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A PROPOSAL TO PRODUCE A TRITON BEAM USING A CAESIUM SPUTTER SOURCE

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Abstract. — Until recently most accelerator laboratories have avoided accelerating tritons because of the excessive activity involved in handling large volumes of tritium. The caesium sputter source utilizes tritium as titanium titride in a sputter cone which releases gas by sputtering the cone with caesium ions at a rate necessary to produce the required negative ion beam.

The efforts at McMaster have been directed in four main areas: reliability of source components, including the cone design; problems associated with loading of titanium cones; contamination of accelerator components and health physics.

Difficulties with the procurement of tritium gas have prevented us from completing this work and deuterium has been used in all of our studies to date.

1. Introduction. — For many years physicists at McMaster University using deuterium, $^3$He or $^4$He have wished to use a triton beam to extend their studies on elements in the 50 to 200 amu range. In particular, they are interested in using $(t, p)$ and $(t, a)$ reactions for studies in this mass region. The large amounts of tritium involved in producing a triton beam using a duoplasmatron source (approximately 100 Ci/hour) have previously made this very difficult and it is only since the development of the Caesium Sputter Source [1] that it has become feasible to consider producing tritons.

The efforts at McMaster have been directed in four main areas: reliability of source components, including the cone design; problems associated with loading of titanium cones; contamination of accelerator components and health physics.

Difficulties with the procurement of tritium gas have prevented us from completing this work and deuterium has been used in all of our studies to date.
It is not expected that the results obtained using deuterium will differ substantially when using tritium.

2. Reliability. — Since the triton source is certain to become heavily contaminated and may not be repairable it is imperative that all source components be extremely reliable. It is intended to produce a source which will operate 1 000 hours without failure.

The ion source being used is a General Ionex model 830 sputter source which has been modified to take a water cooled 12 cone holder. The components subject to failure are: sputter cones, insulators, ionizer, pumps and heaters. It is planned to use 5 sputter cones designed as in figure 1, each loaded with ~ 100 Ci of tritium. Sintered and solid titanium inserts in aluminium and stainless steel cones have been tested. The solid titanium insert in a stainless steel cone has proven the most reliable and is capable of at least 200 hours of operation.

The main high voltage and suppressor insulators have caused some trouble due to the deposition of caesium and sputtered materials. This difficulty has been overcome by optically shielding the insulators. The ionizer, pumps and heaters have proven very reliable. Therefore it is feasible to expect at least 1 000 hours of operation without a source failure. Endurance tests are continuing using our test bench and all components are being evaluated further for maximum reliability.

3. Cone Loading. — It was decided at the start of the project that we would manufacture our own tritium cones. The cone loading apparatus is shown in figure 1. It consists of a tritium supply cylinder, uranium pumping cylinder, ion pump, pyrex loading tube and induction heating coil all contained within a sealed glove box which is maintained at a slight negative pressure. The glove box is exhausted via a pipeline to an exhaust stack.

Five titanium inserts are dry machined and subjected to a brief chemical etching and outgassed at 1 000 °C. The loading procedure consists of placing the inserts into the pyrex loading tube, evacuating the tube to 10^-7 torr using the ion pump, admitting deute-

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**Fig. 1.** — Cone loading apparatus and typical cone.
rium into the system and heating one insert to \( \sim 750 \, ^\circ C \). The insert is held at this temperature until it absorbs \( \sim 40 \) c.c. of deuterium at N.T.P. After the loaded insert has cooled to room temperature, the remaining inserts are loaded in the same manner. When all the inserts are loaded and cooled to room temperature, the residual tritium is pumped out to at least \( 10^{-6} \) torr using the uranium powder and ion pump.

4. Contamination. — There will be 500 Ci of tritium in the sputter source and the possibility of contaminating our regular negative ion source vacuum chamber and downstream components is of real concern. Fortunately, titanium titride is very stable near room temperature, so that the release of tritium in a closed system is negligible. The dissociation pressure for TiD is given by

\[
\log P = -\frac{31220}{4.6}T + 12.41
\]

where \( P \) is in dynes/cm\(^2\) and \( T \) is in K [2].

