# Mechanical Design and Development of a High Power Target System for the SLC Positron Source*

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*Abstract*

In order to bring the SLC Positron Source luminosity up to design specifications, the previous (stationary) positron target had to be replaced with a version which could reliably dissipate the higher power levels and cyclic pulsed thermal stresses of the high intensity 33GeV electron beam. In addition to this basic requirement, the new target system had to meet SLAC's specifications for Ultra High Vacuum, be remotely controllable, "radiation hard", and designed in such a way that it could be removed and replaced quickly and easily with minimum personnnel exposure to radiation. It was also desirable to integrate the target and collection components into a compact, easily manufacturable, and easily maintainable module.

This paper briefly summarizes the mechanical design and development of the new modular target system, its associated controls and software, alignment, and the quick removal system. Operational experience gained with the new system over the first running cycle is also summarized.

## I. MODULE DESCRIPTION

*1. Target Drive System:* Due to the extreme congestion of the Positron production and bunching area, the entire Module system had to be designed *around* the target and its drive system. An extensive amount of effort was initially spent roughly analyzing various target cycle concepts and geometries, calculating the response of these targets to beam induced thermal loads, and then estimating the effect each would have on other system component designs. Kinematic variables for the most promising models were optimized to make the system fit within the spatial constraints of the Positron Vault area.

The actuation system finally chosen, known as "trolling", is shown, greatly simplified, in Figure 1. This concept provided a compact and relatively simple way of providing the specified spacing between beam pulses required to reduce the risk of thermal stress fatigue fracture in the target [1].

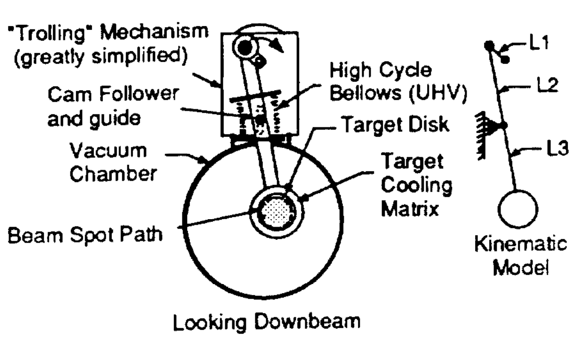


Figure 1. Trolling Target Model

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The target itself is a 2-1/2" diameter, 0.812" thick disk of arc cast and forged W-26Re, ground to final diameter before casting. The disk is copper plated (to aid in metal bonding), cast in sterling silver with its cooling tubes, and post-machined to size. Diffusion bonding and shrink fitting were also considered as manufacturing techniques and both methods were prototyped. However, casting was chosen for production due to its superior thermal and mechanical interface.

The target arm assembly is suspended and supported in the vacuum chamber by the target housing mounted outside the chamber. A specially designed "high cycle" bellows is used to feed the target into the vacuum chamber and provide a flexible pivot. Figure 2 shows the target drive system as it appears when removed from the Module.

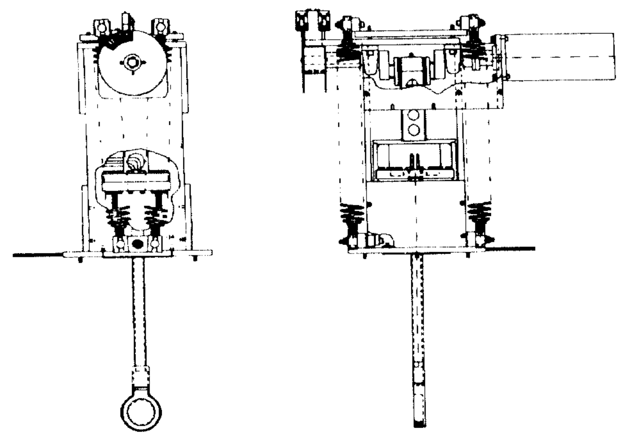

Figure 2 Trolling Target Drive Mechanism

Kinematic, environmental, and life cycle requirements were distributed to various bellows manufacturers throughout the conceptual design of the drive system for feedback.

The bellows chosen is a hydroformed, proprietrary design called a "nested convolute", engineered to withstand one full year's running at 100% duty cycle (~60,000,000 cycles) [2]. It is constructed of 4 hydroformed and heat treated bellows segments of Inconel 718 butt welded end-to-end using electron beam techniques. Special Conflat™ flanges are welded on to complete the assembly and make it interchangeable.

Welded bellows were suggested, but were ruled out due to their inherent stress concentrations, quality control problems, and susceptibility to fatigue failure.

The first two of the special bellows built were tested at an accelerated speed immediately after production. One surpassed 60,000,000 cycles and the other 40,000,000 cycles with no signs of damage or leakage.

All the components in the target drive system, in addition to the bellows, were designed for "infinite life" and high radiation resistance. Dynamic models of the system were constructed to help size components and predict system deflections during operation.

