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Testing Of The Cryogenic Target Handling System For The OMEGA Laser

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General Atomics is designing and building a cryogenic target delivery system for the University of Rochester's OMEGA laser. A prototype fill station and cold transfer cryostat has been constructed and operated to fill a number of polymer shell targets with D_2, including representative “C-mount” targets. These fills demonstrate the feasibility of high pressure filling, cooling, and transporting of cryogenic polymer targets for use in Inertial Confinement Fusion.

1. INTRODUCTION

General Atomics is designing and building the OMEGA Cryogenic Target System for the University of Rochester’s Laboratory for Laser Energetics [1]. The purpose of this system is to deliver millimeter sized polymer shell targets to the center of the target chamber (Fig. 1). Prior to insertion these targets are filled to pressures as high as 1500 atmospheres with hydrogen isotopes (DT), the gas is cryogenically condensed, and the condensed material layered to form a uniform inner shell. A prototype fill station (Fig. 2) and cold transfer cryostat (Fig. 3) have been designed,

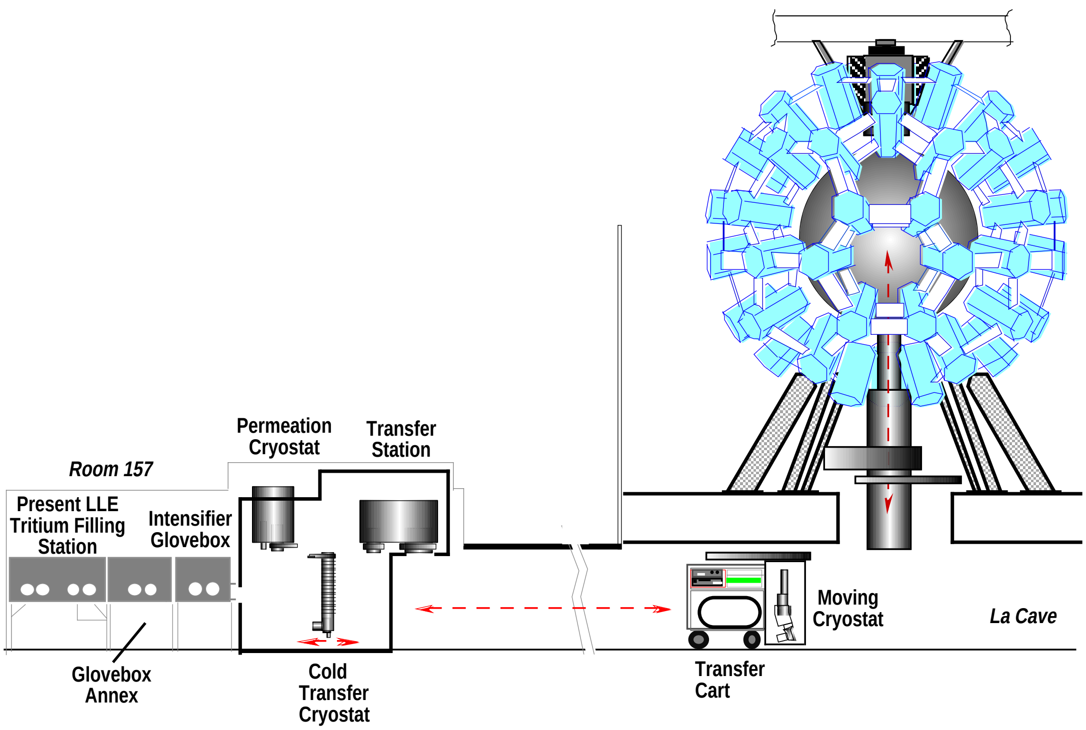

Fig. 1. OMEGA cryogenic target system.

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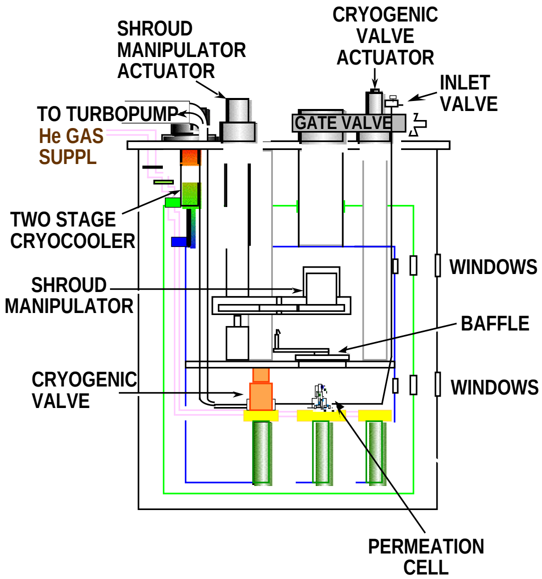

Fig. 2. Prototype permeation cryostat.

