      SUPERVISION        │
                    ├─────────────────────────┤
                    │   F. L. Ribe, CTR-DO    │
                    │   K. I. Thomassen, CTR-DO│
                    └─────────────────────────┘
                                 │
┌─────────────────────┐   ┌─────────────────────────┐
│  INS COORDINATION   │   │     PROJECT MANAGER     │
├─────────────────────┤   ├─────────────────────────┤
│   C. R. Emigh, P-14 │   │   J. L. Anderson, CMB-3 │
└─────────────────────┘   ├─────────────────────────┤
                          │       ALTERNATE         │
                          │     PROJECT MANAGER     │
                          ├─────────────────────────┤
                          │   R. H. Sherman, Q-26   │
                          └─────────────────────────┘
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SECTION A	SECTION B.	SECTION C	SECTION D
D. O. Coffin, WX-5	R. H. Sherman, Q-26 J. R. Bartlit, Q-26	R. A. Jalbert, H-1	J.L. Anderson, CMB-3
MECHANICAL ENGINEER	CRYOGENICS	HEALTH & SAFETY	CONTAINMENT
PUMPS SEALS VALVES FUEL CLEANUP	DISTILLATION GAS ANALYSIS STORAGE ACCOUNTABILITY	MONITORING DETECTION EQUIPMENT WASTE DISPOSAL HAZARD ASSESSMENT HEALTH PHYSICS RESEARCH	DOUBLE CONTAINMENT EMERGENCY CLEANUP SYSTEMS ROUTINE CLEANUP SYSTEMS GETTER BEDS

Fig. 6.1-1   Proposed Organization Chart.

It is obvious that as the TSTF develops through the design, construction and operational phases, the manpower requirements for these various sections will change as to the numbers and qualifications of personnel required. The individuals listed in the organization chart will provide a continuing core of staff members who will make the transition from phase to phase proceed smoothly and in an orderly way.

6.2 Manpower

The projected manpower requirements for the TSTF are listed in Table 6.2-1. During the initial phase which involves scoping and initial design of the TSTF the requirements for the staff will be continually changing. It is deemed unlikely that there will be three full time staff members (SM) working on the TSTF project during FY-1977, but more likely there will be several people in different disciplines working a portion of the year on the TSTF design. This use of different people and disciplines will continue through the construction and installation phases.

As the project moves from the design phase into construction, installation, and testing, the number of necessary technicians will increase rather rapidly. It is anticipated that these technicians will become quite familiar with the components of the TSTF during these phases and that these technicians will then form a core of well trained, experienced technicians as the TSTF goes operational. The requirement of some twelve technicians during the operational phase of the TSTF is projected on the basis of continuous around-the-clock operation of the TSTF. This will require a number of highly skilled technicians capable of assuming some supervisory responsibilities. The number of technicians involved will be somewhat less if continuous operation over extended periods is not required.

The number and types of staff members required will drop off somewhat during the period when a large number of visiting scientists may avail themselves of the facility. Also, as the TSTF becomes operational a number of R&D projects, not funded directly by the TSTF, will undoubtedly be initiated. This could involve a fairly large number of people, but these projections are not included in the Table.

Table 6.2-1

Projected Manpower Requirements for the TSTF

FY	SM	Technician
1977	3	2
1978	4	5
1979	5	7
1980	6	9
1981	5	12

Table 6.2-2

Available Consultants Presently at LASL

R. A. Krakowski (CTR-DOT)	CTR Technology
J. A. Dean (Q-26)	Cryogenic Vacuum Systems
E. Meyer (P-14)	Vacuum Systems
F. J. Edeskuty (Q-26)	Cryogenic Engineering
E. C. Kerr (Q-26)	Cryogenic Technology
A. M. Valentine (H-1)	Health Physics Research
J. N. Lawrence (H-1)	Health Physics Research
D. T. Vier (CMB-3)	Tritium Technology
D. H. W. Carstens (CMB-3)	Tritium Technology
F. A. Damiano (CMB-7)	Design of Tritium Facilities
J. M. Barnes (WX-4)	Engineering Studies on Tritium Facilities

There are a large number of highly qualified scientists at LASL who may contribute to the necessary areas of the TSTF. These are people who have expressed a willingness to serve as consultants to the TSTF staff. Some of them may indeed become members of the TSTF staff, but such an assumption is not projected at this time. A list of these people and an indication of their areas of expertise is given in Table 6.2-2.

