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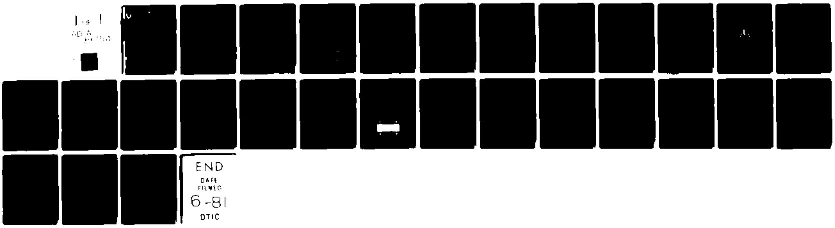

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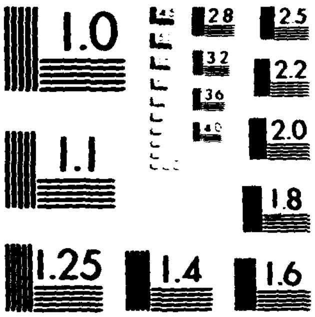

MICROCOPY RESOLUTION TEST CHART

Research and Development Technical Report
DELET-TR-79-0270-4

INSTANT START THYRATRON SWITCH

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May 1981

Fourth Triannual Report for Period 1 September 1980 — 1 January 1981

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Efforts into developing an instant-start thyratron that requires no external heater power are described. Design work on the envelope assembly and cathode structure are basically complete, but an adequate solution to a passive reservoir has not been achieved. These problems and possible solutions are addressed.

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September 1, 1980 through January 1, 1981

Submitted: Rodney Petr
Rodney Petr

Approved: Spencer Merz
Spencer Merz

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1. INTRODUCTION

The purpose of the Instant-Start Thyratron Switch Program is to develop a hydrogen thyratron capable of holding off tens of kilovolts before switching current pulses of tens of kiloamperes without the need of auxiliary power and the corresponding warmup time. The instant-start thyratron must meet the following requirements:

Peak Anode Voltage (epy)	40 kV
Peak Anode Current (ib)	40 kA
Pulse Width (tp)	10 μs
Pulse Repetition Rate (prr)	100 Hz
Anode Delay Time Drift (Δtad)	0.1 μs
Burst Mode Operation	120 sec

The technical guidelines established by ERADCOM require the instant-start thyraton to switch a megawatt of average power. Therefore the physical size of the switch package must be on the order of the standard MAPS-40 tube assembly. However, weight constraints have dictated a modification of the existing MAPS-40 bottle. The additional requirements imposed on the reservoir system and cathode structure to achieve an instant-start capability have led to a division of the instant-start thyratron program into three categories: the envelope assembly, the reservoir system, and the cathode structure. The progress in these three areas is discussed in the following sections.

2. ENVELOPE ASSEMBLY

The instant-start hydrogen thyratron which will satisfy the requirements set forth in Section 1 will be contained in a modified MAPS-40 envelope assembly. No major changes were made in the envelope. Calculations indicate that the control grid will undergo an adiabatic temperature increase of approximately 320°C over the 120 seconds that the tube will operate. The effects of surface vaporization should be no worse for the new lightweight assembly than for the proven MAPS-40 bottle, but an arc at the megawatt power level will damage the grid structure. This factor has been taken into account in the design of the cathode structure, which is discussed in Section 4.

The grid to cathode compartment of the new envelope has been modified so that this lower assembly, along with the cathode, may be separated from the upper portion of the envelope. This provides an option of testing the mechanical integrity of the total envelope assembly with a standard oxide cathode. In any case, the capability of removing the cathode structure from the envelope allows for convenient autopsy of the dispenser cathode after testing without destroying the envelope.

Weight savings for the modified bottle assembly are almost 12 pounds. Table 1 describes the areas and magnitudes of the weight reduction of the new envelope and Figure 1 shows a side-by-side view of the MAPS-40 bottle assembly compared to the new bottle.

Table 1. HY-7312 bottle assembly weight reductions.

