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Facility for the Testing of the TFTR Prototype Neutral Beam Injector

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FACILITY FOR THE TESTING OF THE TFTR PROTOTYPE NEUTRAL BEAM INJECTOR

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Summary

The design of the prototype neutral beam injection system for TFTR is nearing completion at the Lawrence Livermore Laboratory. This paper describes some of the features of the facility at the Lawrence Berkeley Laboratory where this prototype will be assembled and tested.

Introduction

The design of the prototype neutral beam injection system for TFTR is nearing completion at the Lawrence Livermore Laboratory. The details of this injection system are the subjects of a number of papers to be given at this conference.[1] This paper will serve to describe some of the features of the facility at the Lawrence Berkeley Laboratory where the prototype will be assembled and tested.

One of the reasons that lead to the decision to assemble and test the TFTR prototype beamline at the Lawrence Berkeley Laboratory was the availability of a site that could afford the following features: A working space sufficiently large enough to stage, assemble and operate both a neutral beamline and the ion source's high-voltage power supply; access to a crane with sufficient capacity and lift to install cryopanels into the injector vessel, and handle the shielding that would be required around the test area; a floor area strong enough to support the load of the shielding enclosure; access to sufficient electrical power for high voltage power supplies and operating equipment; a sufficient supply of cooling water and other utilities; and close proximity to shop facilities for the fabrication of ion sources and power supplies, etc. Of all the sites that were available at Berkeley, the one that best filled all these needs was the building housing the Laboratory's 184" Synchrocyclotron.

One of the older facilities on the hill, the 184" Synchrocyclotron is presently being operated as a medical accelerator for programs in LBL's Biology and Medicine Division. Over the past two decades, the 930-Mev helium ions from the accelerator have become the established treatment for certain pituitary diseases. Over 700 patients have received therapy at the synchrocyclotron for agromegaly and Cushing's disease. Presently the National Cancer Institute and ERDA(DOE) are sponsoring a new program where patients are being treated with the accelerator's helium ion beam for various kinds of cancer.

There was a portion of the building that had served in past years as space for physics experiments. Before this area could be made available for our use, it had to be cleared of disused experimental equipment, magnets, cabling, and shielding. During the month of May of this year, an intense effort was made to clear this area. Approximately 10 million pounds of concrete shielding blocks, and countless truckloads of equipment were removed to storage. The removal of this equipment and shielding provided a floor space inside the building of approximately 8000 ft^2. Served by a 24-ft x 25-ft access door from the street, this area is covered by two cranes. Each crane carriage has a 30-ton and a 5-ton hook with a 35-ft lift. Numerous covered trenches cross the floor space. Electrical utilities are readily available. Immediately outside the building are water circulating pumps and two cooling towers with a total capacity of 8 MWat s. A 12-kV line from the Grizzly Substation is nearby, and the fabricating shop facilities are a few minutes walk away.

The available space was laid out to best serve three new customers: The TFTR injector and its high voltage power supply; the assembly and test of General Atomic's Doublet III beamline; and a (possible) future R & D program on the electronuclear conversion of fertile to fissile material.

The space that is of most interest, and the subject of this paper, is that devoted to the use of the TFTR injector. This is shown in Figure 1. This report will deal with some of the details of the facility:

The Shielding Enclosure for the
  Neutral Beamline

The Computer-Control Area

The High-Voltage Power Supply Areas

The Cryogenic Supply System for the
  Cryopanels

The Auxiliary Vacuum System

The Utilities Supply

The Shielding Enclosure for the Neutral Beamline

The neutral beam injector is the subject of a number of papers to be given at this conference.[1] It might be well to briefly describe the vessel and its contents here, however, before going on to discuss the shielding enclosure. Basically, the injector is a vacuum vessel with the approximate dimensions 20-ft long, 15-ft high, 10-ft wide. There are three locations about halfway up the rear of the vessel for an ion source and its auxiliary equipment; i.e., isolation valve, remote disconnect coupling, SF$_6$ insulating gas chamber, etc. Hung from this rear cover, on the inside of the vessel, is the cooled neutralizer beampipe for each source. The upper cover of the chamber provides the support for the cryopumping modules that line the side-walls of the vessel, the deflecting magnet and ion dump, and the diagnostic calorimeter. The liquid helium and liquid nitrogen dewars are installed on the outer surface of this cover. The single aperture, through which the three converging beams emerge from the vessel, is covered by a large vacuum valve on the front of the vessel. In locating this neutral beam injector inside the shielding enclosure, consideration had to be given to allow sufficient workspace around the ion source area, and to provide crane access to upper cover of the vessel and each of its individual components.