Other Laboratory personnel who have had past experience in tritium handling are the following: A. C. Briesmeister, CNC-4; R. Potter, Q-11; B. B. McInteer, CNC-4; Maxwell Goldblatt, CNC-4; A. H. Zeltmann, CNC-2; and Q-26 members E. Grilly, R. D. Taylor, W. Keller, S. Sydoriak, R. Mills, and T. Seitz, ADW-PM.

6.3 Schedule

Figure 6.3-1 shows a simplified schedule projection for the TSTF. This timing is based on the assumption that funding for facility design and initial site preparation will be available starting 1 October 1976 (FY-1977) at ~ $500K, with major procurement and site modification funds approved for FY-1978 and -1979. The chart shows the milestones for the four systems considered to be the pacing items. These are the tritium waste treatment (TWT), the cryogenic distillation system, the vacuum system, and the emergency tritium cleanup system (ETC). The schedule for these is shown in detail because they will require the longest lead time for procurement and installation. The schedule assumes that the cleanout of the existing facility can be completed in FY-1977 and that the essential modifications to the existing facility can be completed by mid FY-1978. This will provide beneficial occupancy of the facility at the earliest date. If this schedule is met, then facility preparation will not be a pacing item. The early completion of the TWT is considered essential, as once this system is operational it will be possible to start some experiments using tritium. Many of these experiments and tests can be accomplished even before the main gas loop and ETC are operational.

The critical funding years are FY-1978 and FY-1979. During this period all of the major components for the system must be ordered. If the requested funding is available within this time scale it is felt that the TSTF can be operational by late FY-1980. It is extremely difficult to project an earlier schedule and yet design a facility to completely demonstrate the tritium technology required for the EPR. Any delay in funding for the procurement of these major items will result in a corresponding delay in the on-line operation of the TSTF.

The major milestone dates necessary to achieving this schedule are:

July 1977 - Complete design of distillation system and TWT system.

April 1978 - Complete design of vacuum system and ETC.

July 1978 - Complete building modification; start installation of ETC.

October 1978 - Begin installation of TWT; begin installation of vacuum system and distillation system.

October 1979 - TWT system completed and on-line. Begin final testing of entire TSTF.
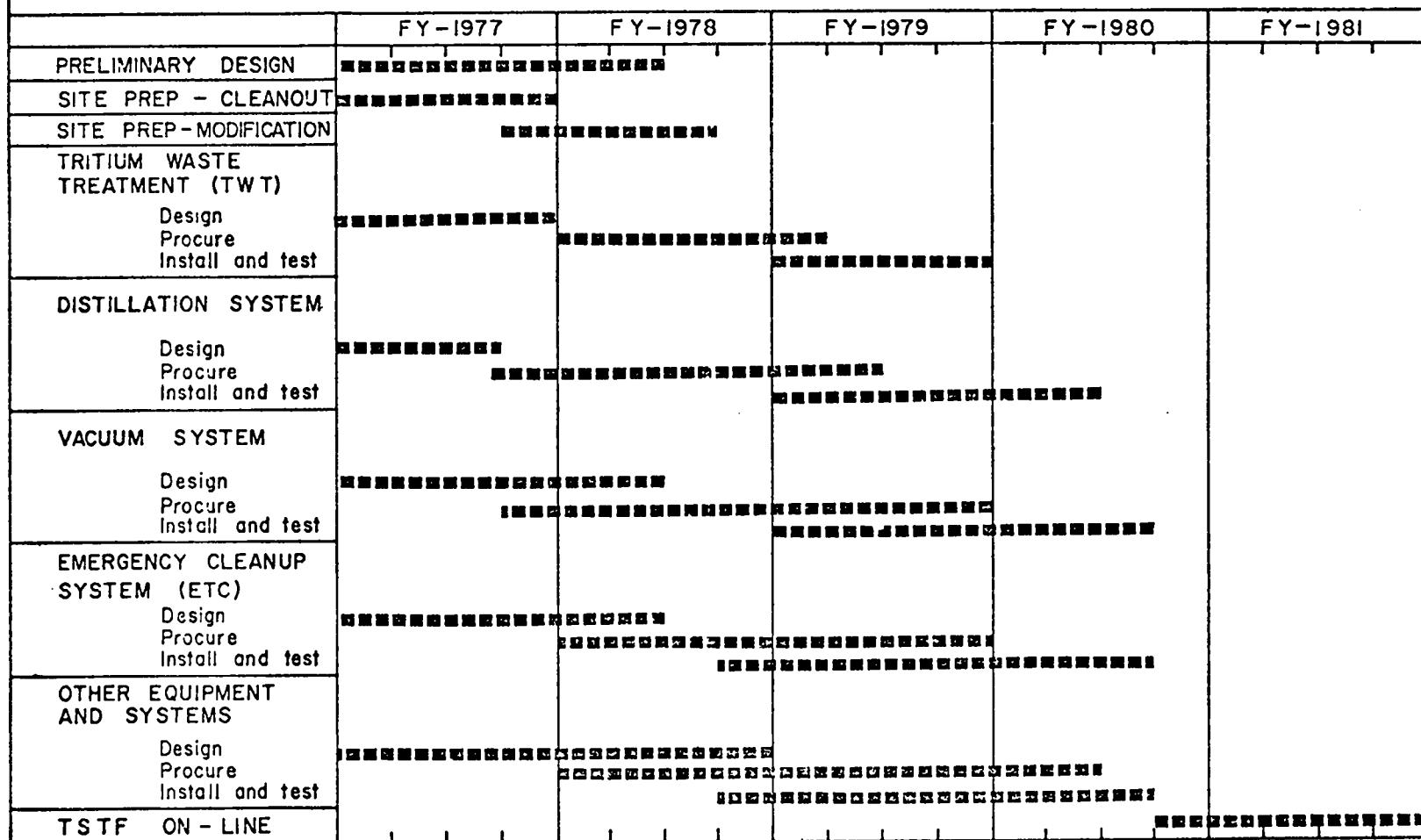
July 1980 - TSTF operational.