	Modification	Weight Reduction (lb) Ceramic	Metal	Total
1.	Reduce length from anode seal to gradient grid flange from 2.3 in. to 1.5 in. (includes shortening anode connector).	0.96	1.29	2.25
2.	Reduce length from gradient grid flange to control grid flange from 2.3 in. to 1.5 in.	0.96	1.71	2.67
3.	Reduce length from control grid flange to auxiliary grid flange from 0.840 in. to 0.5 in.	0.41	0.51	0.92
4.	Reduce length from auxiliary grid flange to cathode baffle flange from 0.840 in. to 0.5 in.	0.41	0.25	0.66
5.	Replace anode connector with copper flange.	--	1.04	1.04
6.	Reduce ceramic wall thickness from 3/8 in. to 1/4 in.	1.80	--	1.89
7.	Reduce length of backup ring from 0.425 in. to 0.36 in.	0.06	--	0.06
8.	Reduce OD of copper flanges from 9 in. to 8.75 in.	--	0.28	0.28
9.	Reduce thickness of copper flanges from 1/16 in. to 1/32 in.	--	0.98	0.98
10.	Combine anode support and skirt, and increase skirt thickness from 0.020 in. to 0.030 in.	--	0.22	0.22
11.	Remove material from back of anode.	--	0.48	0.48
12.	Reduce thickness of skirts (3 places) from 0.125 in. to 0.095 in.	--	0.29	0.29
	(Total 1-12)	(4.69)	(7.05)	(11.74)
	Original MAPS-40 weight (not including 6.2 lb mounting flange).			30.36 lb
	Reductions 1-12			11.72 lb
	Reduction weight			18.64 lb

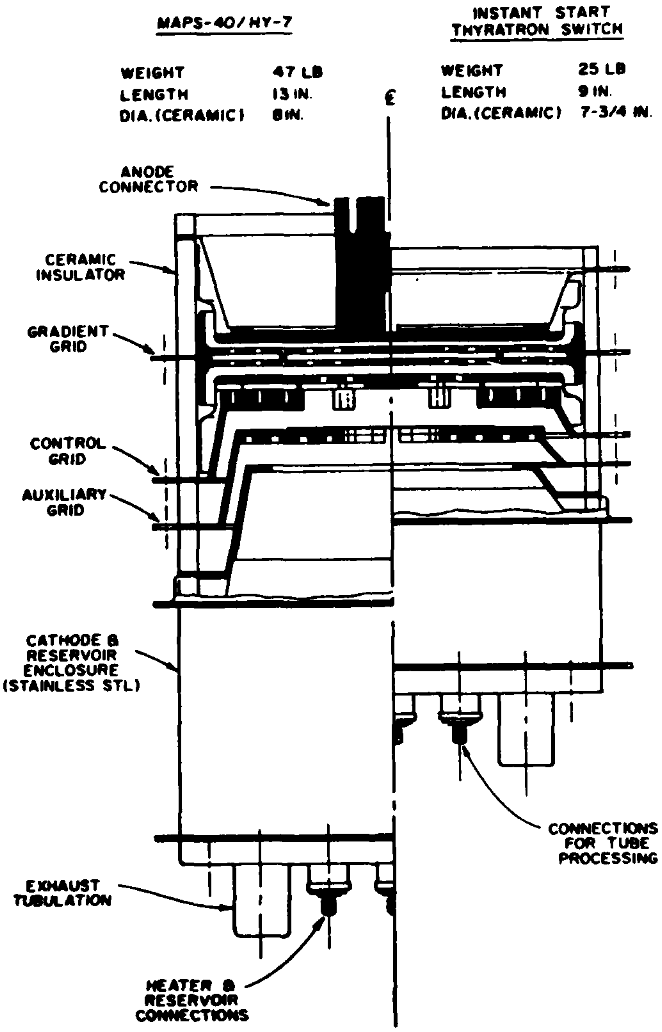

Figure 1. Comparison of envelope assemblies.

3. RESERVOIR SYSTEM

A hydrogen thyratron that has an instant-start capability requires a reservoir system that can maintain a cold tube pressure between 0.2 torr and 0.6 torr. Also, during thyratron operation, the reservoir must maintain the density and purity of the hydrogen gas. A thyratron requires some type of reservoir system because hydrogen gas is depleted during each commutation interval. If this were not the case, then simply backfilling the thyratron to operating pressure would suffice.

In order to determine consumption rates with a dispenser cathode, hydrogen depletion measurements were performed on an experimental instant-start thyratron. This particular thyratron, denoted as the DHB-102, is shown in Figure 2. The tube was contained in a 2-inch diameter bottle, and employed a dispenser cathode with a surface area of 1.5 cm^2. The reservoir assembly was located external to the bottle assembly and connected to the envelope by a valve. Envelope pressure was measured by a Varian TC bulb gauge. This arrangement with the "appendage" reservoir is illustrated in Figure 3.

