DESIGN, CONSTRUCTION, AND TESTING OF THE DIRECT ABSORPTION RECEIVER PANEL RESEARCH EXPERIMENT*

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ABSTRACT

A panel research experiment (PRE) was designed, built, and tested as a scaled-down model of a direct absorption receiver (DAR). The PRE is a 3-MW_t DAR experiment that will allow flow testing with molten nitrate salt and provide a test bed for DAR testing with actual solar heating. In a solar central receiver system DAR, the heat absorbing fluid (a blackened molten nitrate salt) flows in a thin film down a vertical panel (rather than through tubes as in conventional receiver designs) and absorbs the concentrated solar flux directly. The ability of the flowing salt film to absorb the incident solar flux depends on the panel design, hydraulic and thermal fluid flow characteristics, and fluid blackener properties. Testing of the PRE is being conducted to demonstrate the engineering feasibility of the DAR concept. The DAR concept is being investigated because it offers numerous potential performance and economic advantages for production of electricity when compared to other solar receiver designs.

The PRE utilized a 1-m wide by 6-m long absorber panel. The salt flow tests are being used to investigate component performance, panel deformations, and fluid stability. Salt flow testing has demonstrated that all the DAR components work as designed and that there are fluid stability issues that need to be addressed. Future solar testing will include steady-state and transient experiments, thermal loss measurements, responses to severe flux and temperature gradients and determination of peak flux capability, and optimized operation. In this paper, we describe the design, construction, and some preliminary flow test results of the Panel Research Experiment.

1.0 INTRODUCTION

In a solar central receiver power plant, energy from the sun is reflected and concentrated by a field of heliostats. This energy is focused on a receiver located at the top of a tower in the field. The receiver is cooled (and thus the solar energy collected) with a heat transfer fluid. In conventional receiver designs utilizing molten nitrate salt[1] the fluid is contained in tubes; these receivers are called salt-in-tube (SIT) receivers.

Because the concentrated solar energy must be absorbed by the tube and then be conducted through the tube wall, tube material constraints limit the size, efficiency, and peak flux capabilities of the receiver. The direct absorption receiver (DAR) is an alternative central receiver design in which the heat transfer fluid (a blackened molten nitrate salt) flows in a thin, wavy film, typically 2 to 5 mm in average thickness, down a vertical panel and directly absorbs the incident solar flux. The concept was originally investigated in the 1970s by Sandia National Laboratories [2]. In the operation of a DAR, "cold" (285°C, 550°F) salt is introduced onto the DAR panel at the top of the receiver. The salt flows down the panel surface at velocities of 3 to 5 m/s, through the concentrated solar beam, which heats the fluid. Hot (565°C, 1050°F) salt is collected at the bottom of the panel and piped down the tower. The ability of the flowing salt film to absorb the incident solar flux depends on the panel design, hydraulic and thermal fluid flow characteristics, and fluid blackener properties.

Because of its unique design, the DAR offers a number of significant possible advantages over SIT receivers. The performance and economic advantages of the DAR include a significantly simplified design, improved thermal performance, increased reliability and operating life, and reduced capital and operating costs [3,4,5].

A number of technological uncertainties affecting DAR feasibility require resolution before the concept can be considered a commercial alternative. The key issues that need to be addressed include: 1) thermal/hydraulic stability of the flowing salt (including salt loss), 2) DAR panel and component design considerations, 3) salt and blackener chemistry and optical properties, and 4) commercial design and scale-up. A research and development plan to study the DAR was initiated in 1986 by Sandia National Laboratories and the Solar Energy Research Institute (SERI) [6]. This research plan called for systems and design studies, materials testing, and small- and large-scale tests of the DAR. A majority of this testing has been completed to date [7-10]. However, in order to demonstrate the engineering feasibility of the DAR concept a major DAR salt flow and solar test program called the Panel Research

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Experiment (PRE) was developed. The PRE, initiated by Craig Tyner at Sandia [11], will address all of the major features of the commercial DAR design.

In this paper we describe the design, construction, and preliminary flow test results of the Panel Research Experiment.

2.0 OVERVIEW OF THE PANEL RESEARCH EXPERIMENT

The purpose of the PRE is to demonstrate the engineering feasibility of the DAR concept. This experiment will be used to address the uncertainties described in Section 1 about a commercial DAR design, within the limitation of the test facility. This experiment was designed to be tested at the National Solar Thermal Test Facility (NSTTF). An artist's concept of the PRE solar test atop the NSTTF tower is shown in Figure 1.

Figure 1
Artist's Concept of the Panel Research Experiment

The receiver design was based on a commercial design study conducted by Foster Wheeler [3]. The final commercial design uses a thin continuous shell for the absorber. The shell is pretensioned vertically to eliminate potentially damaging compressive stresses and to help absorb the wind loading. The shell is also compressively loaded from the inside, through a rigid subpanel and a layer of dense fiber insulation to provide vibration dampening and horizontal pretensioning of the shell. Within the context of the same study, Foster Wheeler also conducted a preliminary design for the PRE to incorporate into it as many of the commercial design features as possible.

Specific objectives of this experiment are to be met through three specific test phases; water flow testing, molten salt flow testing, and solar testing. All the flow testing will be conducted in the base of the NSTTF tower. The solar testing will be conducted after all the flow testing has concluded and the PRE has been moved to the top of the tower.

3.0 DESIGN AND CONSTRUCTION OF THE PANEL RESEARCH EXPERIMENT

The PRE is a stand-alone system installed on the elevating module at the base of the NSTTF tower. The experiment specifications are provided in Table 1, and a schematic of the experiment arrangement is shown in Figure 2. It should be noted that the PRE design was constrained by limitations of the test facility. For example, the panel size was limited by the maximum amount of power that could be directed onto the panel.

