GA–A22714

THE DESIGN OF THE OMEGA CRYOGENIC TARGET SYSTEM

by
D.T. GOODIN, N.B. ALEXANDER, I. ANTEBY, W.A. BAUGH,
G.E. BESENBRUCH, K.K. BOLINE, L.C. BROWN, W. EGLI,
J.F. FOLLIN, C.R. GIBSON, E.H. HOFFMANN, W. LEE, L. LUND,
J.E. NASISE, A. NOBILE, K.R. SCHULTZ, and R. STEMKE

NOVEMBER 1997

DISCLAIMER

GA–A22714

THE DESIGN OF THE OMEGA CRYOGENIC TARGET SYSTEM

by
D.T. GOODIN, N.B. ALEXANDER, I. ANTEBY,[†] W.A. BAUGH,
G.E. BESENBRUCH, K.K. BOLINE, L.C. BROWN, W. EGLI,
J.F. FOLLIN, C.R. GIBSON, E.H. HOFFMANN, W. LEE, L. LUND,[‡]
J.E. NASISE,[◊] A. NOBILE,[◊] K.R. SCHULTZ, and R. STEMKE

[†]Negev Nuclear Research Center
[‡]Laboratory for Laser Energetics, University of Rochester
[◊]Los Alamos National Laboratory

This is a preprint of a paper to be presented at the 17th IEEE/NPSS Symposium on Fusion Engineering, October 6–11, 1997, San Diego, California and to be published in the *Proceedings*.

Work supported by
the U.S. Department of Energy
under Contract No. DE-AC03-95SF20732

GA PROJECT 3748
NOVEMBER 1997

The Design Of The OMEGA Cryogenic Target System*

D.T. Goodin,[a] N.B. Alexander,[a] I. Anteby, [b] W.A. Baugh,[a] G.E. Besenbruch,[a] K.K. Boline,[a]
L.C. Brown,[a] W. Egli,[a] J. F. Follin,[a] C.R. Gibson,[a] E.H. Hoffmann,[a] W. Lee[a], L. Lund,[c] J.E. Nasise, [d]
A. Nobile,[d] K.R. Schultz,[a] and R. Stemke[a]
[a]General Atomics, P.O. Box 85608, San Diego, California 92186-9784
[b]Negev Nuclear Research Center, Israel
[c]Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623-1299
[d]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Abstract — General Atomics is designing and building the OMEGA Cryogenic Target System (Fig. 1) for the University of Rochester's Laboratory for Laser Energetics. The purpose of this system is to deliver millimeter sized polymer shell targets to the center of the target chamber for inertial confinement fusion experiments. Prior to insertion, these targets are filled to pressures as high as 1500 atm with hydrogen isotopes (DT), the gas is cryogenically condensed, and the condensed material is layered to form a uniform inner shell. GA has demonstrated the successful filling with D_2 of plastic targets to 1100 atm, cooling, and cold transport utilizing prototype equipment. In addition to proving the viability of the proposed fill process, the prototypes have led to significant equipment simplifications and process improvements for the University of Rochester system.

1. INTRODUCTION

Inertial Confinement Fusion (ICF) [1] is supported by the U.S. Department of Energy Office of Inertial Fusion as a part of the U.S. DOE "science-based stockpile stewardship" program. The temperatures and pressures achieved in inertial fusion are similar to those produced in a nuclear weapon.

A major purpose of the ICF program is to provide these conditions for research and maintenance studies without the need for actual nuclear testing. A long term application of inertial fusion is fusion energy for electric power and other energy applications.