Data on hydrogen depletion are shown in Figure 4. The DHB-102 was filled to an initial operating pressure of 400 microns and the reservoir valved off. The envelope pressure versus peak current in Figure 4 shows the tube pressure after 5 minutes of operation. The slopes of the pressure curves for different repetition rates indicate that hydrogen depletion may be a function of the total charge conducted by the thyratron.

The data presented in Figure 4 clearly show the need for some type of cold temperature reservoir system. An early investigation into realizing a passive reservoir was conducted using substituted metal-hydride alloys. These

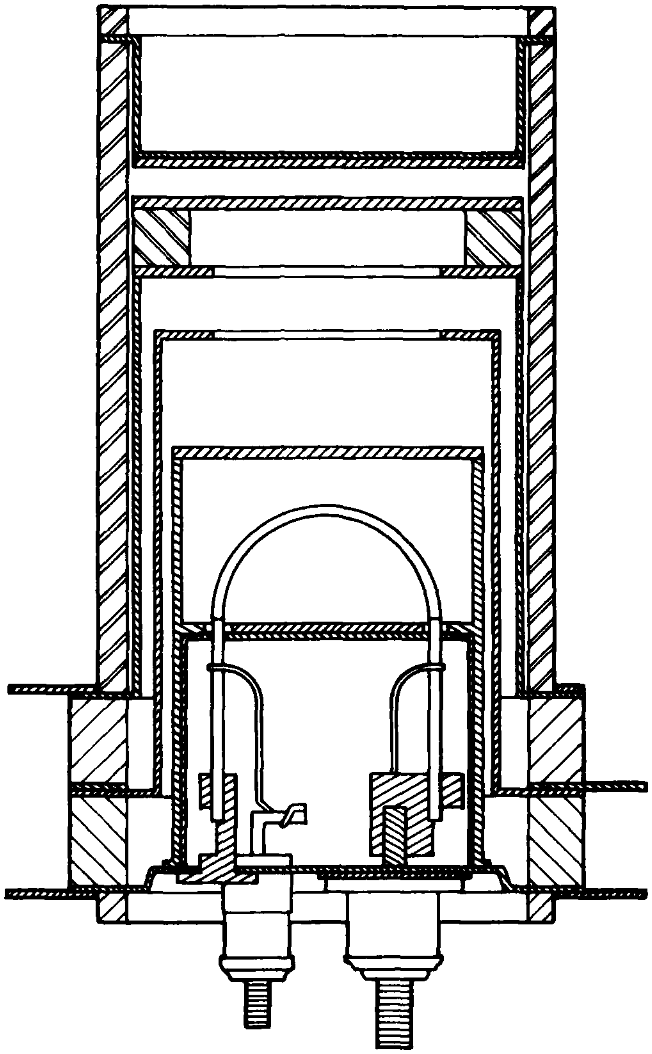

Figure 2. DHB-102 thyratron tube.

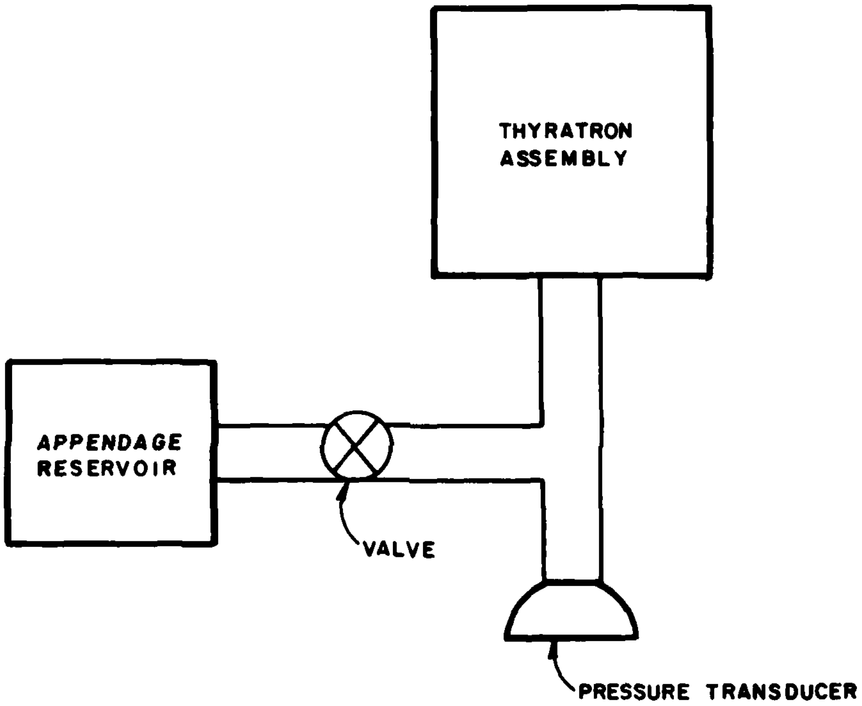

Figure 3. Experimental thyratron setup with appendage reservoir.

