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# Screw Extruder for Pellet Injection System

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*Abstract*— Solid hydrogenic pellets are used as fuel for fusion energy reactor. A technique for continuous production of solid hydrogen and its isotopes by a screw extruder is suggested for the production of an unlimited number of pellets. The idea was developed and patented by PELIN laboratories, Inc. (Canada). A Gifford McMahon cryocooler is used for the generation of solid hydrogenic fluid pellets. Requirements of the pellets is depends upon the energy to be produced by tokamak. This review paper focuses on the model for the screw extruder for solidification of hydrogen ice having high injection reliability.
***Keywords:*** screw extruder, cryocooler

## I. INTRODUCTION

Future fusion reactors should be equipped with a fuelling system operating in a steady state mode. There are three techniques for plasma fuelling: by gas puffing, by compact toroids and by injection of pellets produced from solidified hydrogen isotopes. A key task of the injection is to develop a reliable pellet injector capable of injecting, in the steady state mode, an unlimited number of pellets into the plasma core. Several techniques for continuous pellet production have been proposed. One is a screw extruder type pellet injection system. Another technique is to produce pellets by a porous pellet generator. Recently the screw extruder type pellet injection system has been designed and tested.

## II. DEVELOPMENT OF EXTRUDER TYPE PELLET INJECTOR

**R. Viniar et. al.,** Developed a screw extruder to produce a deuterium ice in 2000. A cylindrical rod of 2 mm in diameter and 100 m in length was extruded over 3000s. The deuterium solidifies by a liquid helium heat exchanger. A schematic diagram of the pellet injector is shown in Figure1. It consists of vacuum chamber (1) with an extruder (2), which equipped with helium heat exchanger (3) and screw (4), A rotating driver (5) connected to screw, A propellant gas valve (6), chopper (7), a gun barrel (8), and diagnostic chamber (9). A transparent chamber (10) is attached to the extruder exit and equipped with pumping system (11).

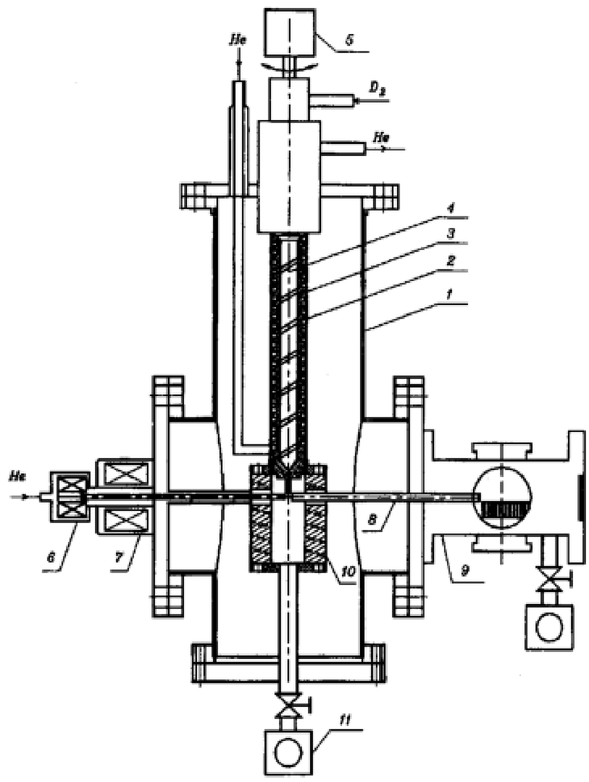


**Figure 1 Schematic Diagram of the Pneumatic pellet injector with a screw extruder. [I. Viniar et. al, 2000]**

**R. Sakamoto et. al.,** in his paper “Development of advance pellet injector systems for plasma fueling” in 2008, the cooling is done by cryo-cooler instead of liquid helium. Its key design futures are as follows,

- Cooling by compact cryo-coolers: the pellet injector is operated using electrical input only, which is the most fundamental facility in a laboratory, instead of a complicated liquid helium supply system. This design enables flexible and reliable operation.

- Screw extruder for solid hydrogen production: The screw extruder can produce solid hydrogen rod via simultaneous replenishment, liquefaction, and solidification of hydrogen gas. This design steady state operation in principle.
- Pneumatic pipe-gun acceleration: the design enables reliable and reproducible pellet injection with easy injection-timing control.