The University of Rochester's Laboratory for Laser Energetics (UR/LLE) is a major facility conducting implosion experiments and basic physics experiments in support of the national Inertial Confinement Fusion program. A major goal of this program is to achieve the conditions for fusion ignition. To reach sufficient density to approach ignition conditions with reasonable laser power requires cryogenic targets with uniform fuel layer thickness and density, and a smooth inner surface finish. UR/LLE will do experiments on the OMEGA laser to study implosion of cryogenic targets. Cryogenic targets require specialized

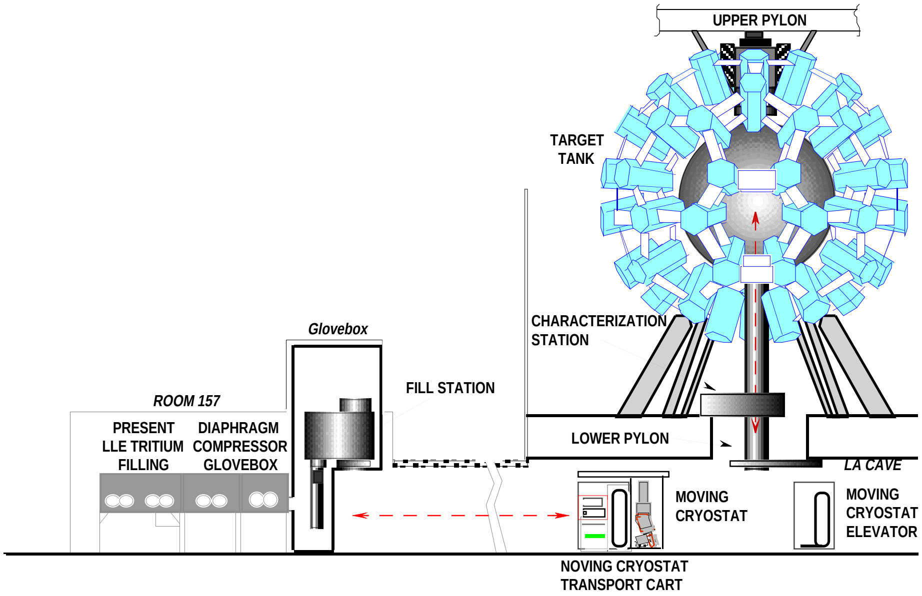

Fig. 1. OMEGA cryogenic target system and the OMEGA target chamber.

---

*Work supported by U.S. Department of Energy under Contract No. DE-AC03-95SF20732.

systems to fill, layer, and characterize targets, and then insert, align and protect them in the target chamber.

General Atomics is designing and building the OMEGA Cryogenic Target System (OCTS, Fig. 1). The cryogenic target delivery system being built for the OMEGA laser will also benefit the National Ignition Facility (NIF) being constructed at Lawrence Livermore National Laboratory, since the same technologies are applicable.

A prototype fill station and cold transfer cryostat have been designed, constructed, and operated at General Atomics with D_2 to demonstrate the fill process and to provide input to the final design. The prototype system definitively demonstrated the feasibility of high pressure filling, cooling, and transporting of cryogenic polymer targets with the UR/LLE C-mount design [2]. Based on the prototype testing and a strong emphasis on design simplicity, the cryogenic target process and equipment have changed significantly from the original conceptual design [3,4]. The remainder of this paper describes the final OCTS equipment and process design.

2. FUNCTIONS AND ESSENTIAL FEATURES

The OCTS fills hollow ICF target shells with DT fuel at 290–400 K to pressures up to 1500 atm and then cools them from the fill temperature to approximately 20 K to condense the fuel. Pressure gradients across the shell must be carefully controlled during the fill/cool sequence (to as little as 0.2 atm, depending on the shell thickness). The targets containing the condensed DT are then layered [5] to develop a uniform layer (<2% variation) of DT between 10 and 100 μm thick on the inner surface. The layered target is then cooled and held at a precise temperature ($\pm$ 0.025 K) in the vicinity of 18 K, characterized to measure the DT ice layer thickness, the uniformity and the smoothness of the inner ice surface, and then inserted into the OMEGA chamber. In the chamber it is positioned within 5 μm at chamber center where a final pre-shot verification will take place. The protective shroud is removed just before the target is shot. The shroud must be removed fast enough to prevent thermal degradation of the target prior to the laser shot (<100 ms) and without significantly disturbing the positioning of the target.

3. OCTS PROCESS OVERVIEW

This section provides an overview of the entire process, while the sections below provide additional details on the equipment design. Fig. 1 shows an overview of the OCTS system as it will be configured at the UR/LLE.

