Target Manufacturing and Delivery for HiPER

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Abstract. For the future, we have to develop new sources of energy. These new source are based on the nuclear fusion by magnetic confinement as with the ITER experiment or with a new concept based on the inertial confinement. The European community plan to build a facility (HiPER project) which is dedicated to prove the capability to reach a high gain with cryogenic targets, to test the concept of target mass production and the rep rate shot. The cryogenic system for 1\textsuperscript{st} phase experiment is based on the cryogenic system developed for the French facility Laser MegaJoule (LMJ). The latter has to be modified and upgraded for direct drive target. In particular the target has to be protected by a thermal shroud from the radiation flux from the vacuum vessel and it is equipped with a thermal system which allows the core layering.

1. Filling and transfer

1.1. Filling
The filling of the LMJ targets is carried out by permeation through the wall of the micro balloon. To have the desired quantity of matter, the pressure of the spheres must lie between 1000 and 1500 bars at 300K. To prevent that the targets do not break down under the effect of the pressure, the pressure difference between the internal and external walls must be lower than 1 bar. DT mixture is liquefied in a small volume in connection with the filling cell maintained at 300 K. Then this small volume is heated from 20 K to 300 K by controlling the temperature on the wall. This system is able to limit the rise in pressure ($\Delta P$ on the $\mu$balloon wall) and it is possible today to ensure periods of filling which can vary from 4 to 48 hours (slopes from 0,5 to 6 bars per minute). This system is intrinsically sure because it does not have any moving part with the difference of piston compressors. Moreover when the system is abandoned with itself (simulation of a loss of the control system) the increase in temperature with the natural losses of the system authorizes only one pressure of 400 bars. [1]

1.2. Transfer
Once the targets filled, they are cooled around 25 K and, in any case, cannot be heated with the risk to be destroyed. It was necessary to develop cryogenic grips able to handle the targets at temperatures close to 25 K. These grips must provide two important functions: the transfer of heat (power dissipated...
by T2 and radiation heat load) and the transfer of information. The coating of surfaces was studied in order to obtain thermal resistances of contact between the target and the grip lowest as possible. This point is extremely important, because this thermal resistance, being inversely proportional to the temperature, conditions on one hand the size of the cold source and on the other hand its limiting temperature. Indeed, if this thermal resistance is bad (3 K/W), to maintain the target to 19 K it will be necessary to have on the cold grip a lower temperature for the price of a cold source more powerful and thus bulkier. During transfers the temperature of the target must be known, it obliges the grip to ensure reliable electrical contacts and thus free from any trace of pollution what obliges to ensure the transfers under a very good vacuum by observing draconian procedures. Today procedures of manufacture of the targets are set up to guarantee this criterion of thermal resistance. The “Service des Basses Températures” (SBT) undertook a research program on this subject and today SBT is able to carry out thermal contacts of low resistance (1 K/W) at 17 K. The cryogenic grip is a key point of the cold chain. Its development required several years and will still require improvements. It is one of the most important technological bolts that it was necessary solve in priority [2].

![Figure1. Cryогrip and transfer](image)

2. Thermal regulation

These objectives were achieved by developing the electronic ones based on synchronous detections and “multivariable” algorithms of regulation. These algorithms make it possible with several data input as well as possible to adjust the parameters of regulation.

Moreover this technique allows, by simple tests in situ, to introduce into the software the true physical values of the variables. This software is not very sensitive to the environmental disturbances what is necessary for reliability in quasi industrial installations like the LMJ. This thermal regulation (0.2 mK at 20 K) and the cooling of the target with a speed of 1 mK per minute will ensure the physicists a powerful tool to reach the necessary geometrical characteristics of the ice layer [3].
3. Thermal shroud
The last important bolt to rise is the shrinking of the thermal shroud. During all handling, from its filling to the shooting, the target is protected from the surrounding thermal radiation by a cooled shroud which must be withdrawn very quickly before the shooting. When the target sees the chamber radiation, its time life is only 180 ms. The problems are complex; the shrinking of the screen should not generate on the target vibrations of amplitude higher than 5 μm and the thermal field around the target should not vary more than 10 mK. Studies are led on the coupling of two cold sources and on the procedures of alignment of the two arms (target carrier and shroud carrier in the experimental chamber). A model of this unit will be brought into service at the beginning of 2007 [4].

4. Cryogenic infrastructures
To answer the strong constraints of environment as well in the field of the robustness of the components as in the field of the biological shielding of the operators, we built a mock-up of the LMJ cryogenic infrastructure to validate the choices which answer the imposed criteria. This installation DEMOCRYTE which includes several cryostats (cryogenic target carrier, unit of transfer and shroud remover) was studied and built in 2001. It allowed to test in full-scale the first main components of the cryogenic target door. This evolutionary desired equipment will receive the entire systems specific to the transfer of the targets, with the conformation of the layer by infra red, with the withdrawal of thermal shroud so that they are tested and validated. With this cryostat we tested the transfer of a target arriving from Valduc on the cryogenic target loading door. This transfer was done at 24 K then it was followed by a fine regulation at 18 K to simulate the solidification of the Deuterium-Tritium mixture with a temperature stability of +/- 2 mK.

The next step will be to test the shrinking of the thermal shroud in 2007. This work, done step by step, shows that it possible to validate the physical concepts and to check their technological feasibility. In this manner by moving back to the maximum the definition of total cryogenic architecture, the risks incurred by a premature choice are minimized.

5. Development for HiPER
The main improvement for the cryosystem of HiPER is to insert a layering system in the front of the cryocarrier. This complex system has to realize the thermal map with a gradient less 75μK around the target and to insure the heat transfer between the target and the cold source. During the single phase shot, many kinds of target will be tested with different morphology and material. The objective of these experiments will be to define a realistic target for the IFE reactor which will be able to be in mass produced with a low cost. In the same time, shooting, tracking and laser synchronization will be improved. So during the high rep rate all systems needed for an IFE reactor will be tested together.
Materials are a key point for the high gain target. These latter have to have good mechanical properties to insure the integrity of the target during the shot (maximum acceleration is 1000g). They must be porous for the filling permeation process at room temperature and leaktight at cryogenic temperatures. Joint and bonding of materials in targets will be a key aspect still to be fully understood when we consider sophisticated new energy targets. For reducing the technological risk, it is very significant that many kinds of target would be tested in particular the materials which are allowed owing to their activation rate. During the high gain experiments the blanket has to be defined with the constraints of the heat transfer, the migration of helium inside the wall which creates exfoliation of the surface. All these debris can reduce the performances of the final optics and increase the time dedicated to the maintenance in a nuclear environment.

6. Conclusion
Many technologies and test beds are now available in different laboratories and many experiments can be driven with HiPER facility. This one can be used a pulsed neutrons source, neutronic experiments under prototypical conditions to IFE are a key issue for future IFE DEMO REACTOR technologies. We essentially are looking for two objectives (a) to get enough safe experimental databases required for approval and licensing of an IFE device, (b) Verification of the prediction capabilities of various computational codes and database in assessing the nuclear performance of various reactor components. We then will quantify the design margins and safety factors to be implemented in future IFE blanket and shield design. Target and blanket materials are really a very strong key issue and HiPER experiments have to be focused on these both points.

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