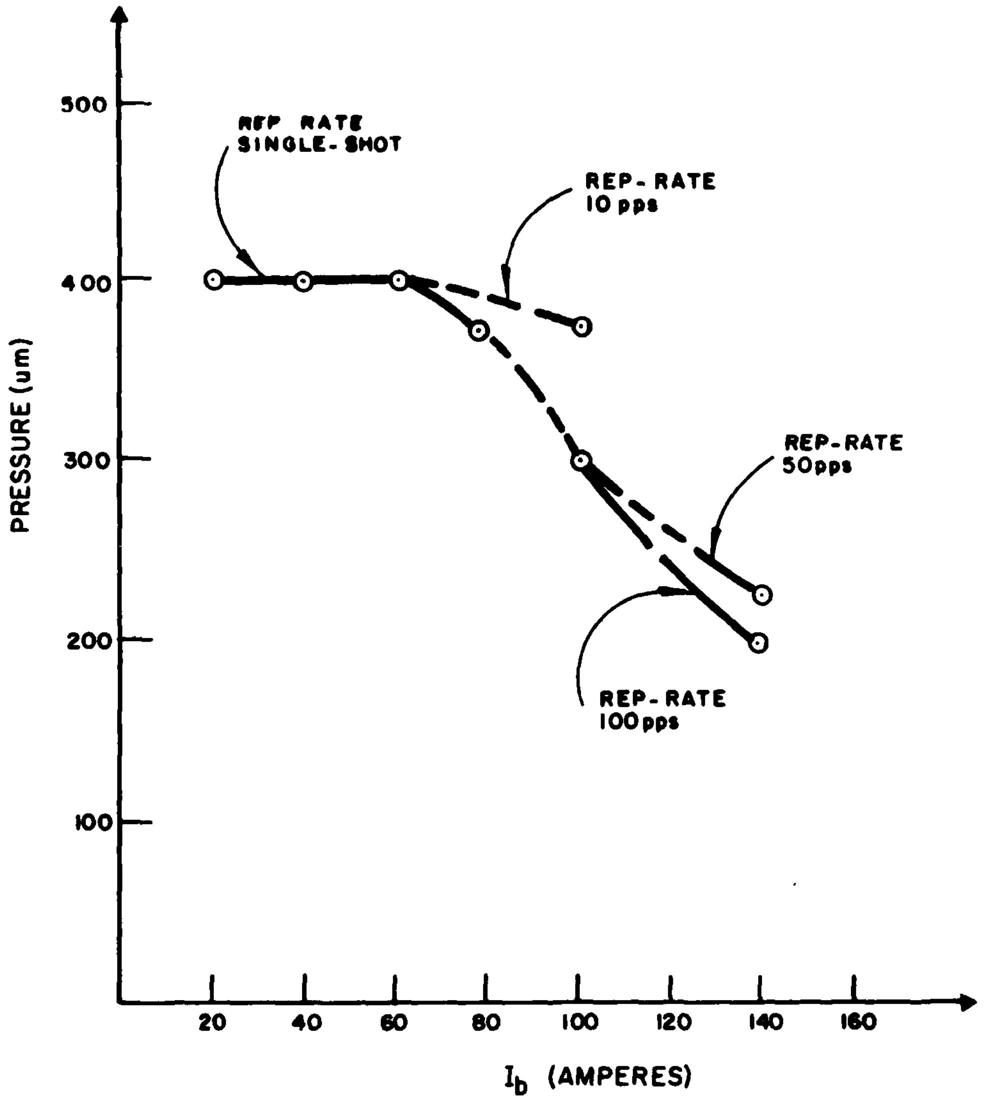

Figure 4. Curve showing pressure change versus peak current for repetition rates of single-shot, 10 pps, 50 pps, and 100 pps. Initial tube pressure was 440 µm.

alloys have a large hydrogen content at room temperature and are reported to have pressure equilibrium in the range of normal hydrogen thyratron operating pressures.