The primary release of tritium will be due to titanium sputtering during source operation. The downstream contamination will be minimized by providing as much pumping restriction and differential pumping as possible. Figure 2 shows the pumping arrangements from the source to the low energy base of the accelerator. The main restriction is a 1 cm diameter tube approximately 12 cm long placed at the exit of the source, with a conductance of approximately 0.8 l/s. Differential pumping is provided by a titanium getter pump and an oil diffusion pump with a speed of 1000 l/s and 135 l/s, respectively. The conductance of the pipe joining these pumps to the source is 375 l/s. The percentage of tritium flowing towards the accelerator will be approximately 0.2 % at the exit of the first restriction and 0.011 % at the entrance to the accelerator.

An automatic closing valve at the exit of the first pumping restriction is adjusted to close if the tritium source vacuum should exceed \( 5 \times 10^{-6} \) torr.

To avoid contamination of the main negative ion source chamber and diffusion pump the triton beam passes through a 5 cm diameter tube extending from the entrance to the exit ports of the chamber.

A second titanium getter pump is located between the exit of the negative ion source chamber and the inflection magnet chamber to remove a large fraction of any tritium getting beyond the first pumping restriction.

A model SPI-10 residual gas analyzer will be used to monitor the vacuum near the low energy vacuum system. If excessive tritium appears indicating a pump failure or overheated cone, the tritium source isolation gate valve will close and the source will be automatically put into a standby condition by reducing the amount of caesium bombarding the cone.

Our laboratory is fortunate in that there exists adjacent to it a 50 meter high stack used by the McMaster central heating plant. It was decided to utilize this facility as a safety precaution for our tritium work. A 7.5 cm diameter pipe extends from the stack, through tunnels into the basement of the accelerator building where it is connected to the exhausts of all our accelerator vacuum pumps as indicated in figure 2. This pipe is also connected to the glove box and exhaust pump used to prepare tritiated cones. A blower is mounted at the base of the stack maintaining a slight vacuum of approximately 15 cm H\(_2\)O in the pipe. In the event of a blower failure a vacuum switch will provide an alarm and automati-

![FIG. 2. — Tritium source arrangement showing pumps and exhaust systems.](image-url)
cally seal the exhaust pipe from the glove box to prevent possible blow back into the box.

The dilution factor for a 50 meter stack has been shown to be $3 \times 10^{-7}$ s/m$^3$ [3] and the maximum permissible concentration of HTO for the general public is $2 \times 10^{-7}$ Ci/m$^3$. The maximum permissible emission rate is then 0.67 Ci/s. Assuming a safe level of 1% of the maximum permissible concentration the $^3$H emission rate could be $2.1 \times 10^5$ Ci/year or approximately two orders of magnitude more than the anticipated use.

5. **Health Physics.** — The chemical behaviour of tritium is very unlike that of hydrogen or deuterium due to its low energy beta radiation. When tritium contacts organic materials there is often a breaking of a chemical bond in the organic material by the beta particle and subsequent recombination with a nearby tritium atom. Thus many materials which would ordinarily be inert to hydrogen or deuterium will combine with tritium because of this radiation effect.

Loading the titanium cones with tritium and subsequent cone and source installation will be the most dangerous periods for possible tritium contamination. During these operations personnel involved will be required to wear fresh air masks and protective clothing and continuous monitoring of air in the general area will be made using a model 955 B high sensitivity tritium gas monitor. This monitor will also be used to check the main exhaust pipe.

Maintenance of the tritium source or adjacent beam line components will also be a very dangerous time for possible contamination. During these periods the same safety precautions will be taken as for loading cones until it has been established by monitoring that no contamination is present.

Finally all personnel who may have contact with tritium will be required to have routine urinalysis.

6. **Summary.** — We have described a system which should safely produce a microampere beam of tritons utilizing a caesium sputter ion source with an operating lifetime of approximately 1 000 hours. Special emphasis has been made regarding reliability, loading cones with tritium, contamination problems and health physics. Operation of the system should commence during the summer of 1977 subject to the availability of tritium gas.

**References**