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ENERGY STORAGE-BOILER TANK, 1979 PROGRESS REPORT

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PROJECT OUTLINE

Project Title: Heat of Fusion Energy Storage - Boiler Tank

Principal Investigator: Dr. Talbot A. Chubb

Organization: Naval Research Laboratory
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Project Goals: Demonstrate feasibility of heat-of-fusion energy storage-boiler tank.

Evaluate media and heat transfer fluid properties and cycle life characteristics.

Perform storage media-containment materials compatibility studies.

Design, build, and operate a 2 MWh storage-boiler tank.

Project Status: Completed property determinations and selected a eutectic salt (NaCl, KCl, Mg Cl_2) having a melting point of about 385°C, and M-terphenyl as the heat transfer fluid.

Compatibility studies are complete and mild steel containers have been selected.

Fabrication of 2 MWh storage-boiler tank is proceeding and scheduled to be completed in December, 1979. Operation and tests are scheduled through 1980.

Contract Number: EC-77-A-31-1024 and NRL M003

Contract Period: July, 1976 to February, 1980

Funding Level: DOE - $360,000, NRL - $190,000

Funding Source: DOE-Division of Energy Storage Systems and NRL

ENERGY STORAGE-BOILER TANK, 1979 PROGRESS REPORT*

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The objective of the Program EC-77-A-31-1024, Heat of Fusion Energy Storage-Boiler Tank, is the demonstration of heat-of-fusion energy storage in containerized salts. The smallest size storage unit that effectively demonstrates the heat transfer problems associated with such storage, is about 2 MWh. A proof-of-concept 2 MWh energy storage tank is currently under construction on the grounds of the Naval Research Laboratory in Washington, DC. This energy storage unit is the largest heat-of-fusion storage unit in the U. S. program.

Fig. 1. Energy Storage Boiler Tank at the Naval Research Laboratory

Figure 1 shows the energy storage site at the Naval Research Laboratory. The energy storage tank proper is being installed in the square building in the right center of the picture. The roof covering the tank site is a weather shield which can be removed by the light gantry crane. The Butler building is used for storage of Dacotherm insulation, a light-weight sodium silicate insulation, which surrounds the tank during operation. The small sheds near the tank are electrical junction boxes from which 150 kW of heater power is made available for energizing the tank and from which power connections are made to the feedwater pump, the terphenyl circulation pump, an air compressor used for