Tests performed on ZrFeV alloy indicated that the alloy was able to produce the expected amount of hydrogen gas, but no pressure equilibrium was achieved. Also, this reservoir material allowed gas flow in only one direction — from the reservoir to the envelope. Obviously a reservoir material must allow bidirectional gas flow in order to be a viable pressure regulator. The inadequate performance of the metal-hydride alloy may have been due to poisoning of the material by air, but further development efforts were postponed in favor of a palladium valve system.

Palladium is a metal which is "transparent" to hydrogen when heated to sufficient temperature and is almost impenetrable to hydrogen when cold. Extensive research has been performed on palladium-hydrogen systems in the past and a large background of experimental data is available in literature. Therefore, it seemed possible to design a system that would use a standard titanium-hydride reservoir separated from the tube volume by a palladium barrier. At cold temperatures the palladium would isolate the titanium-hydride material from the envelope gas, allowing the thyratron to maintain operating pressure. The thyratron would then be capable of commutating properly at cold temperature. Heat introduced to the reservoir would liberate hydrogen gas, and a corresponding rise in temperature of the palladium barrier would allow gas to flow into the tube volume.

Experiments proved the feasibility of a palladium barrier between the tube volume and a conventional titanium-hydride reservoir. The apparatus that was used to study the palladium barrier scheme employed two palladium tubes, a nichrome heater-coil, and a heat shield, all contained in a metal test-can. Figure 5 illustrates the experimental setup. The palladium tubes were connected to a hydrogen supply, and the test-can was evacuated. The test was expected to function in the following manner. Heating the palladium tubes would allow hydrogen gas to fill the evacuated volume. A thermocouple placed at the tubes would measure the temperature of the palladium and a pressure gauge would record hydrogen pressure in the test-can. From this information,