The screw extrusion concept, which was proposed by Mitsubishi Heavy industry and developed by PELIN L laboratory, can produce a solid hydrogen rod continuously. A conceptual drawing of the screw extruder is shown in Fig.1. There are two Gifford-McMahon cycle 4 K cryo-coolers to cool the cryo-cylinder, the total cooling capacity of the cryo-coolers is 20 W at 8 K. The lower part of a copper cryo-cylinder is cooled to below 6 K in the standby phase.

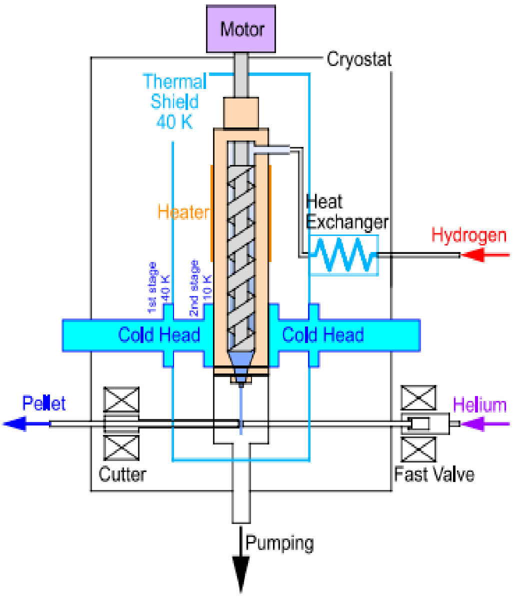


**Figure 2 Conceptual drawing of screw extruder [R. Sakamoto et. al, 2008]**

Hydrogen gas is pre cooled in a heat exchanger at the same temperature with the thermal shield, and then flows onto the cooper cryo-cylinder to be liquefied and solidified, while the solid hydrogen rod is extruded by the rotating screw from a nozzle (Fig.2).

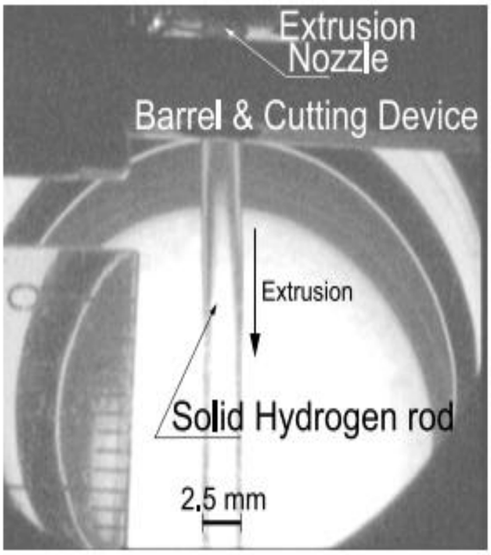


**Figure 3 Solid hydrogen Road [R. Sakamoto et. al, 2008]**

**J.W. Leachman et. al.,** in his paper "Model of a Twin-Screw Extruder operating with a Cryocooler for the Solidification of Deuterium" in 2009, Analysis carried out using the numerical model. Nine parameters are considered in his sensitivity analysis.

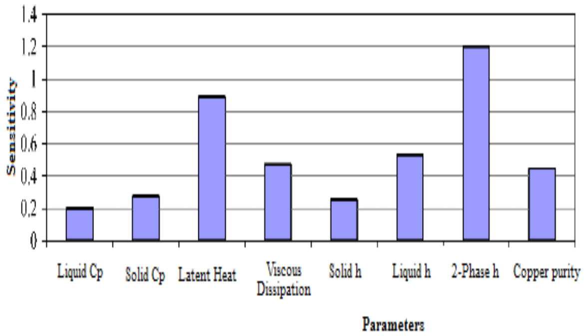


**Figure 4 Sensitivity of extruder performance [J.W. Leachman et. al, 2009]**

Figure 4 indicates that the extruder performance is most sensitive to two-phase convection coefficient, Followed in order by latent heat of fusion, Liquid convection coefficient, and liquid heat capacity.

## III. CONCLUSION

The sensitivity of extruder performance is complex to control due to two phase flow. Among two methods of producing solid hydrogen and its isotopes, the GM cryocooler based cooling system is preferable to control load capacity over liquid helium heat exchanger system.

## REFERENCES

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