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A FREEZE, MELT VALVE AND DISPENSING SYSTEM FOR CESIUM

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SUMMARY

Nuclear thermionic diodes for space electric power require cesium purity control, which vacuum packaging allows. However, dispensing small quantities of such a reactive element into prebaked evacuated capsules poses unique valving problems. One answer is the freeze, melt valve, an orifice that closes or opens as the cesium solidifies or liquifies locally. Here a single resistant metal contacts the corrosive liquid in a very simple, extremely compact, reliable flow regulator. These characteristics make it a good valve for reactive liquids in general. But in particular this report describes the design and operation of a freeze, melt valve used in vacuum encapsulating cesium for thermionic diodes.

INTRODUCTION

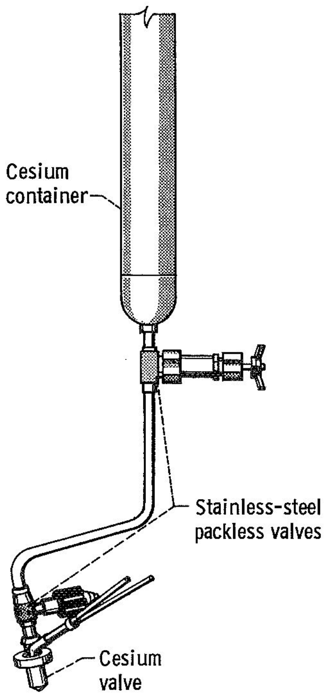
Many space power systems rely on alkali metals for high-temperature energy transport. In out-of-core thermionics, for example, alkali metals transfer heat to and from the converters, while cesium carries electric power through them (refs. 1 to 4). Because cesium strongly affects electron emission, transmission, and collection in thermionic diodes, its purity is critical. And one of the best ways to ensure that purity is vacuum packaging. But putting a few drops of cesium into a degassed ampule and sealing it in without contamination causes difficulties. Many of these problems diminish, however, with the use of a freeze, melt (FM) valve. The present report discusses such a valve and a dispensing system developed to encapsulate cesium in vacuum.

In this FM valve, cesium flows fully, partly, or not at all when it completely melts, partially freezes, or totally solidifies locally. So the cesium (Cs) valve is just an orifice with provisions for heating and cooling across the melting point of the liquid it regulates. Where such a thermal cycle is permissible, FM valving adapts to handling liquids in general - not just cesium. For this reason, references on FM valving are not uncommon, but they fail to mention the present application, the FM valve refined to dispense cesium.

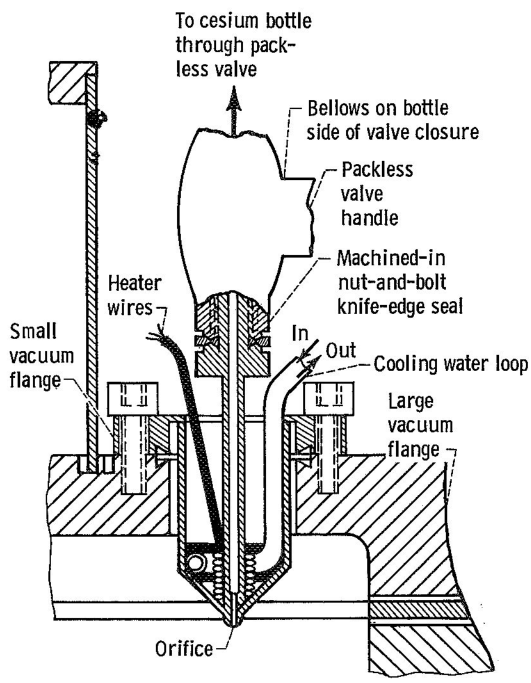
Although this report describes cesium dispensing primarily, the advantages of FM valving should also extend with increasing temperatures to the other alkali metals. Similar to cesium these elements are very reactive and cause special problems like the rapid corrosion of many materials. Even at low temperatures, cesium handling generally requires stainless-steel valves sealed with welded-in bellows; two such valves appear in the sketches shown in this report. These valves are complex, prone to failure, difficult or impossible to repair, and bulky with large hold-ups. For high temperatures, regulating alkali-metal flows demands packless valves involving several different resistant refractory alloys. As reference 5 states, "the valves are quite sophisticated from a materials viewpoint." In contrast the FM valve combines ultimate simplicity and extreme compactness.

CESIUM VALVE

The following sketches show the FM valve adapted for a special system to vacuum package cesium. Because the packaging station dictates the design, the present Cs valve



Cesium dispensing system



Cross section of freeze, melt valve (actual size) is bigger and more complex than the basic function requires. As the sketch reveals, a thick vacuum flange imposes the long tube between the packless and the Cs valves. And the upper left and lower right chamber walls restrict insertion and rotation. Otherwise the small vacuum flange for removal of the cesium dispensing system would not be necessary; then the packless and the Cs valves could be much closer together. Now, however, the dispensing system must be removed from the station to enable breaking the nut-and-bolt knife-edge seal for replacement of the cesium cylinder. During resealing the stainless-steel knife edges rotate relative to each other as they deform the copper gasket; this configuration is a superposition of two such seals described in reference 6. The resulting joint bakes out at 450° C without leaking and reseals on new copper gaskets. This requirement for easy replacement of the cesium cylinder also adds size and complication to the Cs valve.