In addition to providing space for this beamline, the shielding enclosure was made large enough to provide space for a downstream chamber that would house the beamdump that would simulate the target plasma in the TFTR Tokamak. Pumped by its own cryopanels, this chamber would be connected to the injector vessel by a vacuum pipe that would simulate the one at PPPL.

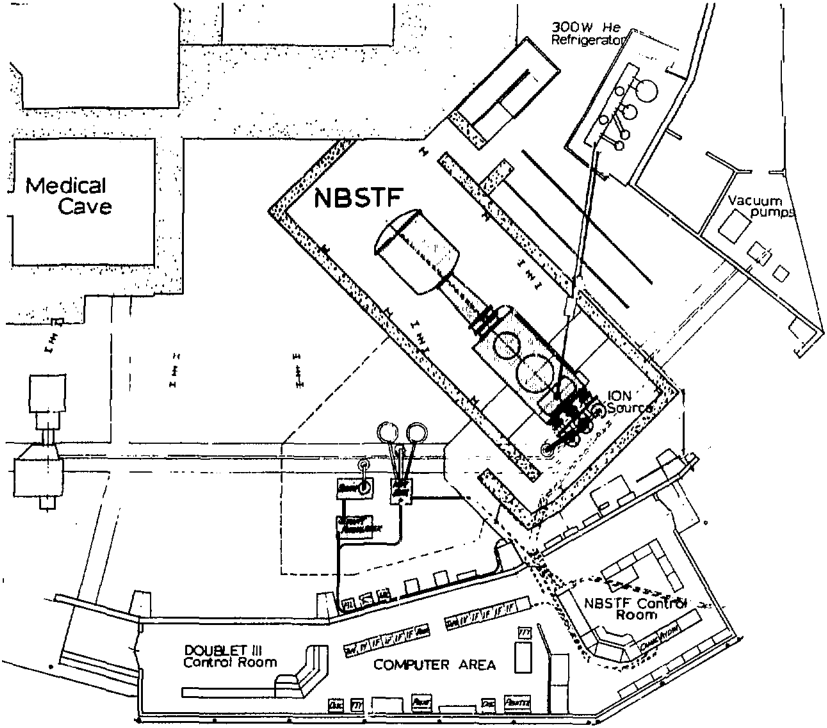

Figure 1. Layout of TFTR Neutral Beam Test Facility

The thickness of the concrete walls and roof of the shielding enclosure were determined by calculating the radiation flux that would come from the calorimeter in the injector vessel and the beamdump in the target chamber. Not considered were neutrons produced by d-d reactions in the neutralizer column, and neutrons from the dumping of the non-neutral beam. This decision was reached after observations at LBL's 150-kev Test Facility[2] showed that the neutralizer column had a neutron emission of one-tenth that of the target. The surface temperature of the copper target plates were considered to be warm enough to prevent deuterium self-loading. During the beam pulse, half of the beam particles were considered to constitute the target atoms while the remaining half were incident on the target. With an expected beam current of 65A at 120 kev, and a beam pulse duration of 0.5 sec at a repetition rate of 12 pulses/hour, an assumed projected beam area of 85 cm^2 produced an emissivity of 8.2 x 10^9 neutrons per second.

ERDA regulations require that new installations show a factor of 5 reduction from previous design requirements, so that at the outside of the shielding the dose equivalent should be no more than 1 rem/year based on a 40-hour week. The thickness of shielding deemed necessary to reduce the neutron dose equivalent rate to 0.5 mrem/hour (av) or 3.5 n/cm^2 was based on a safe working distance of 5 M from the target. With these criteria, a 2-ft thick wall and roof were determined to be suitable, thereby permitting unlimited access to the exterior of the shielding enclosure during operation.

In planning the shielding vault, consideration was given to the following points: A minimum size enclosure that would provide ample working space at minimum cost; a 30-ton limitation on the crane, and a 5000 psf load limit on the floor; a design criteria of 0.5-g horizontal seismic loading; and a modular construction that would permit the same sized blocks to be used on the roof as well as in the walls.