The target filling equipment is located within the tritium laboratory. A cryogenic DT intensifier is used to supply low pressure tritium (~125 atm) to a diaphragm intensifier that increases the pressure up to 1500 atm. The DT mixture is routed to a high pressure Permeation Cell where the diffusion filling process takes place. The Permeation Cell is contained within a Fill/Transfer Cryostat (FTS) to provide for cooling after the fill. The targets are mounted utilizing a convoluted wire (to avoid the laser beams during a shot) and suspended by three spider silk strands. The targets are filled in one operation, four in a rack, and then separated within the FTS for transfer to the Moving Cryostat (MC).

The MC is contained within a Moving Cryostat Transport Cart and receives the filled, cryogenic target from the FTS. The MC maintains the cryogenic target environment as the target is moved to the area beneath the target chamber, and within the target chamber before the shot. The MCTC attaches to the target chamber Lower Pylon, providing a vacuum seal, and the MC moves from the cart to chamber center. The MC's thermal shroud is attached to a linear motor (Shroud Puller) positioned overhead in the Upper Pylon.

Immediately before the shot, the Shroud Puller is used to remove the MC thermal shroud, exposing the cryogenic target to the chamber for the laser shot.

4. PRESSURIZATION SYSTEM

The diaphragm intensifier design is based on a similar compressor utilized at the Weapons Engineering Tritium Facility at Los Alamos National Laboratory. The three-layer diaphragm position is precisely controlled by pressurized oil on one side from a hydraulic syringe pump, controlled in turn by a reducing gear and stepper motor. The tritium is separated from the oil by three diaphragms. The center one of the three diaphragms is etched on each side to allow any oil or DT leaking through the outer diaphragms to be channeled to leak detectors. The pressurization sequence is computer controlled through the stepper motor, and allows for active pressure control during cooling if needed to maintain a very low pressure gradient across the filled shell.

The intensifiers, the high pressure Permeation Cell, and the cryostat containing it, are all located within a secondary enclosure (glovebox) to control the spread of tritium contamination from routine operations and to provide additional release barriers in the event of accidental tritium release.

5. FILL/TRANSFER CRYOSTAT

Fig. 2 shows a sideview of the FTS. The FTS is a cryostat consisting of an insulated three-layer dome and a cooled base. The dome has a permanent vacuum insulation space and is removed as one piece, for ease of maintenance of underlying components in the Glovebox. The FTS base has two parallel plates with an integral liquid nitrogen bath. The FTS has an associated Cooling Module which contains the cryocoolers and heat exchange gas system.

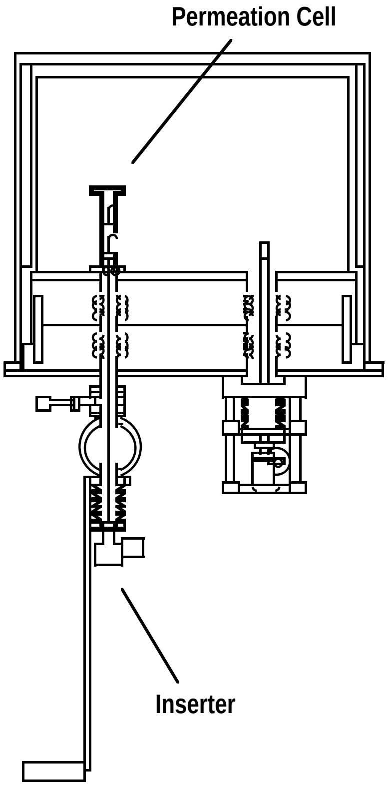

Fig. 2 Side view of FTS showing inserter and permeation cell.