Fig. 6.3-1   Projected Schedule and Milestones for TSTF.

6.4 Cost Estimate

Table 6.4-1 is a breakdown of the cost estimate to design, construct and operate the TSTF through FY-1981. The costing is based on redundancy of all major components except the cryogenic distillation system and the large vacuum tank. This estimate includes some 270 ft^3 of gloveboxes most of which will be used for secondary containment of components. However, some of the glove box volume will be used for maintenance and as a preparation-packaging area for waste management.

Table 6.4-2 shows the projected costs by Fiscal Year for FY-1977 through FY-1981. The allotment of funding as shown in the table will be required if significant data are to be available by the end of FY-1980. The costs listed as Operation in Table 6.4-2 are based on the projected manpower requirement as listed in Table 6.2-1.

The cost estimate is based on a system with an ~ 200g tritium inventory with the main gas loop capable of handling 540-moles DT per day. The vacuum system will process 1/32 of this flow with the remaining gas bypassing the vacuum system. If this gas loop is reduced to handle only half this flow, i.e., 270 moles per day with a 100-g tritium inventory, there would be only a slight reduction in the cost estimated. The single most expensive item in the gas loop is the $800K distillation system. This includes the refrigerator, vacuum jacket, controls, and monitoring systems associated with the distillation system. The cost of this system will be only slightly decreased by reducing to half scale. The cost estimate for this system is based on the experience gained in designing a similar system for the INS.

The combination of the ETC-ventilation system is another very expensive item. The cost of the ETC can be almost halved by not requiring redundancy of this system. There is indeed considerable merit in not requiring redundancy here; this system is an emergency system,and it is not anticipated that the ETC will be activated with any high frequency. Included in the cost of the ventilation system is a 30-m stack.

The instrumentation and control system is estimated at $500K. Again, this system is completely redundant and is a high quality, high reliability system. These costs could conceivably be reduced to $300K by using instruments of lower reliability and by reducing the degree of redundancy. Included

in this cost is an emergency power supply that would be automatically activated during a power outage. This will provide for a safe, orderly shutdown of the TSTF during such an outage.

In summary, the cost estimate is based on a system capable of processing gas at a flow rate comparable to that projected for an EPR. The system is perceived to be highly redundant to assure reliability and will include many valves, flanges and other components that are necessary to assure safe, rapid maintenance procedures. Little savings can be achieved by reducing the flow rate of gas through the loop since many components such as the TWT and ETC are relatively independent of the flow rate. Additionally, most components that will handle a flow rate of 270 moles per day can also handle the 540 moles per day. Savings can be achieved by reducing the degree of component redundancy, but this is offset by a corresponding reduction in system reliability.