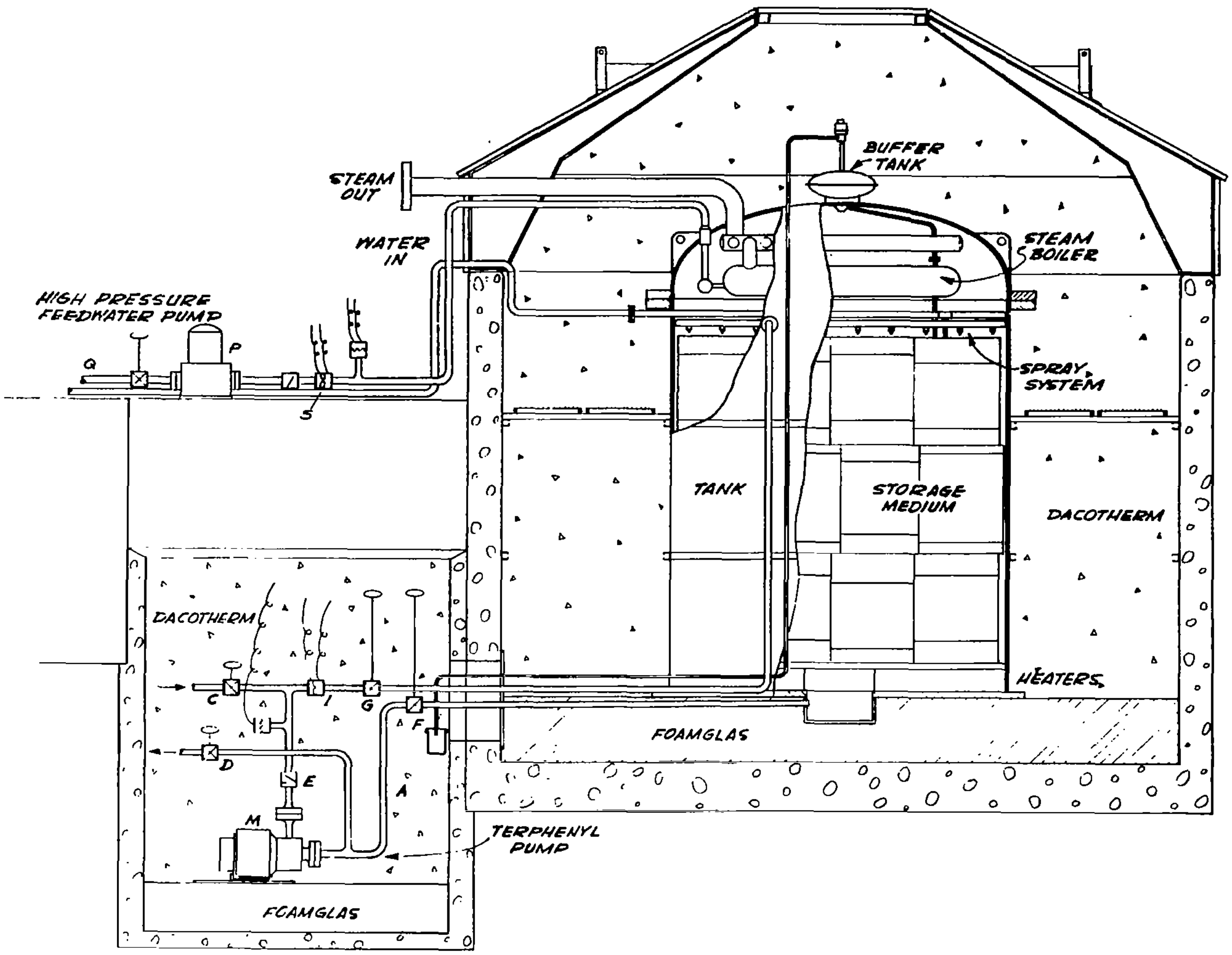

Fig. 2. Cutaway view of 2 MWh Energy Storage Boiler Tank

conveying the Dacotherm insulation, and other auxiliary power purposes. The larger shed houses the compressor, feedwater pump, and controller. The trailer is used to house instrumentation which will monitor temperatures, pressures, flow rates, etc., connected with operation of the facility.

Figure 2 shows the energy storage boiler tank design. The tank is 10.5 feet in diameter and 12 feet high to the level of the flanged ring. A mating domed lid interfaces with this flange, increasing the interior height to 15 feet. The tank is largely filled with containerized salt. The salt cannisters are 4" in diameter, 19" high and are racked into hexagonal baskets for loading. The tank rests on a Foamglas base 2 feet thick, and is surrounded on its side by 40+ inches of Dacotherm insulation. Insulation is adequate to permit the tank to hold its heat for more than 3 weeks. Energization is provided by electrical heater elements embedded in aluminum castings. Twelve such castings rest on the bottom of the tank and provide a total input capacity of 180 kW. Power is brought into the tank through hermitic electrical feedthroughs (Varian #9545009). Internal heat transfer is provided by about

1600 kg of M-terphenyl heat transfer fluid which is operated in a boiling-condensing mode (M-terphenyl is the major constituent of Monsanto's Therminol 88 heat transfer fluid). The lid of the tank contains a boiler-superheater assembly. This assembly receives its energy by condensation of M-terphenyl vapor. The boiler-superheater is expected to provide a peak power output of more than 500 kW.

Also shown in Figure 2 is a pit located below tank level. This pit is the terphenyl pump pit. A hot chemical circulation pump is located in the bottom of the pit. It receives liquid terphenyl from the tank under gravity head. The chemical pump delivers the liquid terphenyl to shower heads located above the salt cans and sprays the terphenyl over the salt cans during energy withdrawal periods. Evaporation of the liquid film of terphenyl which coats the salt tanks provides the means by which heat is removed from the salt cans during energy withdrawal.

