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SCIENTIFIC OBJECTIVES OF THE PROPOSED

HIGH VOLTAGE TEST STAND

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January 15, 1975

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SCIENTIFIC OBJECTIVES OF THE PROPOSED
HIGH VOLTAGE TEST STAND*

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January 15, 1975

The pacing item in the LLL/LBL Neutral Beam Development program is the capability of our test stands.

As outlined in the DCTR Interim Plan for Neutral Beam Development,¹ our present program has two main areas of responsibility:

1. High current pulsed sources based on a redesign of our 50A, 10 millisecond source to operate at energies up to 80 keV (or more).
2. 150 - 200 keV injector with improved performance characteristics (primarily efficiency) aimed at use on TCT and other future devices, including advanced mirror systems.

Parameters for the proposed High Voltage Test Stand² were chosen originally to carry out the second of these tasks.

However, for greater flexibility, from the beginning the facility was designed for variable voltage up to the desired 200 KV limit. With the goal of a megawatt or more of neutrals, power supply components were chosen at multi-megawatt ratings and it was expected that higher power could be available

¹ Interim Plan May 29, 1974. See Appendix A, LLL Prop-115, Sept. 1974.

² LLL Prop-115, Sept. 1974.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

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in shorter pulses at lower voltage. With the concurrence of DCTR, we have been able to take advantage of the availability of rugged transformers meeting these requirements. It is our conclusion that the proposed High Voltage Test Stand designed around these transformers can, in two different operating arrangements, provide the following broad capability:

Δ - y mode: 25A, up to 200 KV, D.C.

Δ - Δ mode: 100A, up to 100 KV, 0.1 second up to D.C.

It is planned to provide isolation of the power supplies and the ion source to permit operation with either positive or negative ions. Also, the facility will be located in a shielded building to permit operation with high energy deuterons.

It is already apparent that the flexibility we have provided for is in fact needed as soon as we can get it. Even on the present schedule, calling for completion of the test stand by January 1977, once again it is the test stand that will pace the development.

Since the Interim Plan was drafted in May 1974, further study of TCT has indicated the desirability for high current, pulsed injection before compression as an alternative startup approach. Because of the large energy required to fill TCT, the pulse length should be longer than 10 milliseconds. Nominal parameters are 80-100 keV at 30 msec or more. This is a natural extension of our present program, but we presently have no test stand with this capability.

A similar beam with even longer pulse length will be required to test steady state neutral injection in the MX mirror experiment presently planned

for construction beginning in FY 77. Because of limited access and the necessity for burying untrapped beam in MX, it will be necessary to retain the good convergence and high current density characteristic of our 50A pulsed beam, but at higher voltage and for longer times. Anticipated requirements for MX are 25-100A, 100 keV, for at least 0.1 sec up to seconds. Development of this beam would simultaneously satisfy the requirements for MX and the high current startup mode for TCT described above. The High Voltage Test Stand would be essential to carry this development to completion.

These are only some of the beam requirements under discussion in what is necessarily a still unfolding national program. But the trend is clear, as is illustrated by the history of actual and planned neutral beam requirements listed in Table 1. The High Voltage Test Stand we are proposing is essential if we are to fulfill our responsibility in helping to meet these requirements.

Thus far we have addressed only the high voltage capability designed into the test stand. The pumping capability in order to handle the gas load from the ion source is equally important. Essentially the test stand consists of two parts, one being the power supply and the other the pumping system. Ion sources, accelerating columns and neutralizers for particular applications would be installed and removed from one test to another.

The pumping system will employ large cryopanelts to maintain 10^{-4} torr pressure against a gas load of 250 amperes equivalent such as might be associated with a 100A ion current. The cryopumping system lies within the state of the art in principle, but systems of this magnitude have not been built. Experience with this system will be very valuable to ongoing engineering designs. The pumping system represents nearly half of the cost of the test stand.

Finally, a word about efficiency. The CTR program is already planning and building very expensive devices in which neutral beams are a dominant element in the cost, as is evident in Table 2. The kind of improvements in efficiency that would be possible by developing direct recovery of unneutralized ions and negative ion sources could save millions of dollars and greatly reduce the risks and complexity associated with handling even larger amounts of power.