TABLE 6.4-1

COST ESTIMATE FOR TSTF

Initial Site Preparation	$190K
Final Site Preparation	176
Equipment Services	292
Fire Protection Modification	100
Tritium Waste Treatment System (TWT)	200
Emergency Tritium Cleanup System (ETC)	500
Vacuum Systems	300
Gas Analysis	120
Transfer Pumps & Getter Beds	100
Instrumentation & Control System	500
Glove Boxes	50
Distillation System	800
	$3328
Contingencies @ 20%	665
Installation @ 10%	333
Sub Total, Capital Equipment	$4326
Operating expenses FY-1977 through FY-1981	$3400K
Total, Design, Construct & Operate through FY-1981	$7726K

TABLE 6.4-2

PROJECTED COST ESTIMATES BY FISCAL YEAR

FY-1977 — FY-1981

FY-1977

Initial Site Preparation	$190K	
Capital Equipment*	100	
Operations	260	
Sub Total	550	$550K

FY-1978

Final Site Preparation	$176K	
Equipment Services	140	
Capital Equipment	1450	
Operations	485	
Sub Total	2251	$2251K

FY-1979

Equipment Services	$152K	
Fire Protection Modification	100	
Capital Equipment	1059	
Operations	680	
Sub Total	1991	$1991K

FY-1980

Capital Equipment	$700K	
Operations	925	
Sub Total	1625	$1625K

FY-1981

Capital Equipment	$259K	
Operations	1050	
Sub Total	1309	$1309K

Total, Design, Construct and Operate through FY-1981	$7726K

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*Capital Equipment Costs include installation and contingencies.

APPENDIX A

GLOSSARY

CAMAC	–	A computer interfacing device
CGL	–	Circulating Gas Loop
CPU	–	Central Processing Unit
CRT	–	Cathode Ray Tube
EPR	–	Experimental Power Reactor
ETC	–	Emergency Tritium Cleanup System
INS	–	Intense Neutron Source
MB	–	Megabites
SFTR	–	Scyllac Fusion Test Reactor
TSTF	–	Tritium Systems Test Facility
TWT	–	Tritium Waste Treatment System
χ/Q	–	An atmospheric dilution factor comprised of the ratio of the atmospheric concentration, χ (in Curies/meter^3) and the radioactivity release rate, Q (in Curies/second)

APPENDIX B

Curriculum Vitae

Name: James Lowell Anderson   Business Phone: (505) 667-6074

Home Address: 716 Meadow Lane   Home Phone: (505) 672-9117
                      Los Alamos, NM 87544

Date & Place   January 3, 1939   Marital   Married,
   of Birth: Santa Rita, NM   Status: 3 children

                                                Military Status: None

Education:

New Mexico State University   B.S.   1961 Chemistry
                                  M.S.   1963 Chemistry

Florida State University   Ph.D.   1966 Nuclear Physics

Membership in Professional Societies:

        Member, American Nuclear Society
        Member, American Chemical Society

Membership in Scientific Organizations, Committees, etc.

        Program Committee and Session Chairman, Tritium Technology
            Session, 24th Conference on Remote Systems Tech.,
            American Nuclear Society 1976.

        Member, LASL Tritium Operating Safety Seminar, 1975

Employment and Experience:

Sept. 1966   Staff Member-Supervisor, Los Alamos Scientific Laboratory,
to Present: Group CMB-3, Dr. John D. Farr, Group Leader. Investigation
                of the physical and chemical properties of the lithium
                hydride-lithium tritide system, including radiation effects
                resulting from the beta decay of tritium in this system;
                metal hydride chemistry and isotopic effects in these
                systems; investigation of the consequences of using molten
                lithium as a breeding blanket in a controlled thermonuclear
                reactor and a study of techniques for separating tritium
                from a lithium blanket. Investigation of low melting binary
                metal eutectic mixtures for extracting tritium from lithium;
                design, testing and operation of large tritium handling
                facility at LASL; supervisor 3-5 staff members and technicians
                involved in tritium technology.

Publications: 20 publications. Many of these deal with tritium technology
                and design of tritium facilities.