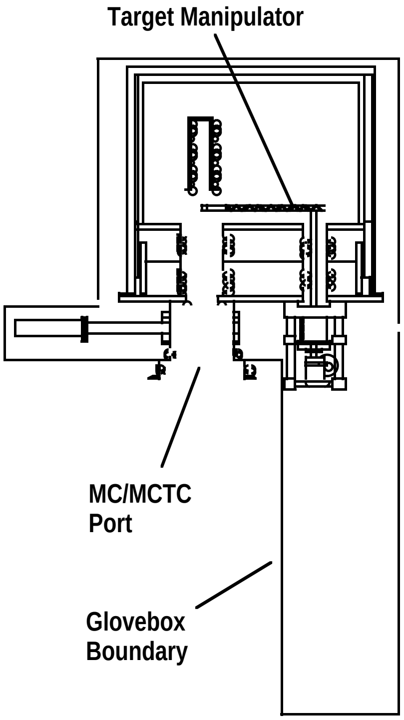

Fig. 3. Side view of FTS showing target manipulator.

The FTS has an insertion system which positions a target rack containing up to four mounted targets within the permeation cell. The target rack is manually loaded onto the insertion system through a vacuum lock. The high pressure Permeation Cell is closed with a rotating breech-lock and sealed by a helium gas actuated diaphragm. After filling and cooling of targets, excess DT is removed from the Permeation Cell by evacuating it through the inlet line.

The FTS also contains a precision remote manipulator (Fig. 3) that removes individual filled (cryogenic) targets from the target rack and places them onto the moving cryostat (Fig. 4, as described below). The outermost line in Fig. 3 indicates the limits of the Glovebox containing the FTS.

6. MOVING CRYOSTAT

The moving cryostat (MC), and its support system, the moving cryostat transport cart (MCTC, Fig. 5), attaches to the lower FTS port (shown outside of the Glovebox in Fig. 3). The vacuum isolation gate valves are then opened and the MCTC and FTS inner vacuums are connected. An internal lift system is used to raise the MC from its transport position in the MCTC to the interior of the FTS. The MC thermal shroud is removed by a manipulator inside the FTS dome. The Target Manipulator then removes a single filled, cryogenic target from the target rack and places it into the MC, followed by replacement of the thermal shroud. The MC is then lowered back into the MCTC, detached from the FTS, and transported to the area under the Target Chamber (La Cave). The MCTC, which weighs approximately 4000 lbs, is supported by four air casters during its journey to La Cave. Power and air are supplied via umbilicals from the building facilities.

In the MC thermal shroud, the filled cryogenic target is located within a highly isothermal layering sphere at ~18 K. In this isothermal environment, heat energy from the beta decay of the tritium results in a redistribution of the DT into a uniform layer on the inner surface of the shell.

After layering, the target is characterized by a convergent beam interferometer through windows in the thermal

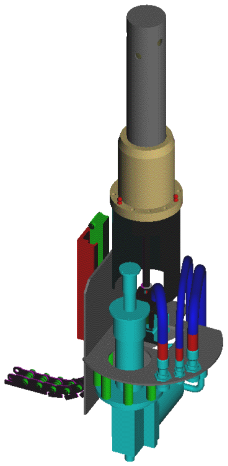

Fig. 4. Moving cryostat schematic view (~48 in. Tall).

