Refrigeration storage in a direct liquid to freezing liquid system

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SECURITY CLASSIFICATION O P E N

SUBJECT REFRIGERATION STORAGE IN A DIRECT LIQUID TO FREEZING LIQUID SYSTEM.

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ISSUED TO INTERNAL

REFRIGERATION STORAGE IN A DIRECT LIQUID TO FREEZING LIQUID SYSTEM

1 SUMMARY

A proposal for refrigeration storage is outlined, in which the trichloroethylene heat transfer fluid is in direct contact with the heat storage material, freezing calcium chloride brine. The scheme, if successful should result in savings in cost and space.

2 INTRODUCTION

Several attempts have been made to find a method of storing refrigeration that would be more economical and attractive than the 53,000-gallon all-trichloroethylene (TCE) system that has been proposed for the Engine Laboratory's requirement of 927 standard commercial tons for one hour for the testing of large jet engines. Two schemes using heat storage in cheap solid materials were described in an earlier memo (1). Freezing eutectic calcium chloride brine in small containers or tubes was suggested by Ringer and has been analyzed by Baxter (2). This indicates that this otherwise interesting scheme would require 250 miles of 1/2" tubing for heat transfer area.

The present note suggests the possibility of eliminating the intermediate heat transfer surface, with direct heat transfer between the refrigerated TCE and the freezing calcium chloride solution.

3 DESCRIPTION

The system is shown schematically in Figure 1. The tank contains 14,200 gallons of eutectic calcium chloride brine and 1,000 gallons of TCE. The latter, being much heavier, sinks to the bottom. The freezing point of 31.4% calcium chloride is -59.8°F, with a latent heat of fusion of 59.2 Btu/lb. A layer of about 2 feet of crushed limestone is spread over the cross-section of the tank on a supporting grid near the top of the tank. The level of the liquid is maintained so that the upper surface of the calcium chloride brine is always within the limestone layer.

The crushed limestone ($CaCO_3$) serves a double function, acting as a spreader for the TCE and preventing corrosion by the TCE in other parts of the system by neutralizing any hydrochloric acid formed by any decomposition of the TCE.

During the pull-down cycle, cold TCE from the refrigeration plant is sprayed on the crushed limestone. After trickling through this bed it descends by gravity in a finely divided state through the calcium chloride brine, taking up latent heat of fusion. At the bottom of the tank the TCE separates out and is circulated back to

the heat exchanger of the refrigeration plant. When all the calcium chloride brine has been frozen to a fissured mass, the pull-down process is complete.

During the load cycle, circulation is maintained in the same manner, except that the cold TCE from the bottom of the tank is pumped to the heat exchanger of the test cell and the warm TCE returned to the spray nozzle at the top of the tank.

Provision for expansion of the calcium chloride brine on freezing could be provided as shown in Figure 2. Here the freezing calcium chloride solution is contained at all times within a flexible corrugated-walled cylinder, backed by a well of TCE around the circumference.

4 SIZES AND PRACTICABILITY

To supply 927 standard commercial tons of refrigeration for one hour would require 14,200 gallons of calcium chloride brine, using only the latent heat of fusion of the brine. This compares with 57,300 gallons of TCE in an all-TCE storage system with a 60°F temperature drop (2).

The cost of the calcium chloride in the proposed system would be between $2000 and $20,000, depending on the purity required and the cost of the tank pump and plumbing of the order of $35,000. In a comparable all-TCE system, the cost of the equipment would certainly be more than this, and the fluid would cost about $135,000. This indicates a potential saving of over $100,000, a saving in space, and reduced hazard by reducing the large quantity of toxic fluid.

5 UNKNOWNS

Some small-scale experiments were done in laboratory glassware, which indicated that the scheme would work in principle. These experiments showed that the TCE would sink through the freezing $CaCl_2$ brine and continue to do so after the brine was completely solidified into a porous mass. The two liquids separated readily and showed no serious tendency for entrainment.

Before a full-scale system of this type could be seriously contemplated, further knowledge of the heat transfer characteristics and possible corrosion problems would be required. This would have to be determined by model experiments and laboratory tests. However, this is not a disadvantage peculiar to this system, since model tests would be required in almost any scheme other than a two- or three-tank all-TCE system, which would be very expensive,

In a very general way there are some indications that the system would release its stored refrigeration at the rate required. If we considered the frozen mass to have one 1/4" diameter TCE worm hole per square inch of horizontal cross-section, this would give 21,600 feet^2 of surface area. For the required load of 927

standard commercial tons, and assuming a TCE temperature rise of only 30°F in the test cell heat exchanger, the over-all co-efficient of heat transfer would be:

$$U = \frac{Q}{A\Delta t} = \frac{927 \times 12,000}{21,760 \times 30} = 17 \text{ Btu/hr. ft}^2 \text{ °F}$$

6 CONCLUSIONS AND RECOMMENDATIONS

The present proposal offers large potential savings in cost and space over other systems so far considered. Along with other latent heat devices it would give substantially constant outlet temperature characteristics.