The sketch shows the Cs valve with cooling that reaches the orifice through only the conic surface for fine, quick control. But the Cs valve in the dispensing system has the coolant tube and the sheathed heater wire potted in copper, and it works very well. As the most critical part, the orifice should be small enough in diameter to produce good lengths of liquid at that diameter for the amounts to be gated or controlled. Even this is not required, though, because the present Cs valve with its 0.015-centimeter orifice dispenses flows ranging from steady nonspraying streams to separate drops of less than 3 milligrams each.

Since this valve entails only heating or cooling an orifice, it offers many advantages for dispensing cesium: First, the basic FM valve is completely compact. This attribute reduces hold-ups to absolute minimums and contributes strongly to cleanliness. It also allows great freedom in placing the gating position. And although the FM valve serves well in-line, locating the orifice as the exit makes it ideal for dispensing. The terminal orifice eliminates overruns and drainage from postvalve tubing. Second, the FM valve is ultimately simple. This means fabrication causes comparatively few difficulties. Just opening an orifice by drilling, cutting, melting, burning, or vaporizing admits an almost unlimited choice of materials. For example, stainless steel is satisfactory for the present Cs valve; but the design, machining, and operation did not prohibit the use of tungsten or alumina. Furthermore, in the FM valve, only one selected resistant material contacts the flow. This obviates corrosion by reactions of dissimilar metals immersed in conducting liquids. And it precludes failures by straining, fretting, or clogging moving parts. These and other advantages of the FM valve in handling reactive liquids derive from its simplicity and compactness.

The FM valve adapts readily to many demands because it has several degrees of freedom in its operation. These latitudes include the kind, rate, and switching of heating or cooling the orifice; the temperature of the liquid being regulated; the diameter (and length) of the orifice; and the pressure difference across the valve. And the vast body of experience with simple orifices indicates that, for a clean system, duplicating the operating conditions means repeating the flows. So the design is not at all demanding.

If situations require it, the Cs valve can be shut down, removed, and handled in air. The tiny slug of cesium in the orifice oxidizes externally. But all cesium oxides vaporize readily and dissolve in cesium itself above 170^{0} C, and heating the orifice and backup cesium in vacuum frees the valve for further use. Thus, FM valves have few serious restrictions.

One major limitation of FM valves is that they operate around the freezing points of the liquids they regulate. And another comes in handling alkali metals; here high pressure drops are undesirable since they might extrude these solids through the orifices.

CESIUM DISPENSING SYSTEM

For the dispensing system shown in the sketch, cesium arrives from the supplier in cylinders with valves and tubing extensions on both ends. Argon at atmospheric pressure fills the volume unoccupied by cesium in each container. To provide a fixed head for cesium flow, an external source of pure argon could maintain the bottle pressure after an appropriate attachment and bake-out sequence. But because a gram of cesium loads many capsules for thermionic diodes, the pressure difference between the cylinder and the vacuum chamber changes negligibly throughout each run. Thus, special pressurizing is unnecessary.

Welding on a small stainless-steel packless valve, with its bellows opening toward the cylinder, isolates all big-volume parts of the cesium system. Then, after attachment of a vacuum line, heating cleans up that section, and closing the added valve keeps it clean. The outlet of the newly attached packless valve has half of the nut-and-bolt knife-edge seal machined into it. So it close couples easily to the other half of the seal on the Cs-valve tubing. Making the line between the packless and the Cs valves as short as possible minimizes the small-volume parts of the dispensing system. This section bakes out through the Cs valve into the vacuum chamber before the calibration with expendable cesium, which also cleanses the dispenser.

Several important steps precede calibrating. These include sealing the Cs valve into the packaging plant with the small vacuum flange, baking out, and setting heating and cooling rates. Then, after final adjustments of controls during calibration into a throwaway ampule, the system is clean - ready for the vacuum encapsulation of cesium. And to assure purity the packaging sequence includes samples large enough for wet chemical analyses.

CONCLUDING REMARKS

Freeze, melt valves allow ultimate compactness and simplicity of design, material, and fabrication. As a result they offer convenience, effectiveness, versatility, reliability, corrosion resistance, minimal hold-ups, and long lives. These characteristics make the FM valve an important factor in vacuum packaging cesium for the development of out-of-core nuclear thermionic diodes. And the performance of this Cs valve indicates no major problems in adapting FM valving to handle other alkali metals. In fact, preprocessing and loading lithium for heat pipes in out-of-core thermionics may soon involve FM valves.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, September 1, 1970,
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