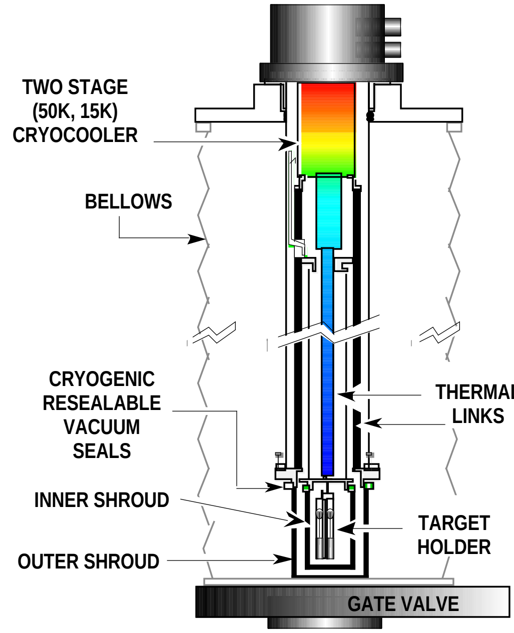

Fig. 3. Prototype cold transfer cryostat.

constructed, and operated at General Atomics with D_2 to demonstrate the fill process and to provide input to the final design. [2,3]

2. PURPOSE AND SUMMARY

A series of thermal and mechanical performance tests of the prototype fill station equipment were conducted. These performance tests demonstrated the front end of the cryogenic target system and included: system cryogenic permormance, leak and vacuum testing of the permeation cryostat, the shroud manipulator, the permeation cell, and the cryovalves; loading of targets into the permeation cell with the cell warm and the cryostat cold; closing the permeation cell with the cryowrench under operating conditions; pressurization of the permeation cell to ~1100 atm; removal of condensed deuterium from the permeation cell; opening the permeation cell with the cryowrench under operating conditions; removing and installing the cold transfer cryostat's shrouds with the shroud manipulator in the permeation cryostat while at low temperatures; picking up the targets in the target rack from the permeation cell with the cold transfer cryostat while at cryogenic temperatures; removing the cold transfer cryostat from the permeation cryostat; and returning the target rack to the permeation cryostat with the cold transfer cryostat.

Following modifications to the equipment as a result of the equipment shakedown, final tests were carried out where polymer shell targets were successfully filled to high pressures (~1100 atm) with D_2, cooled to below 31 K, and cryogenically transported with the Cold Transfer Cryostat (CTC). They were then heated to observe destruction of the targets and verify fuel filling and retention during the transport.

3. DEMONSTRATION TESTS CONDUCTED

In the first test, a set of six unmounted targets had been placed into individual holes in a specially designed multi-shell target rack. The filling with deuterium was accomplished stepwise with 0.68 atm (10 psi) increments followed by ≥27 s wait periods to a final pressure of ~700 atm, for a total fill time of ~10 hours. Examination of the targets with a long-distance microscope clearly showed a liquid meniscus (Fig. 4). The targets were rapidly heated and showed changes in the appearance of the meniscus as heating progressed, followed by sequential explosion of the six targets. Room temperature optical microscope examination of the

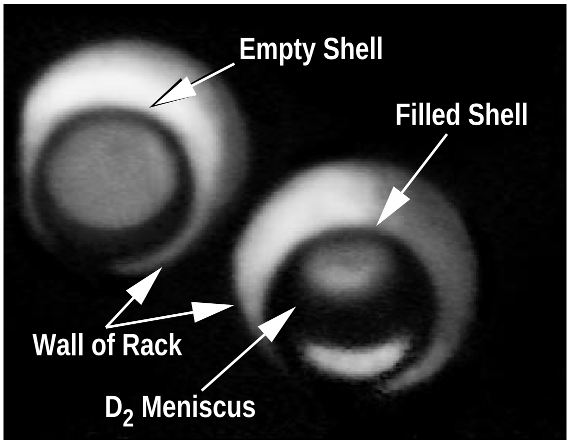

Fig. 4. Filled shells have distinctive appearance (filled shell on right).

rack showed only finely divided shards remaining in the target holes.