Curriculum Vitae

Name:	John R. Bartlit	Business Phone:	(505) 667-5419

Home Address: 113 Monte Rey Dr.   Home Phone: (505) 672-9792
Los Alamos, NM

Date & Place June 1, 1934   Marital   Married,
of Birth   Chicago, IL   Status: 2 children

Education:

Purdue University	B.S.	1956 Chemical Engineering
Yale University	Ph.D.	1963 Chemical Engineering

Honors and   American Men and Women of Science; NASA Technology
Awards: Applications Award - 1971

Membership in Professional Societies:

> Cryogenic Piping Code Committee of American National
> Standards Institute,
>
> Environmental Advisory Committee of Federal Energy Administration
>
> Sigma Xi and Tau Beta Pi scholastic honoraries

Employment and Experience:

1962 to   Staff Member in Los Alamos Scientific Laboratory Cryogenics
Present   Group.

> Work on: liquid hydrogen - storage, flow, heat transfer,
> two-phase flow, instrumentation, etc. - in Rover Program,
> 1962-71; design and fabrication of automated systems for
> handling liquid hydrogen in thin-walled (0.005-inch) flasks
> for use in physics experiments; cryopumping; and, at present
> Project Manager for hydrogen isotope distillation section
> for LASL's Intense Neutron Source facility.

1960   Instructor in chemical engineering, Yale University.

Publications: About 26 publications in the field of cryogenic engineering.

Curriculum Vitae

Name:	Don Owen Coffin	Business Phone:	(505) 667-6612
Home Address:	101 Grand Canyon Los Alamos, NM	Home Phone:	(505) 672-3307
Date & Place of Birth	June 27, 1929 Marshalltown, IA	Marital Status:	Married 2 children

Education:

Simpson College	B.A.	(Physics/Mathematics)
University of Coloardo	M.S.	1953 (Physics)

University of New Mexico Graduate Center
  25 hours graduate course work in
  physics, mathematics and computer science

Employment and Experience:

1965 to
Section Leader, TA-33 Tritium Gas Facility, WX-5.
Work involves design and operation of remote equipment
for purifying, analyzing, transferring and compressing
tritium gas for a wide variety of physics and chemistry
experiments. Electric, hydraulic and pneumatic control
elements are used, and design modifications are made to
provide tritium compatibility to vendor-supplied pumps,
valves, compressors and process instruments.
Computer programming experience, both for scientific
calculations and for instrument interfacing. A program-
mable controller is presently being interfaced to the
tritium handling system. This position requires careful
scheduling of maintenance and system upgrading with a
variety of jobs for many LASL groups. Supervise one
additional staff member and two technicians.

1955-65
Staff Member, TA-33 Tritium Facility, W-3.
Previous to becoming section leader, worked in all phases
of the tritium-gas-handling project. This experience
includes mass spectrometry, remote process control, remote
process instrumentation, high vacuum and high pressure work,
and materials testing.

June 1953 –
Physicist, Cryogenic Engineering Laboratory, National
Bureau of Standards, Boulder, Colorado.
Designed experiments and equipment to acquire data on
materials at cryogenic temperatures (20-300 K). Most
measurements were on metals and plastics for thermal
conductivity and transport properties. Used high vacuum
and low-level electrical measurement techniques.

Sept. 1951   Teaching Assistant (1/2 time), University of Colorado,
                  Boulder, Colorado
                  Taught labs in general and modern physics. Built
                  apparatus for new student experiemnts.

Publications: 10 publications, mostly about tritium apparatus and control
               technology.

Curriculum Vitae

Name:	Roland A. Jalbert	Business Phone:	(505) 667-4047

Home Address: 525 Rover Blvd.   Home Phone: (505) 672-9779
Los Alamos, NM 87544

Date & Place   August 7, 1924   Marital   Married,
of Birth: Woonsocket, RI   Status: 4 children

Military Service: U. S. Army Signal Corps
1942 - 1946

Education:

Massachusetts Institute of Technology   B.S. 1949 Physics
                                             M.S. 1949 Biophysics
University of Washington   1949-1950 Biophysics
University of Minnesota
  Radiation Biophysics (N.I.H. Fellow)

Radiological Defense, O.C.D. Staff College
  Battle Creek, Michigan Summer 1965

Membership in Professional Societies:

Member, Health Physics Society (HPS)
Member, American Board of Health Physics Panel of Examiners
HPS Sub-Committee on Internal Dosimetry Standards for
  Tritium (ANSI)

Patent: U. S. Patent No. 3,621,238 (with R. D. Hiebert)
               Gamma insensitive air monitor for radioactive gases.