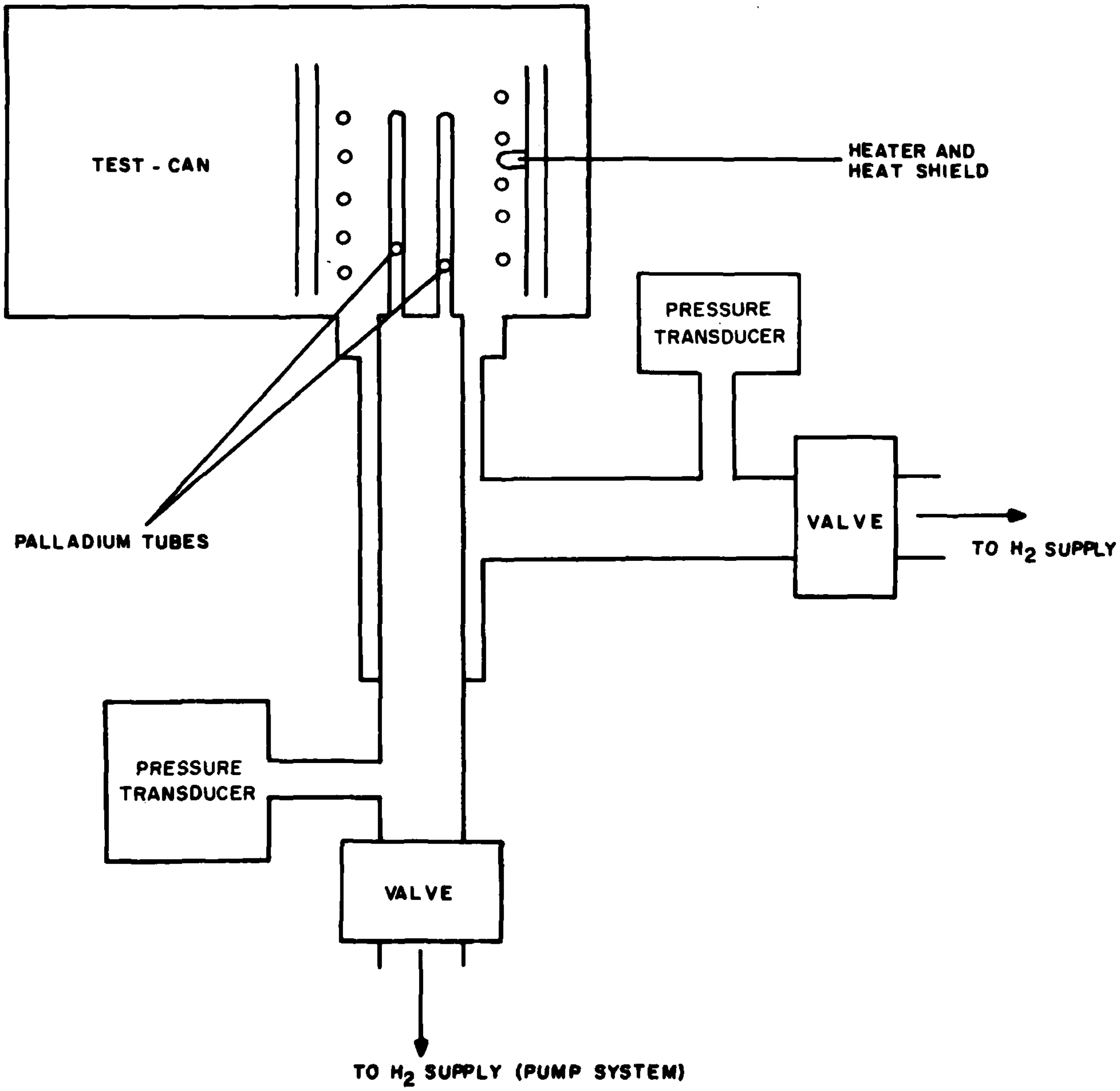

Figure 5. Experimental setup to study gas-flow rates of palladium.

flow rates through the heated palladium barrier as a function of temperature could be determined. Conversely, the test-can could be filled with hydrogen and leak rates through the cold palladium could be measured.

Typical flow rates through the heated palladium barrier are presented in Table 2. The test-can was held to a pressure of 200 to 220 microns with the hydrogen supply set at 400 microns. The time delay between application of heater power to the palladium tubes and stabilization of gas flow was less than one minute. With no heater power applied to the palladium, the hydrogen diffusion rate dropped dramatically, locking hydrogen gas in the test volume, and thus performing in precisely the expected manner.

Table 2. Typical flow-rates through palladium with test-can pressures of 200-220 microns and system pressure of 400 microns.

Temperature	Flow Rate (liter-microns per cm^2 per minute)
20°C	0.04
30°C	0.1
280°C	0.3
400°C	6.0
700°C	16.0

Unfortunately, the leak rates of cold palladium are too high to guarantee operating pressure in a megawatt thyratron over a period of several months. However, the leak rates are such that the palladium barrier will maintain proper envelope pressure for a period of weeks. Other encouraging results of these tests were:

- No poisoning or embrittlement of the palladium was observed during heating and cooling cycles.
- The mechanical assembly of the palladium did not present any unusual problems.

Another solution to a reservoir design giving long-term instant-start capability to a thyratron is to use a back-up valve in conjunction with the palladium barrier. If a back-up valve could isolate the palladium from the envelope gas at low temperature, the slow leak characteristics of the barrier would be eliminated.

One type of back-up valve that has been investigated employs the thermal expansion of a metal for actuation. The valve consisted of two stainless steel sheets bolted together with a heater element between sheets. Two pieces of stainless steel tubulation were compressed between the steel sheets and spot welded to the body. A gold-washer of 5 mil thickness was placed on the end of one tube to serve as a valve seat. At cold temperatures (20°C), the washer made sufficient contact with the tubulation ends so that a leak-tight seal resulted. Figure 6 illustrates this valve.

Application of power to the heater element caused the stainless steel sheets to expand, thus retracting the tubulation from the gold washer and opening the valve. Once the valve assembly proved to be leak-tight (as tested on a helium leak detector), the expansion obtained by moderate heating allowed for satisfactory gas flow.