These are not distant enterprises. In view of the beam development required, they are very near term. While it is prudent not to rely solely on development of advanced, efficient beams to meet the nearer term requirements, likewise it is only prudent to carry out these advanced developments as rapidly as possible in view of the considerable savings they might afford. There is no doubt that a superior, efficient beam would be adopted whenever it becomes available.

Attention to efficiency is especially important at high energy. In TCT and advanced mirror systems, high energy ions produce fusion reactions as they slow down in the plasma. To optimize this, it is necessary to inject the ions at energies well above the D-T cross section maximum and it is this which leads to an interest in 200 keV injection. As was made clear in the deliberations that led to TCT, for the foreseeable future even tokamak systems will depend largely on fusion by high energy beam interactions and not on thermal fusion. Moreover, in tokamak systems large enough to sustain thermal ignition, beam penetration of the plasma may well require injection at energies of 200 keV or more in any case. Hence, we can anticipate a continuing requirement for high energy beams in D-T experiments.

At 200 keV, efficiency is much improved by using negative ions, as is illustrated for deuterium in Table 3. For ordinary hydrogen, which will continue to be important in confinement experiments for many years, the same results apply at 100 keV.

Development of efficient beams based on negative ions will continue to be an important component of the program utilizing the High Voltage Test Stand. In this we expect to work closely with other groups. We have taken as our special task the approach of creating negative ions from positive ions by double charge exchange. This is relatively straight-forward and should provide valuable experience with negative ion acceleration. It has the disadvantage of a rather high energy cost per negative ion (> 20 keV), so that an advantage is gained only at high energies. However, we will expect to follow closely the work of other groups on direct extraction of negative ions and to cooperate with them in testing improved negative ion sources on the High Voltage Test Stand at Livermore. We will also continue to study designs incorporating direct recovery and the multiple-pass neutralizer concept.

Table 1. Examples Showing Trends in
Neutral Beam Requirements

	<u>MIRROR</u>	<u>TOKAMAK</u>
1972	Baseball II 0.3 KW up to 3 KV DC 12 KW up to 15 KV DC	
1973	2XII 200 KW 20 KV 10 msec	ORMAK 200 KW 30 KV 300 msec
1975	2XIIB 12 MW 20 KV 10 msec	ATC 2 MW 20 KV 10 msec
1976	BBII-T 5 MW 20 KV 10 msec 1 MW 40 KV 100 msec	PLT up to 4 MW 40 KV 300 msec
~ 1978	MX 20 MW 20 KV 10 msec 10 MW 100 KV > 100 msec	Doublet III 10 MW 40 KV 1 sec
~ 1980		TCT(?) 60 MW 80 KV 30 msec 10-20 MW 150 KV 300 msec
~1985	FERF(?) 35 MW 100 KV D.C.	

Table 2. Importance of Neutral Beam Costs
in Future CTR Projects

FERF Cost Estimate (1974\$)

Magnet	\$ 76 M	
Neutral Beams	64	28%
Other	85	
	<hr/>	
	\$225 M	

Other Projects with Similar
Beam Power Requirements

FERF	35 MW
TCT	10-20 MW
Doublet III	10 MW
MX	10 MW

Table 3. Power Efficiency of 200 KeV Deuterium Neutral Beams

Ion Type	Without Direct Recovery	With Direct Recovery
D_+	20%	60%
D^- Double Charge Exchange in Cs	54%	78%
D^- Direct Extraction	59%	89%

Assumptions:

1. 2.5 keV Energy required per ion by direct extraction (D_+ or D_-).
2. 21 keV Energy required per D_- by double charge exchange.
3. 85% direct recovery of unneutralized ions.
4. 60% $D_- \rightarrow D_0$ conversion and 20% $D_+ \rightarrow D_0$ conversion at 200 keV.

Table 4. Estimated Costs for
High Voltage Test Stand (\$K)

High Voltage Power Supply	\$ 770
Cryopumps, Liquid Helium, etc.	1050
Site Modification, Utilities, etc.	450
Target Tank and Misc. Mechanical	310
Power Supplies (filament, arc, etc.)	590
Controls, Telemetry, etc.	730
Contingency	<u>600</u>
	\$ 4500 K

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