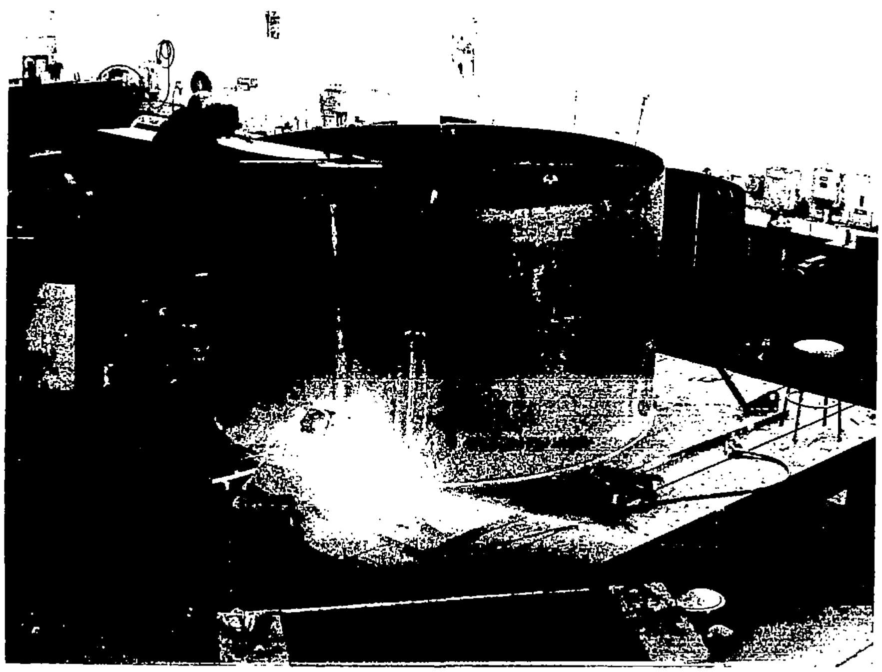

Fig. 3. Containment vessel of 2MWh tank under construction in NRL shop.

Figure 3 shows the energy storage boiler tank under construction in the NRL shop. The tank has a two inch thick steel base with reinforcing ribs. The tank walls are half inch mild steel. The tank is of normal welded construction.

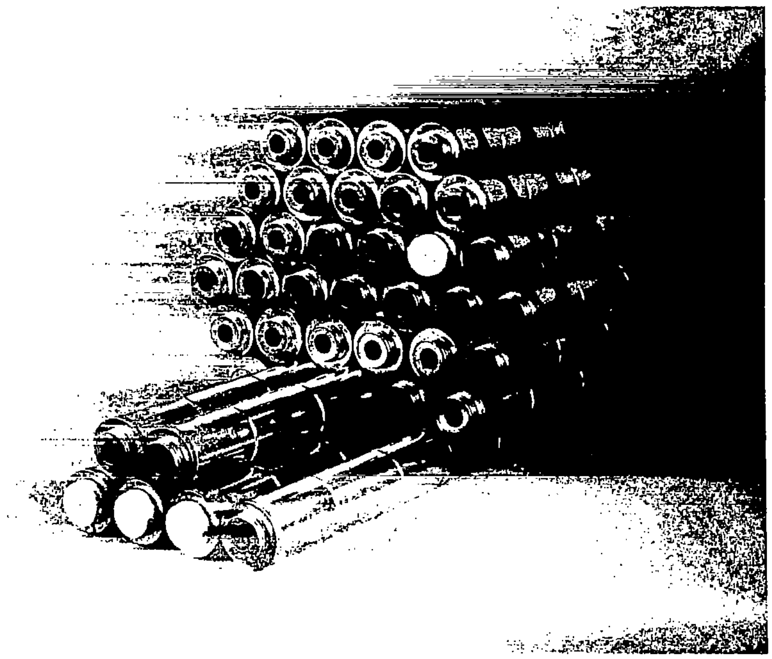

Fig. 4. Salt cans for 2 MWh tank.

Steel cans play an important role in the energy storage boiler tank. These cans, which must contain molten eutectic salt, make use of welded seams in the forming of the can bodies. The cans to be used in the 2 MWh tank were procured from Ellisco Corporation, Fig. 4. The screw-on caps provide protection during salt warehousing, but contain breathing holes that open at operating temperature.