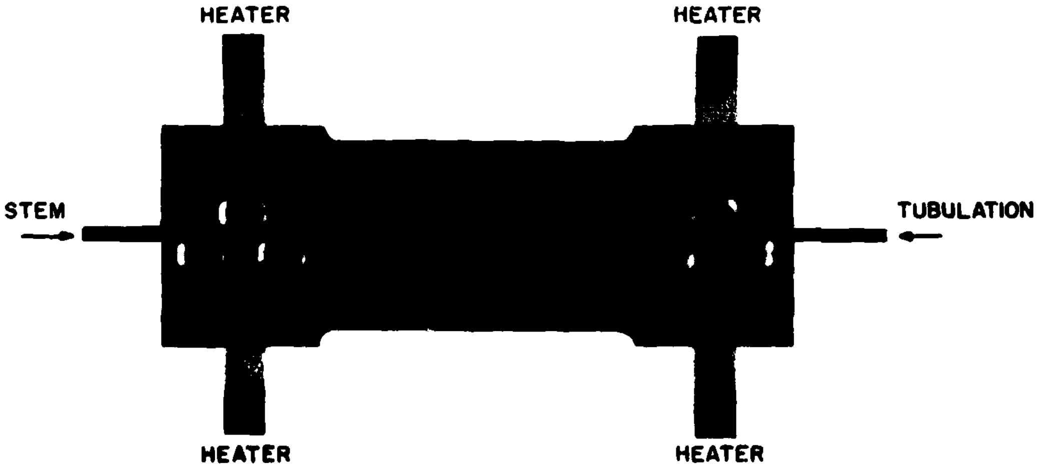

Figure 6. Back-up valve employing thermal expansion for actuation.

4. CATHODE STRUCTURE

In order to realize a thyratron that has an instant-start capability, the cathode structure must be able to supply the required current emission dictated by the external circuit at cold temperatures. If the cathode cannot produce the needed emission, then an arc will occur. As stated in Section 2, an arc will damage the grid structure for a thyratron operated at the megawatt average power level. Therefore, the cathode structure must be designed in such a manner that its emission capability is sufficient at any operating temperature.

A dispenser cathode material consisting of porous tungsten filled with barium aluminate and nickel has proven to be a satisfactory solution for a cold cathode. Earlier reports (1,2) have documented the performance of the dispenser cathode in hydrogen thyratron applications. Pertinent cathode data are reviewed below, along with progress in developing the final cathode structure to be utilized.

Investigations into the emission properties of a dispenser cathode supplied by outside vendors have shown:

1) Cold emission densities of 50 A/cm^2 can be obtained (20°C).

2) Emission characteristics do not appear to be strongly affected by cathode geometry.

3) Hot emission densities of 200 A/cm^2 can be obtained (1100°C). The dispenser cathode realizes its emission properties by a thin layer of barium that is formed on the surface of the cathode due to tungsten reduction of the barium aluminate by heat. It appears that this process will occur when the cathode is raised to a temperature above 300°C.

After studies had been completed on dispenser cathodes available in the marketplace, investigations into the emission characteristics of dispenser cathodes produced at EG&G were performed. It was found that emission current densities of 80 A/cm^2 could be drawn from the cathode produced in-house. Also, the time required to condition the cathode was substantially less than the time needed to condition commercially available dispenser cathodes. This may be due to the fact that vendors chemically clean their cathodes while EG&G cathodes do not undergo this process. It was decided to pursue the EG&G cathode because it is less expensive, its emission characteristics are superior, and the time to fabricate the cathodes is less. Table 3 compares the EG&G cathode with those available from industry.

Table 3. Cost comparison of dispenser cathodes produced at EG&G and by outside vendors.

	Outside Vendors		EG&G	
	1"x2"x0.100"	1"x1"x0.100"	1"x2"x0.100"	1"x1"x0.100"
Price	$126 each	$77 each	$20 each	$10 each
Lag Time	16 weeks	16 weeks	2 weeks	2 weeks
Cold Emission	50 A/cm^2	50 A/cm^2	80 A/cm^2	80 A/cm^2
Aging Time	30 hours	30 hours	5 hours	5 hours
Start-up Cost	---	---	$4000	$4000
Cost per HY-7 Cathode	$5000		$750 (excluding start-up cost)	

The instant-start thyratron is required to conduct a maximum current of 40 kiloamperes. The possibility of an arc is greatest at start-up since the emission capability of a cold cathode is minimal, and therefore the cathode must be designed around worst-case conditions. Since approximately 50 A/cm^2 can be drawn from a cold dispenser cathode, the emitting surface area of the cathode structure was set at 1000 cm^2. A "rising-sun" cathode geometry was chosen because this configuration will allow the dispenser vanes to be welded to the cathode pan with the least amount of difficulty. Figure 7 illustrates this cathode geometry.