The resulting enclosure shown in Figure 1 has the following dimensions: Walls and roof blocks 2-ft thick of ordinary concrete; inside floor space 24-ft x 66-ft, and a ceiling height of 20-1/2-ft. Every effort was made to keep this ceiling height to an absolute minimum.

This was dictated not so much as a matter of economy, but because of the stringent earthquake requirements that apply in this area. The shielding enclosure is supported by an internal structural steel framework, the columns of which are shown sectioned in Figure 1. This frame has interconnecting beams at the column tops, just under the ceiling. The position of the injector in the shielding enclosure was chosen to not only provide workspace around the ion source area, but to eliminate the need to unbolt any of the crossbeams should the calorimeter or the magnet need to be removed from the vessel. Notches will be cast into the roof blocks to provide access to the dewars for the cryogenic transfer lines.

The synchrocyclotron was shutdown during the month of August because of patient scheduling at the medical facility. We took advantage of this period to perform the noisy, dirty, work of drilling through the flooring and installing the support caissons for the steel framework. A dozen caissons were installed in holes which were 3-ft in diameter to a depth of 8 ft, then 18 inches in diameter to a depth as great as 30 ft. The structural framework is presently under construction and will be erected in early December. When the injector arrives at the building in March, portions of the structural framework will be temporarily removed to allow its installation. Should funds be made available in Fiscal Year '78, the concrete shielding blocks will be fabricated and installed on the support frame.

A simple maze of concrete blocks will provide access to the vault at opposite corners. These maze openings have been made long enough to limit, as much as possible, streaming of neutrons towards occupied areas. ERDA regulations impose a requirement that dose levels be "as low as practicable"; should it be found to be required, surplus shielding doors will be brought out of storage and substituted for the maze openings.

The Control-Computer Area

When the cyclotron's outside shielding was removed to storage, its support pad was left behind. This concrete pad was extended, to provide the floor slab for a new 2000 ft^2 building which will house the TFTR control room, the Doublet III control room and a computer that will be shared by both facilities. This flat-roofed building is of simple framed construction; the interior is painted sheetrock and the exterior transite sheathing.

When the building was completed, a 42-inch wide strip of sheetmetal was unwound from a continuous roll; it was fastened to the floor slab, and the wall between the computer and the high voltage power supply, with a waterproof contact adhesive. These sheetmetal strips were overlapped and soldered along their edges to form a continuous unbroken groundplane. All electrical conduits, ducting, and cabling that enter the control-computer room are to be fastened firmly to the sheet and kept as close to it as possible. This will minimize noise-current pickup, and its transmission into other areas that might be sensitive to it. In addition, the sheetmetal on the wall will provide a barrier to radiated electromagnetic noise that might reach the area from the high voltage power supply.

A raised floor has been installed throughout the computer-control room. It will provide easy access to the conduit, wiring, and ducting that will be installed underneath it. It is made of commercially-available 2-ft x 2-ft carpeted panels supported on pedestals that have been fastened to the subfloor. The panels are covered with a nylon carpet that has been made with static-control additives. A conductive vinyl cushion between the panels and the understructure provides sealing, sound deadening, and grounding to eliminate static buildup. The panels are capable of supporting a uniform load of 250 lbs/ft^2 and a concentrated load of 1000 lbs. The pedestals are fastened to the subfloor with both adhesive and powder-actuated fasteners to provide rigidity, a good electrical contact, and seismic restraint. The carpeted panels in the large unbroken floor area will allow easy penetration of wiring to the computers, and will reduce the noise level in the area, and minimize operator fatigue.

Ventilation and air-conditioning will be provided with a roof-mounted unit. Its ducting will be in the overhead space shared with the lighting and fire control sprinklers. Fire protection under the access flooring will be provided by a self-contained halide system. Floor space in the central area of the room will be shared by the computer, tape deck, decwriter, disc, and line printers. The space at the rear of the control room will accommodate storage lockers and a limited workshop area for ion source maintenance.

The High Voltage Power Supply Areas

Components for the high voltage power supply occupy two separate areas: A 24-ft x 80-ft concrete pad outside the building, and an 825 ft^2 screened area immediately adjacent to the shielding enclosure.

