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Status of the Design And Testing Of The OMEGA Cryogenic Target System (OCTS)

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The OMEGA laser at the University of Rochester Laboratory for Laser Energetics (UR/LLE) will begin Inertial Confinement Fusion (ICF) implosion shots on cryogenic targets in 1999. The OMEGA Cryogenic Target System (OCTS) will fill these plastic targets to high pressure, cool them to cryogenic temperatures, layer and characterize the targets, and then transport them to the center of the OMEGA Target Chamber where they are shot. The OCTS has been designed and is now being constructed and tested by General Atomics. The high pressure DT cryostat will be delivered to UR/LLE early in FY99 and the remainder of the target positioning system components will be delivered in mid-FY99.

1. INTRODUCTION

Inertial Confinement Fusion [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 long term goal of the ICF program 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. To reach sufficient density to approach ignition conditions with reasonable laser power, these experiments call for cryogenic targets with uniform fuel layer thickness and density, and a smooth inner surface finish. Cryogenic targets require specialized systems to fill, layer, and characterize targets, and then insert, align and protect them in the target chamber. 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 (GA) 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/Rochester C-mount design [2]. The remainder of this paper describes the status of 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 at 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 (3 psi), depending on the shell thickness). The targets containing the condensed DT are then layered [3] 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 and 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

Figure 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. 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 filled in one operation, four in a rack, and then separated within the FTS for transfer to the Moving Cryostat (MC). The MC (contained in a cart) maintains the cryogenic target environment as the target is moved to the area beneath the target chamber (La Cave), and to target chamber center. Immediately before the shot, the Shroud Puller is used to expose the cryogenic target to the chamber for the laser shot.

4. DT PRESSURIZATION SYSTEM

DT is condensed as liquid in a cryointensifier tube, where the pressure is then increased to ~140 atm by raising the tube temperature. The DT is fed through a metering valve which slowly increases the pressure in the permeation cell. Once the pressure in the permeation cell reaches 100 atm, a three-layered diaphragm compressor increases the pressure to the final target fill ($\leq$ 1500 atm). The diaphragms are displaced into the cavity by oil that is pressurized by a piston. Careful control of the oil pressure is accomplished with the use of a stepper motor. The triple diaphragm allows for detection of failure of one of the diaphragms. This triple diaphragm approach has been used successfully for many years in tritium service at Savannah River and at the Los Alamos Weapons Engineering Tritium Facility. Fabrication of the compressor will be completed in FY99 and testing will be performed at UR/LLE.

5. FILL/TRANSFER CRYOSTAT

Figure 2 shows a sideview of the FTS. The FTS is a cryostat consisting of an insulated three-layer dome and a cooled base. The FTS has an associated Cooling Module which contains the cryocoolers and heat exchange gas system. 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

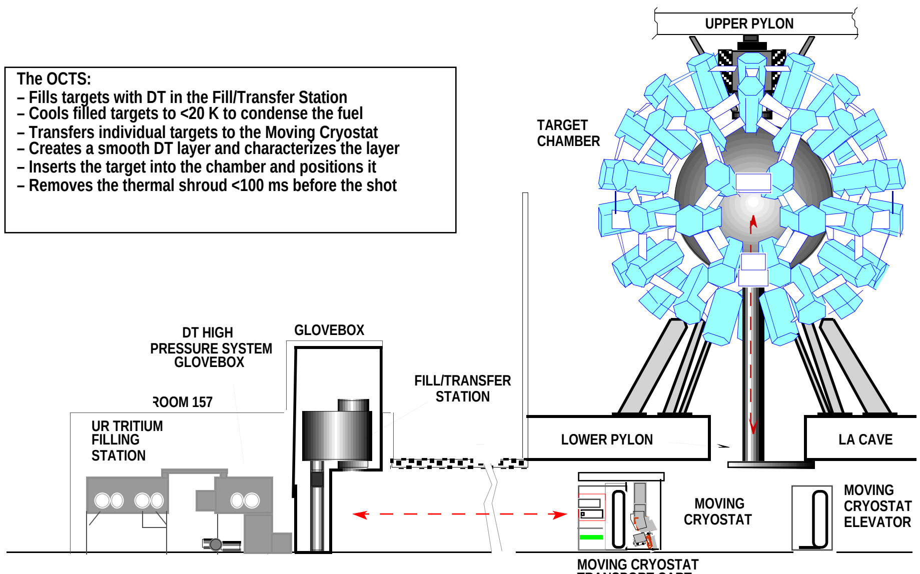

Fig. 1. Overview of OMEGA Cryogenic Target System (OCTS)

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. Most of the FTS components have already been fabricated and are being tested, including the Cooling Module. The FTS itself is in the final stages of fabrication and will be delivered to UR/LLE in early FY99, after preliminary cryogenic testing at GA.