The springs which were installed to back-up the vacuum load imposed on the assembly due to the large I.D. of the bellows were custom designed with conical ends and matching end retainers to reduce stress concentrations and facilitate easy assembly and maintenance.

With the exception of the insulation on the control wires, the entire Module system is designed utilizing non-organic or radiation resistant components. All insulators and cooling water stand-offs are ceramic or Macor (machinable glass ceramic).

The complicated kinematics of the drive system produce a path of the beam on the target which is not perfectly circular. A more detailed discussion of the beam trace details and operational ramifications is given in [1].

2. *Flux Concentrator:* The original design of the Spiral Flux Concentrator was extremely simple and effective and had proven itself quite well over the past two years of running. The basic design was left intact in the new target system with some minor modifications to the supports and vacuum interface.

The Flux Concentrator is designed to run at 10kV and 16kA, with a 5μs pulse width at 120 pps. The peak field generated is 58kG and the RMS power deposited in the flux concentrator body (from the pulser) is about 3kW. At full beam rep. rate and current, the power deposition in the body due to the beam shower is 4kW. These deposition rates were estimated using EGS[3] and verified by extrapolating operational measurements from lower beam currents.

3. *Tapered Field Solenoid (TFS):* A high DC magnetic field is required at the target downstream face to capture the low energy positrons. Duplication of the axial field profile and 10kG field strength from the previous target system was a design goal for the new system. Many POISSON (2D finite difference magnetostatic/electrostatic code) iterations were run to optimize the flux return iron geometry and coil placement around the new target system. Field inflections were eliminated and the peak field at the target face was increased by ~20% over the old design. Practical requirements such as manufacturability and ease of assembly and maintenance were concurrently designed in as well.

Magnetic measurements conducted on the first Module verified the field profile to be within 2% of design. At a maximum current of 750A, the TFS generates a 13kG DC field at the target exit face.

4. *Vacuum Chamber:* The vacuum chamber used to house the flux concentrator and target is contained within the Tapered Field Solenoid. It is a custom design and was configured to maintain structural rigidity, provide the maximum pumping speed to the target and flux concentrator area, accomodate the pole tip section of the Tapered Field Solenoid flux return iron, mate up to the existing accelerator section, and allow the target and flux concentrator to be removed independently.

The downstream vacuum flange of the chamber was designed to be used with a remotely actuated quick-disconnect system. The disconnect utilizes an air driven motor to open and close a rigid hinged clamp by turning a single screw. This hinged clamp compresses a custom aluminum seal between the Module flange and the mating flange of the accelerator structure downstream. Only 10 ft-lbs. of torque is required to make the seal Helium leak-tight. A single convolution bellows between the chamber and the flange provides enough compliance to take up any slight angular misalignments of the two mating flanges while still being rigid enough to support the flange without vertical restraint. A picture of the completed Module is shown in Figure 3. A 3D isometric wireframe of the Module as designed is shown in Figure 4.