Briefly, the concrete pad accommodates the interrupter switch and step start contactor, two 12 kV - 4.16 kV transformers, step tap-changers, step voltage regulator, phase shift transformers and two 3.38 MVA rectifier transformers. Power from this equipment is fed into the building via a transmission line enclosed inside a 6" rigid steel conduit. This conduit runs under the roadway outside the building where it then enters a 16-in. x 24-in. trench which brings it to the inside screened enclosure of the power supply.

The screened area of the power supply inside the building houses a number of major electrical components: The hot box containing the arc modulator, and the telemetry equipment for the arc, filament, accel, and gradient grid supply; the shunt regulator containing its control system, the ignitron crowbars, six parallel varistor stacks and their DP-15's and filament transformer, the MOV varistor string and its 4CW 50000C and filament transformer; the arc and filament power supply transformers in their respective SF_6 enclosures; the SCR switch; the crowbar; and the 1H reactor.

The arc, filament, and accel are combined into a single 50-ft long high-impedance air dielectric transmission line which runs from the hot box through a sheetmetal-lined trench to the adjacent shielding enclosure housing the beamline. Emerging from the trench, it runs through the center of a toroidal transformer core arc snubber to the ion source. The last few feet of the transmission line are flexible enough to accommodate the ± 3-ft transverse motion of the source.

The details of this high voltage power supply are covered in another paper to be given at this conference.[3]

This power supply area is enclosed inside a 20-ft high fence. This fence, built of 3-ft wide moveable panels, is covered with a 1/4-inch mesh hardware cloth. In addition to providing a personnel safety screen to the high voltage equipment, the fence also forms a barrier to radiated electromagnetic noise that might reach control equipment from the power supply. The floor of the power supply area, similar to the computer control room, is covered with an unbroken sheetmetal floor. This floor is electrically common to the computer control room, the power supply area and the shielding enclosure. All conduits, etc., are firmly fastened to it in an attempt to minimize noise-current pickup and transmission into sensitive areas. The screened power supply area is accessible through interlocked doors; and since the area will be unroofed, access to the space by the crane hooks will be similarly interlocked.

The Cryogenic Supply System for the Cryopanels

For operation at the Princeton site, three ion sources will be installed on the injector vessel. The total gas flow for these sources is estimated to be as much as 100 Torr liters per second per injector. Condensation cryopumping will be used to handle this large gas load. Although only a single ion source will be tested at a time, a full complement of cryopanels will be installed on the prototype injector. The design and operation of the cryopanels will be discussed in detail in another paper to be given at this conference.[4]

The cryopanels consist of eight modules; four on each side of the injector, supported from the cover of the vessel. The liquid-helium temperature pumping surface of the panels and its liquid-nitrogen temperature radiation shield will be constructed of quilted double-walled stainless sheets. The liquid helium cooled cryopanels will be gravity fed from a 750-liter dewar located atop the injector. No attempt will be made, at LBL, to subcool the helium for operation lower than 4.2K in order to improve hydrogen pumping. The panel's inner chevrons will be made of copper, and will be cooled by liquid nitrogen that will be gravity-fed from the U-shaped dewar also located on the injector cover.

A helium liquefier-refrigerator has been ordered, and it is scheduled for delivery during October 1978. As a refrigerator, it is rated at 200 watts without liquid nitrogen precooling; 300 watts with precooling. As a liquefier, it will supply 80 liters per hour.

The location of the two-expander coldbox is shown in Figure 1. It will be mounted on an elevated platform and its vacuum-insulated helium transfer lines will travel the shortest distance possible between the coldbox and the 750-liter dewar atop the injector. The final size and shape of the target chamber has not as yet been decided. The cryopanels for the one shown in Figure 1, typical of its type, have been discussed in an earlier paper.[5] The liquid helium transfer lines for this chamber are not shown in the figure, for simplicity; they would come directly from the liquid nitrogen shielded distribution box, accessible from the roof of the shielding vault. Liquid nitrogen will be supplied to the coldbox of the liquefier-refrigerator, the dewar atop the injector, the chevrons in the target chamber, and the Doublet III experiment located elsewhere in the building through the vacuum insulated transfer lines and distribution boxes shown atop the shielding closure. The skid-mounted single-stage screw compressor, and its oil removal system, are not shown. They will be located outside the building to reduce the noise level in the operating area.