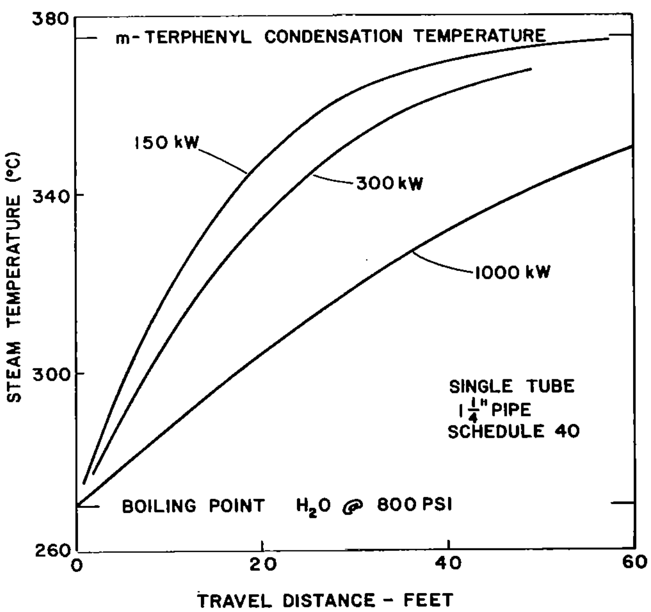

Fig. 5. Calculated temperature growth inside superheater.

Fig. 5 shows the calculated temperature growth in the steam as it flows through the superheater. The figure permits calculation of output steam temperature for various energy withdrawal rates. The superheater in the 2MWh tank is 60 feet long. At 1000 kW energy withdrawal an output temperature of 350°C is predicted. The boiler-superheater assembly consists of 12 4-inch boiler tubes in parallel feeding a single superheater line. Energy transfer to the boiler-superheater assembly is limited primarily by thermal conduction through the film of

TABLE 1 - Specifications: 2 MWh Tank

ITEM	VALUE
Storage Characteristics	
Storage Capacity[(a)]	1.82 MWht = 6.55 GJ = 6.2×10^{6} BTU
Max Energy Input Rate	150 kW
Min Fill Time	12.1 h
Design Output Rate	150 kW
Design Energy Withdrawal Time	12.1 h
Heat Loss to Environment	3000 W estimated
Energy Half-Life	25 days
Tank Configuration	
Inside Diameter	3.18 m (10.4 ft)
Inside Height to Flange	3.66 m (12.0 ft)
Inside Height to Dome	~4.6 m (~15 ft)
Containerized Salt	
Salt Mass	27 T (metric)
No. Cans	4000
Can Diameter	4" = 10.2 cm
Can Height	18.2" = .46 m
Can Volume	3.75 liter
Salt Mass Per Can	6.82 kg (liquid density = 1.82 gcm^{-3})[(b)]
Heat Flux Into Salt	
Can Sidewall Area	690 m^2
Heat Flow Density @ 150 kW at Can Wall	254 W m^{-2}
Temperature Drop Through 4 cm of Salt [(c)]	20°C
Terphenyl Circulation	
Terphenyl Content	1.6 T (metric)
Mass Flow Rate @ 150 kW	.54 kg s^{-1}
Condensation Rate @ 150 kW	.68 liter s^{-1} of liquid (10.7 gpm)
Vapor Pressure @ 365°C[(d)]	100 kPa (1.0 atm, 14.7 psia)
Perfect Gas Density	4.40 g $liter^{-1}$
Gas Volumetric Flow	.123 m^3 s^{-1}
Flow Velocity for 10% Open Area	.15 m s^{-1} (.05 ft s^{-1})
Steam System	
Steam Pressure	5.4 MPa (800 psi)
Steam Temperature	371°C (700°F)
Steam Output (@ 150 kW Withdrawal)	.05 kg s^{-1} (393 lb hr^{-1})
Water Feed Temperature	21°C (71°F)
Water Flow Rate	.05 liter s^{-1} (.8 gpm)

(a) Salt heat-of-fusion only.
(b) Based on observed pour level in cans which are subsequently weighed.
(c) Based on k = .87 W m^{-1}. Ref. radius = 3 cm.
(d) Handbook of Chemistry and Physics, 48th edition, p. C-560 (1967).

terphenyl condensate which continually forms on the boiler components; to a lesser extent heat transfer is limited by heat flow across the metal-steam interface in the steam superheater tube.

Specifications for the tank are shown in Table 1. Heat-of-fusion storage provides 90% of the 2 MWh rated storage capacity. The specified energy withdrawal rate is 150 kW, corresponding to an output of 800 psi superheated steam of 180 kg hr^{-1} (393 lbs hr^{-1}). A maximum steam output rate of more than 600 kg hr^{-1}, i.e. 500 kW, should be achieved.

It is expected that the energy storage boiler tank will be installed onsite within the next couple of months. It is hoped to initiate heat transfer tests later in the winter. Installation of the salts will probably occur during the spring of 1980, with energy storage runs beginning shortly thereafter. A detailed report is in preparation.