It is recommended that the idea should be considered for the Engine Laboratory requirement if it is pursued further, and it is considered that it might be useful for smaller applications--perhaps in the Low Temperature Laboratory.

7 REFERENCES

1. Macaulay, G.A. Notes on Regenerative Heat Storage for Refrigeration of Cell No. 4. Laboratory Memorandum NAE-ENG-59. March 1958.

2. Baxter, D.C. Brine Refrigeration System for Engine Laboratory Test Cell No 4 - Feasibility of a Combined Trichloroethylene-Calcium Chloride Brine System. Laboratory Memorandum NAE-LT-103. Nov. 1957.

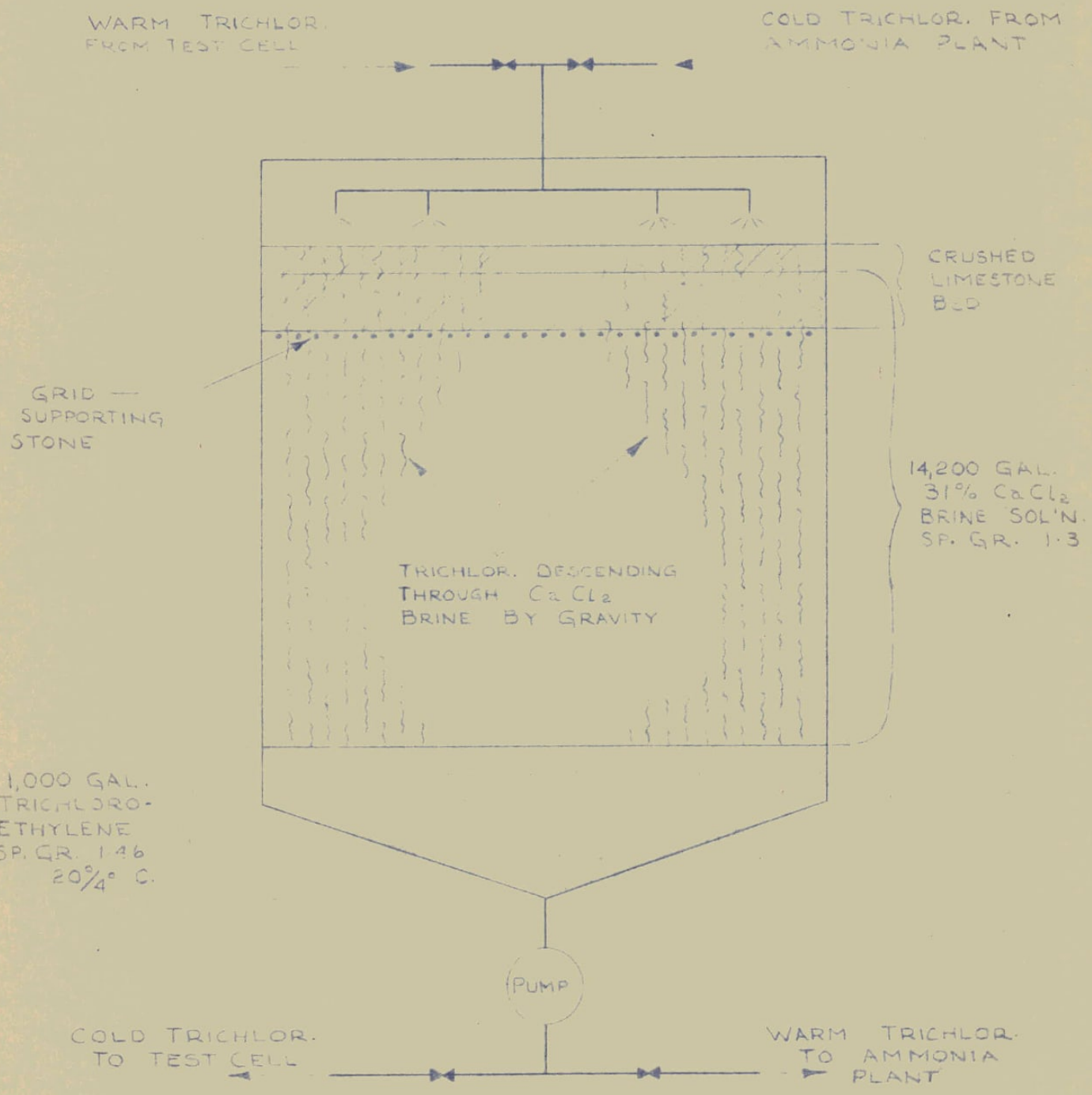

FIG. 1

SCHEMATIC ARRANGEMENT OF DIRECT LIQUID TO FREEZING LIQUID REFRIGERATION STORAGE

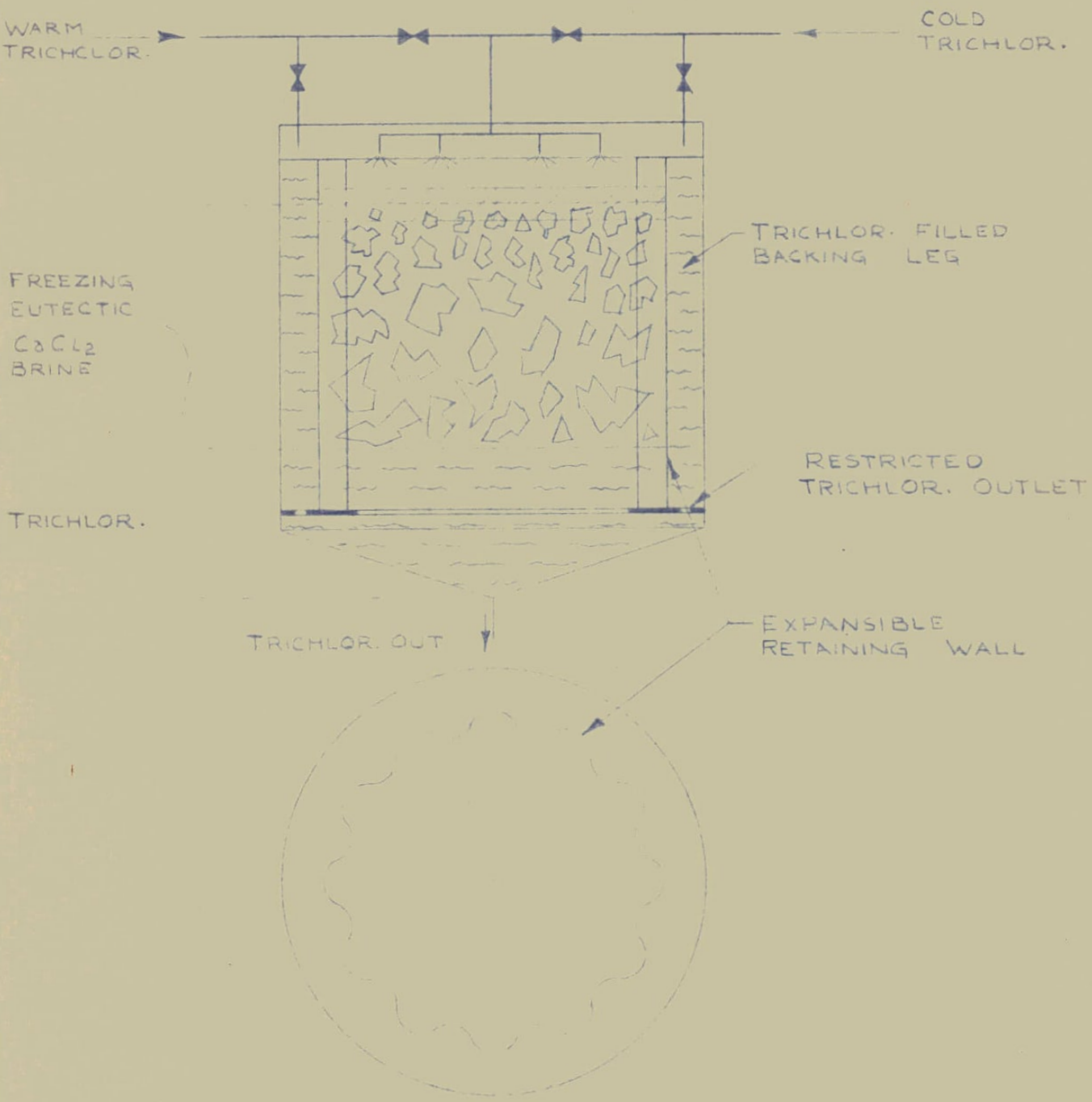

FIG. 2

PROVISION FOR EXPANSION ON FREEZING