6. MOVING CRYOSTAT AND TRANSPORT CART

The Moving Cryostat (MC) (Fig. 4), and its support system, the Moving Cryostat Transport Cart (MCTC, Fig. 5), attaches to the lower FTS port. The vacuum isolation gate valves are then opened and the MCTC and FTS inner vacuums are connected. The MC is raised into the interior of the FTS, where its thermal shroud is removed by a manipulator. 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). 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 [3]. After layering, the target is characterized by a convergent beam interferometer through windows in the thermal shrouds, and the MCTC is attached to the Lower Pylon. The MC is pushed with a rigid chain approximately 20' to tank center where it is locked in place onto positioners. Sighting through the windows, positioning signals are provided to place the target at the shot position ($\pm$ 5 µm) using fine positioning motions in the MC. The MC is currently being fabricated and the MCTC is being tested at GA.

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. Fabrication of the linear

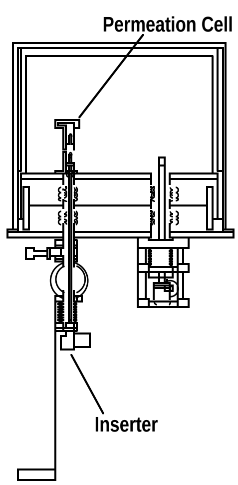

Fig. 2. Side View of FTS showing inserter and permeation cell.

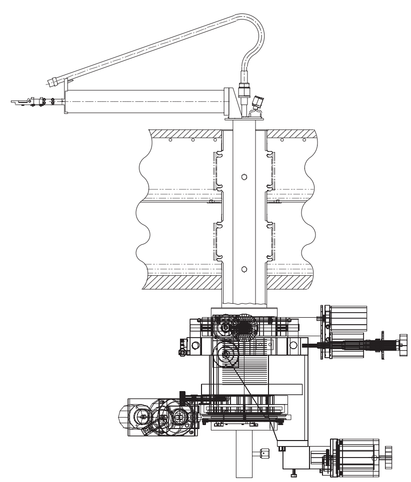

Fig. 3. Side View of FTS target manipulator.

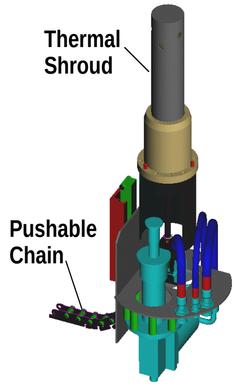

Fig. 4. Moving cyrostat schematic view (~48" tall).

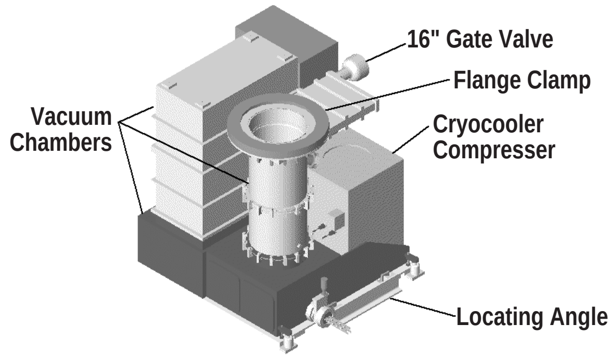

Fig. 5. Moving cyrostat transport cart (MCTC).

motor is near completion. A test station, including a surrogate of the target chamber, is being assembled at GA. Testing of the Shroud Puller will be completed in early FY99 and all the components will be delivered to UR/LLE by mid-FY99.

8. CONCLUSIONS

Based on testing with the prototype equipment, the cryogenic target process and equipment have changed significantly from the original conceptual design. 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.

In summary, the design of the OMEGA OCTS is complete, and fabrication of components is nearing completion. Testing of the FTS and MCTC is well underway, and a test station is being prepared for the Shroud Puller. The FTS and associated systems are on schedule for delivery to UR/LLE in early FY99, while the MC, MCTC, and Shroud Puller are on schedule for delivery in mid-FY99.

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REFERENCES

[1] Lindl, J.D., *et al*., Physics Today **45** 33 (1992).
[2] Goodin, D.T., *et al.*, “Testing Of The Cryogenic Target Handling System For The OMEGA Laser,” Proc. 19th Symposium on Fusion Technology, Lisbon Portugal, (1996).
[3] Hoffer, J.K., *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.