It is intended that the liquefier-refrigerator will be installed during fiscal year 1979. As a temporary measure, in the months prior to the delivery of the coldbox, the 750-liter liquid helium dewar will be supplied from a transport dewar that will be filled at the 1500-watt ESCAR liquefier-refrigerator located at another building at the Laboratory.

The design, fabrication, installation and operation of this cryogenic supply system will be covered in a separate paper to be written at a later time.

The Auxiliary Vacuum System

The use of non-cryopumps on a neutral beam injector has been determined to be unsatisfactory because of some combination of their being too large, too dirty, requiring too much maintenance or presenting substantial danger of contamination to the ion sources or the Tokamak's vacuum chamber. Nevertheless, the vacuum vessels must be roughed-down to the point where the cryopanels can be chilled.

Of the two mechanical pumps used to rough the prototype injector, one is a Stokes Model 1722 two-stage unit: A rotary oil-sealed 300-cfm, Model 412 vacuum pump backing a 1300-cfm rotary lobe dry high vacuum booster. The second vacuum pump is also a Stokes Model 412 300-cfm vacuum pump. The roughing line has a trap of refrigerated copper wool used to prevent oil migration from the mechanical pump.

From atmospheric pressure, the injector vessel can be rough-pumped to 100 mTorr in 34 minutes; to 50 mTorr in 41 minutes. It is calculated that the cryopanels will take approximately 8 hours to cool to 77°K, and about 4 more hours to cool to 4.2°K. The base pressure in the tank, upon pumpdown, is expected to be in the low 10^{-7} Torr region. The pumping time required to achieve this base pressure will vary, depending upon the amount of water vapor in the chamber and the length of time it has been exposed to air. So that these pumpdowns will be as short as possible, the vessel will always be returned to atmosphere by first letting in a few cylinders of dry nitrogen, followed by air that has been filtered to minimize surface contamination.

The vacuum system is protected by a system of interlocks that protect the chamber and individual vacuum components against serious damage, should there be failure of any of the supplied utilities or any part of the system or upon any operational error.

The cryopanels are supplemented by a 3500 liter per second (air) Leybold-Heraeus turbomolecular pump, backed by a Leybold-Heraeus 26 liter per second oil-sealed rotary piston pump. Various supplementary vacuum pumping systems were examined and of all systems considered, the performance of a turbomolecular vacuum pump was preferred. Although the initial capital investment is high, there is a net savings in maintenance costs for the life of the experiment over a mercury and oil vapor diffusion pump or a titanium bulk-sublimation/ion pumps. The turbopump can handle large gas loads on a continuous basis and achieve the desired vacuum pressures. Maintenance on the pump is expected to be minimal. When used on TFTR, occasional oil changes will be needed to be made in a controlled manner in case of tritium contamination. The pump is compact and on the prototype will be mounted close to the vacuum vessels to reduce conductance losses.

Although turbopumps are often connected to other systems without valves, interlocked pneumatically-operated valves will be placed in the line between our turbopump and the vacuum vessels to lessen the danger of contamination to the cryopanels. At this time, it is deemed not necessary to provide a refrigerated trap over the turbopump to reduce the movement of oil into the vacuum vessels. However, if it is seen at a later time that one is desirable, room has been left in the connecting piping to accommodate it.

The Utilities Supply

The items that require cooling on the injector are: The ion source and accelerator, the neutralizer, the magnet, the ion dumps, the beam scrapers, and the calorimeter. With one source at a time in operation, the ion dumps, scrapers, and calorimeter will require only one-third the water required at the PPPL location, although their piping will be installed full-size.

There are two cooling towers adjacent to the building. They provide a total capacity of 8 MWatts; 4.3 MWatts tower water, 3.7 MWatts low-conductivity water. Their piping circuits already exist in the building, close to the shielding vault. Only the manifolding and short runs of piping to the injector beamline need to be completed.

Conclusion

It is planned that the prototype injector complete with cryopanels and associated manifolding, the deflection magnet and ion dump, one source and its neutralizer, and the calorimeter will be installed in late Spring, 1978. The auxiliary vacuum system, cryogenic supply system except for refrigeration, the utilities, controls and computer housing will be operable at about the same time. Debugging of the power supply will start in July, 1978. Installation of the shielding blocks and target vessel will be deferred until FY '79. An adequate control and diagnostic system for manual start-up will be installed in FY '78, and single source testing is scheduled to start in late December 1978.

References

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