Employment and Experience:

1966 to   Health Physicist, LASL, University of California. LASL
Present: experience involves responsibility for 1) radiative safety
               at sites handling tritium, nuclear weapon components,
               uranium and transuranium foils and accelerator targets,
               sealed and unsealed radioactive sources, and at sites using
               accelerators (cyclotron, betatron, Van de Graaff accelerators,
               various other x-ray machines and neutron generators): 2)
               reviewing and preparing S.O.P's for radiation safety;
               3) advising personnel regarding a) means of reducing risk
               of radiation exposure, b) pertinent local and government
               regulations, and 3) proper radiation monitoring techniques;
               4) quality assurance review (for new facilities or
               modifications); 5) assisting with training of health physics
               surveys and other Laboratory personnel; 6) radiological

engineering for the proposed Intense Neutron Source and
the Scyllac Fusion Test Reactor. Some research in
permeability of light-weight gloves used for handling
tritium (unpublished) and in tritium instrumentations
(see below).

1964   Visiting Summer Professor at G.E. Co., Richland, Washington

Sept. 1955 -   Assistant Professor of Physics, University of Alaska
June 1962

July 1963 -
July 1966

Oct. 1951 -   Health Physicist, G. E. Co., Richland, Washington
Mar. 1953

Jan. 1951 -   Radiological Physicist, MIT Cancer Clinic, Cambridge, Mass.
June 1951

Oct. 1950 -   Physicist, High Voltage Engineering Corporation
Jan. 1951   Cambridge, Massachusetts.

Curriculum Vitae

Name:	Robert H. Sherman	Business Phone:	(505) 667-5472
Home Address:	50 Kachina Los Alamos, NM 87544	Home Phone:	(505) 662-7980
Date & Place of Birth:	November 18, 1929 Chicago, IL	Marital Status:	Married, 3 children

Education:

Illinois Institute of Technology, Chicago IL	B.S.	1951	Chemistry
University of California, Berkeley, CA	Ph.D.	1955	Physical Chemistry

Profession: Physical Chemist

Honors and Awards:
American Institute of Chemists Medal 1951
Sigma Xi
Phi Lambda Upsilon (Chemistry, IIT)

Membership in Professional Societies:

Fellow, American Association for Advancement of Science
Member, American Chemical Society
Member, American Physical Society
Member, New Mexico Academy of Sciences
Member, American Society for Mass Spectroscopy

Membership in Scientific Organizations, Committees, etc.

Faculty, NERVA Cryogenics Course April 1964
                                            May 1964
Invited Lecture, National Bureau of Standards, Heat Division
    November 1964
Consultant to Argonne National Laboratory, Liquid Hydrogen
    Targets 1967
Member, LASL Central Computing Facility Users Group 1968-1971
Program Committee and Session Chairman, "4th Symposium on
    Temperature - Its Measurement and Control in Science
    and Industry, 1970-1971
Member, AEC Materials Information Meeting, Ames, Iowa, 1970
Member, LASL Tritium Operating Safety Seminar, 1975

Employment and Experience:

January 1955
to Present:

Staff Member, Los Alamos Scientific Laboratory,
Group Q-26, W. E. Keller, Group Leader, Isotopic
Separation of Helium and Hydrogen Isotopes;
Equation of State Data on Hydrogen and Helium
Isotopes; Dielectric Constant Studies on Helium
Isotopes; Fundamental Thermometry of Low Temp-
eratures; Vapor Pressures of Helium and Hydrogen
Isotopes; Phase Equilibria in Helium-Hydrogen
Isotope Systems; Mass Spectrometry of Hydrogen
Isotopes; Neutron and Pion Scattering from Liquid
Helium and Hydrogen Isotopes; Computation of
Thermodynamic Functions.

Equipment Used: Cryostats; High vacuum systems,
mass spectrometers; extreme precision measurements
of mass, volume, pressure, temperature, capacitance,
resistance, emf; digital computers.

1957-1958:

Visiting Consultant, Argonne National Laboratory
Argonne, IL

Calorimetry of ^{3}He at Low Temperatures, Magnetic
Thermometry; Adiabatic Demagnetization

Publications:

52 Publications