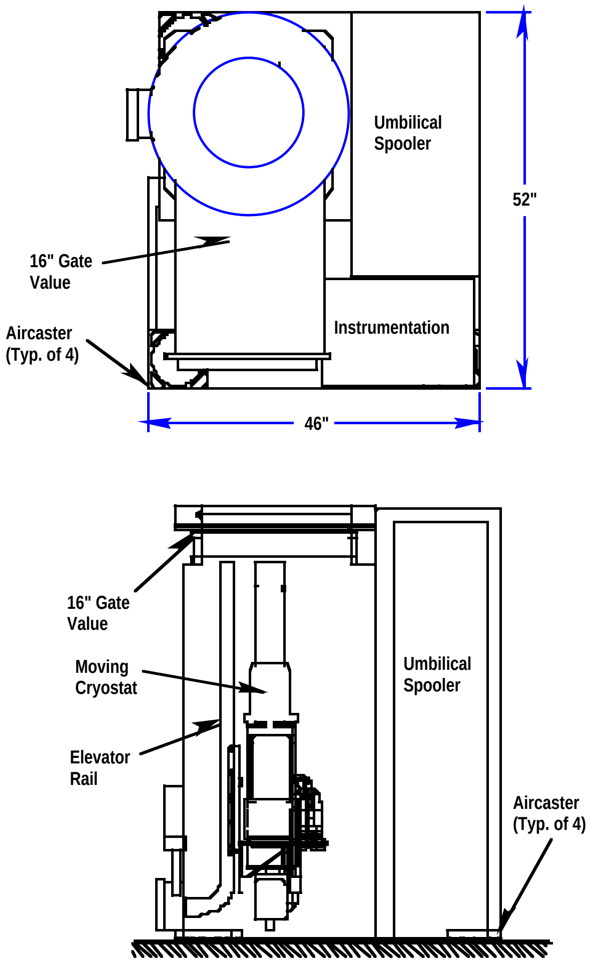

Fig. 5. Moving cryostat transport cart (MCTC).

shrouds, and the MCTC is attached to the Lower Pylon. The MC is pushed with a rigid chain approximately 20 ft. to tank center where it is lacked into place. Sighting through the windows, positioning signals are provided to place the target at the shot position (± 5 µm) using fine positioning motors in the MC. A final check of the target layer is performed at tank center.

7. SHROUD PULLER

Immediately before the shot, the Shroud Puller is used to remove the Moving Cryostat thermal shroud, exposing the cryogenic target to the chamber for the laser shot. The shroud must be removed fast enough to prevent thermal degradation of the target prior to the shot. A linear motor is utilized to achieve the accelerations needed. The Upper Pylon is independently supported in order to decouple the shroud retraction force from the target chamber. After the shroud is removed, a target existence detection system is used to verify that the target remains in position. This precludes damage to the optics which would occur if the shot were to take place with no target.

8. CONCLUSIONS

Based on testing with the prototype equipment, the cryogenic target process and equipment have changed significantly from the original conceptual design [2,3]. Equipment has been relocated into one tritium laboratory, the number of process steps has been reduced by process simplification, and the equipment has been optimized for ease of maintenance and from an operational and human factors viewpoint.

The DT Fill and Transfer functions are now located in one Glovebox in the tritium laboratory, keeping all major tritium inventories in one work area. An entire transfer cryostat system has been eliminated by combining the functions of previously separate subsystems into one cryostat (the FTS). The FTS was redesigned based on a similar cryostat in use at Los Alamos National Laboratory. The one piece dome simplifies the maintenance operations greatly, and eliminates the need for indium (cryogenic) seals. High pressure cryovalves have been replaced with one room temperature valve, reducing the penetrations into the vessel and simplifying maintenance. The high pressure DT cell has been simplified, using an integral actuator that eliminates a separate cryogenic wrench, and reduces the operational steps significantly.

Overall, these changes have resulted in a streamlined process that will decrease cycle times and reduce operational costs. The final design is nearing completion and construction is underway for completion of installation of the OCTS at UR/LLE in FY99.

REFERENCES

[1] J.D. Lindl, *et al.*, Physics Today **45** 33 (1992).
[2] D.T. Goodin, *et al.*, “Testing of the cryogenic target handling system for the OMEGA laser,” Proc. 19th Symposium on Fusion Technology, Lisbon Portugal, (1996).
[3] R.L. Fagaly, *et al.*, “High pressure fill system for the OMEGA Upgrade ICF laser,” Proc. 5th Topical Meeting on Tritium Technology in Fission Fusion, and Isotopic Applications, Lake Maggiore, Italy, (1995).
[4] R.L. Fagaly, *et al.*, Proc. 10th Target Fabrication Specialists Meeting, Taos, New Mexico, Department of Energy Doc. No. LA-UR-95-2938 (1995) 223.
[5] J.K. Hoffer, *et al.*, “Forming a ‘perfectly’ uniform shell of solid DT fusion fuel by the beta layering process,” Proc. 14th International Conference on Plasma Physics and Controlled Nuclear Fusion, Würzburg, Germany, September 1992.