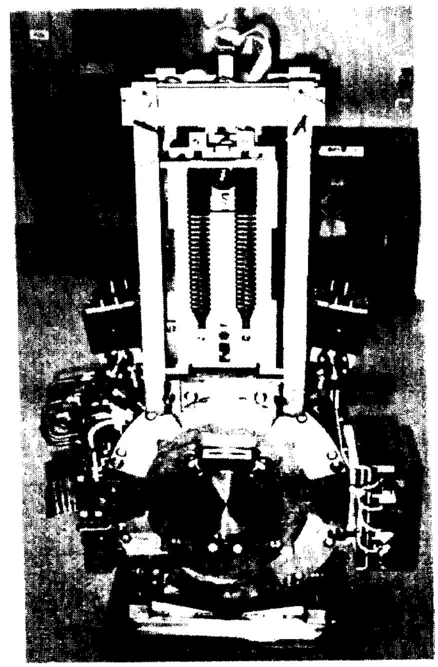

Figure 3
High Power Target Module

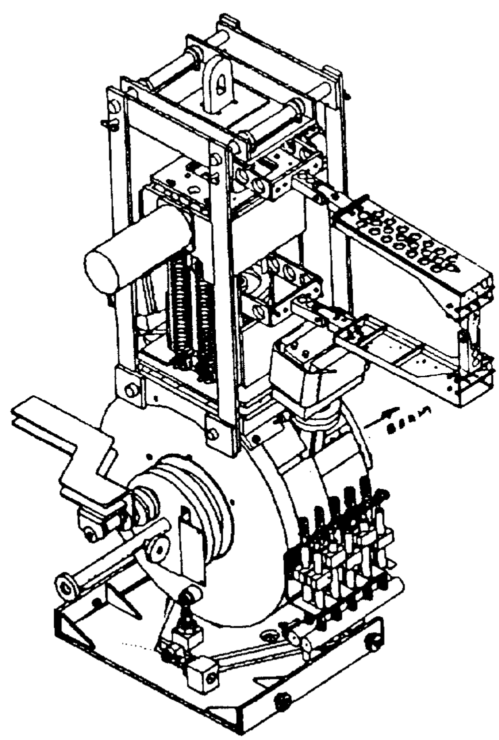

Figure 4
High Power Target Module 3D Model

## II. TARGET CONTROL & INTERLOCK SYSTEM

The monitoring and control system hardware for the target drive was also largely custom designed due to the high radiation levels and RF noise in the Positron Vault. Two aluminum toothed wheels, one with 60 radial slots and fiducial with 1 slot are installed on the target drive crank opposite the motor drive in a shielded housing. Four sets of ferrite pickups (2 per wheel) are placed symmetrically around the outer rim of the disk. These are used to generate the incremental and fiducial pulses as the target crank is rotated. These pulses provide the basis for the entire control and interlock system. They are used in conjunction with a local ion chamber and toroids, a custom series of CAMAC modules, the Main Control Center VAX 8800, a local microVAX, and custom SLAC SCP software to control and interlock the drive system. Yield and status information on the incoming electron beam and outgoing positron beam are also provided by the system.

## III. ALIGNMENT

The precise alignment of all the Module components to each other and to the beam is critical to optimize positron yield and prevent premature target failure. Since final alignment could not be completed until the system was fully assembled, the components each had to have their own adjustment system and fiducialization step or had to be designed to be self-aligning. Tolerances for the total system component-to-component alignment were held to +/- 0.010". The maximum total system alignement tolerance is +/- 0.020".

The target and Flux Concentrator are independently pre-aligned on the SLAC Leitz Coordinate Measuring Machine (CMM) The coordinates of the theoretical center of the downstream target face (as well as its planar orientation) are transferred to tooling balls mounted on the side of the target drive housing for easy viewing.

The Tapered Field Solenoid is optically fiducialized to the vacuum chamber contained within it. All the components are then assembled into the vacuum chamber and aligned using optical methods. The target position within the chamber is then nominally adjusted (using an external alignment adjustment system) to the T.F.S. pole piece and to the upstream face of the flux concentrator. This relative positioning must be maintained to withing 0.010" to optimize Positron capture.

The entire assembly is then placed on a test stand identical to the mounting system in the Positron Vault and aligned to theoretical beam center. The Module can then be installed and run with no on-line alignment. The initial installation and alignment check of the first production Module in the Vault verified the remote alignment techniques.

## IV. REMOTE REMOVAL

The Module system was designed so that in the event of a component failure, the option to remove the entire Module and replace it quickly could be exercised rather than attempting to perform maintenance on the "hot" system in place.

Before removal, the Module instrumentation, power and water connections must be disconnected. All are designed to be manually removed in less than 10 seconds each. Most of the connects utilize standard components. However, the high current connections for the Tapered Field Solenoid are a custom fork design and will handle up to 1000 Amps (DC). They use Multilam™ contact bands to provide a reliable, repeatable contact.

The Module is retracted away from the accelerator section (and out of the vacuum quick disconnect clamp) and then translated out into the aisle by a 2 stage translation mechanism which is mounted permanently on the accelerator girder. This operation (including activating the vacuum quick-disconnect) can be done automatically or manually utilizing a remote control panel located away from the target but still in the Vault area. A remote crane (radio controlled) is hooked onto the Module and it is lifted and trollied along the Vault wall to another translation stage which moves the Module out into a specially designed penetration. A jib crane, mounted at the klystron gallery surface level (30 ft above) lifts the Module to the surface where it can be removed to repair or taken to radioactive storage.

## V. OPERATIONAL EXPERIENCE

The first production prototype High Power Target Module was successfully run at full power on all systems and has logged over 20 million cycles in the beam over the past year with virtually no maintenance or beam down-time. Three spares have been built and are ready for beam. Initial problems encountered during start-up included a main bearing failure in the target drive (cause never determined) and a failure of the bellows on the osculating arm which feeds cooling water to the target from above the Module.

## VI. AKNOWLEDGEMENTS

The author wishes to thank everyone at SLAC and elsewhere who contributed to the implementation and success of the project. Special thanks are extended to Bob Gardner and the staff of Gardner Bellows for their exceptional bellows design and to the individual members of the High Power Target Design Team whose teamwork and comradery were critical to the successful and timely completion of the project. The success of this design effort hopefully will provide an example of the results which can be achieved when concurrent engineering and design principles are embraced.

## VII. REFERENCES

[1] Eric Reuter "3D Numerical Thermal Stress Analysis of the High Power Target for the SLC Positron Source" IEEE Particle Accelerator Conference Proceedings Record ( 1991)

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[3] W.R. Nelson, H. Hirayama and D.W.O. Rogers, "The EGS4 Code System," SLAC-265 (1985).