The second successful deuterium fill was carried out with a target on a convoluted C-mount supplied by UR/LLE (Fig. 5). The target was filled to ~1100 atm, cooled to ~20 K to condense the deuterium in the target, pumped to remove the excess deuterium, picked up by the CTC, transported to the mobile power cart, and returned to the permeation cryostat. While the mounted target did not have the viewing advantage of the specially designed target rack above, visual observations after these process steps showed deuterium present in the target. In contrast to the unmounted filled targets which burst when heated, the mounted target exhibited rapid emptying of the deuterium upon heating. A videotape of the mounted target during heatup shows the deuterium leaving the target. Our explanation is that the GDP coating developed micro-cracks through which the deuterium could escape, but the paralene overcoat (not present on unmounted targets) prevented catastrophic failure of the shell. Microscope and SEM investigation confirmed the presence of cracks in the shell after loss of the deuterium.

A third successful D_2 fill was carried out with targets in different stages of processing. The objective of this fill was to systematically examine the effects of mounting on survival during filling. Five targets (one C-mount and four unmounted shells) were loaded into a single target rack and filled to ~100 atm. The targets shells were all from

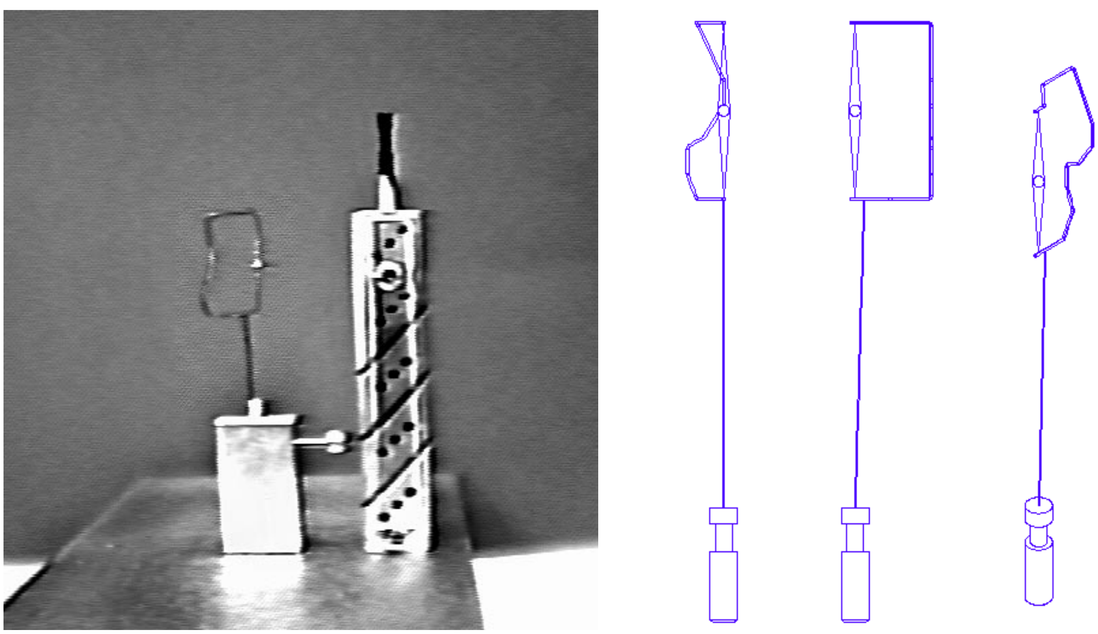

Fig. 5. Comparison of C-mount and multi-shell rack.

the tsame parent batch and consisted of one representative C-mount, two unmounted shells (burst tested at 10 atm to verify their integrity), one unmounted filled to ~1100 atm. The target shells were all from shell with no burst test, and one demounted shell (mounted and cut from webs). Long distance microscope examination of the five cryogenic shells after filling showed the characteristic meniscus in each target that we have observed previously in filled shells. Upon rapid heating (same as done previously), all five shells exhibited first a redistribution of the deuterium (loss of meniscus) followed by violent destruction of the shell (explosion). All the shells failed within a fairly small time frame, and indicated no significant difference between the mounted and unmounted shells with respect to cryogenic burst pressure.

4. LESSONS LEARNED

The thermal and mechanical testing and the prototype equipment operations during the D_2 demonstration fills was very successful and showed that simplification of the process and equipment was possible. Thus reducing the labor-intensive operation. The current design heavily relies on the testing experience and incorporates simplicity, miniaturization, and human factors to a greater extend.

5. CONCLUSION

We have been able to demonstrate the feasibility of high pressure filling, cooling, and transporting of cryogenic polymer targets for use in Inertial Confinement Fusion. The lessons learned during operation of the prototype equipment have significantly simplified the design of the production equipment.

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