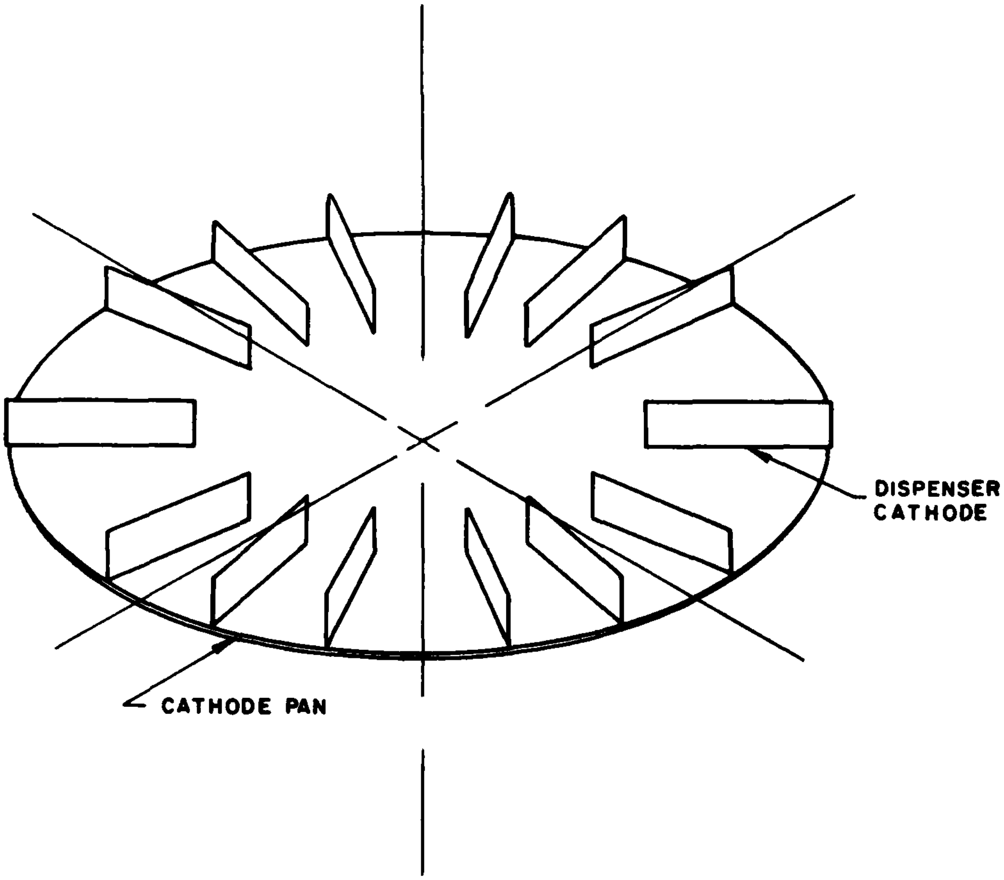

Figure 7. Cathode geometry for the instant-start thyratron.

In order to achieve a cathode structure that will be able to supply the needed emission current, fairly massive cathode vanes are required. It has been found from flash-tube work that, to realize a dispenser cathode, the tungsten-barium aluminate mixture must be pressed to a pressure of approximately 40 tons per square inch. Calculations indicate that a 2-inch x 2-inch x 0.100-inch cathode vane is needed in the megawatt instant-start tube, and thus 160 tons of pressure are required to fabricate the cathode.

5. CONCLUSIONS

Efforts aimed at producing a hydrogen thyratron that has an instant-start capability at the megawatt power level have continued to the point where the design work on the envelope assembly and cathode structure is basically complete. The envelope is a modified version of the MAPS-40 bottle assembly. This new bottle structure will prove to be at least 12 pounds lighter than the MAPS-40 version.

The cathode structure will consist of tungsten and barium aluminate; this dispenser material will allow cold emission currents (20°C) to be drawn by the external circuit. A die set is being fabricated which will allow the production of dispenser cathode vanes that will be sufficient to meet the requirements of the program. This die set will be available in February 1981, and production of dispenser cathodes should begin in March 1981.

A reservoir system that will allow the thyratron to operate properly at cold temperatures has proven more difficult to realize. Since room-temperature reservoir materials have proven unsatisfactory at this time, efforts have centered around trying to produce a cold reservoir system using the standard titanium-hydride material. Since titanium-hydride acts as a hydrogen "getter" at cold temperatures, this material must be isolated from the tube volume. A palladium barrier will achieve this result; however, leak rates are such that the palladium can hold gas pressure in the tube in the required operating regime for only a few weeks. Since the gas pressure must be held for a period of months, a back-up valve system must be incorporated into the reservoir system. Investigations into a thermal valve may prove to be a satisfactory solution to this problem; therefore, effort in the future will center around developing a parasitic titanium-hydride reservoir.

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