The major components of the PRE are described in the following pages.

Table 1
Specifications for the Panel Research Experiment

Thermal Rating:	3 MW_t
Working Fluid:	Nitrate Salt (60%,40%--sodium,potassium)
Salt Inlet Temperature:	285°C (550°F)
Salt outlet Temperature:	565°C (1050°F)
Salt Flow Rates: (2 control zones)	10-22 kg/m.s (27-60 gpm/ft)
Panel Size (absorber area):	1-m wide by 5.9-m long (3-mm thick stainless steel)
Panel Tension:	175 N/cm sides, 1051 N/cm top (100 lb/in sides, 600 lb/in top)
Flux Levels:	1.5 MW/m^2 maximum, 0.75 MW/m^2 average
Salt Blackener:	Cobalt Oxide, micron size

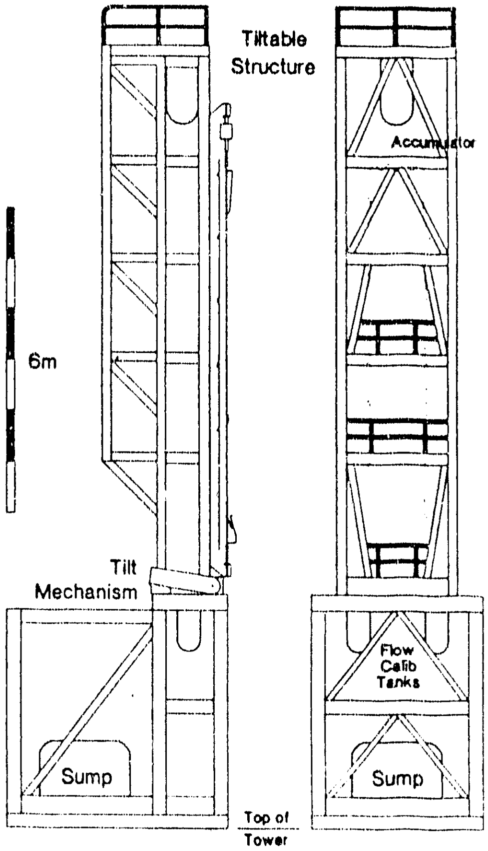

Figure-2
Schematic of the PRE Design

Support Structure

The PRE is designed to fit on the elevating module in the base of the NSTTF, and its support structure is designed to hold all its components. The support structure is shown in Figure 2, and consists of a base structure and a tiltable tower. The panel fits on the front of the tiltable tower structure. The tilt mechanism was built into the structure to allow the tower part of the structure to tilt back as far as 10° from vertical with replaceable shims supporting it in the 5° and vertical positions. The reason for tilting the tower back is so that the effects of panel tilt on fluid stability can be evaluated. The panel is tilted using a jack screw mounted to the tower structure and base structure. For the initial phase of testing, the tower structure was tilted back to 10° from vertical.

Salt Flow Loop

The salt flow loop consists of the pump, valves, piping, pump sump, accumulator tank, and calibration tanks. A schematic of the flow loop is shown in Figure 3. Molten salt is pumped from the pump sump through the heat exchanger. Flow up to the accumulator is controlled by a by-pass valve, which returns a portion of the flow back to the pump sump. The valve in the riser line is an open/close valve, which allows flow up to the accumulator tank. The accumulator tank is pressurized by the inflowing salt. Once salt begins to fill the accumulator tank, the level is controlled by the by-pass valve. When the panel is ready for salt flow, the two control valves between the accumulator tank and the inlet manifolds are opened and flow is initiated (the manifold operation will be discussed later). There are two feed lines from the accumulator tank to the inlet manifold because there are two separate control zones on the panel, for the east and the west flow zones. After the salt flows down the panel and is collected, it flows back down to the pump sump through the two return lines. The salt flow loop was designed to handle molten salt at temperatures of 285 °C to 565°C.

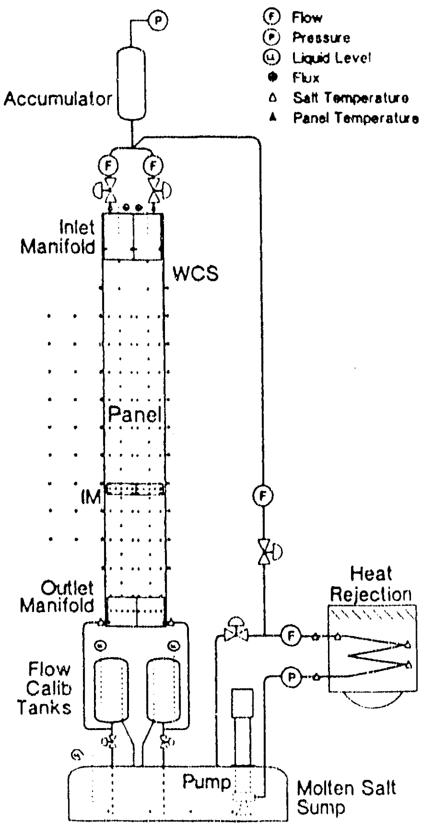

Figure 3
Schematic of the Flow Loop and
Process and Instrumentation Diagram

The pump sump, which contains up to 5500 kg (12,000 lbs) of molten salt, is insulated and electrically heated to maintain the salt at temperatures ranging from 285 to 565°C. Salt is pumped using a vertical cantilever pump with a 18.7-kW (25 HP) electric motor. The pump is designed to provide 11.4 kg/s at 30.5 m of salt head (100 gpm at 100 ft of salt head). This will provide film Reynolds numbers of approximately 46,000 with hot salt.

The accumulator tank was designed into the loop to provide approximately 60 seconds of salt flow in the event of a pump or electric power failure. The accumulator tank will hold and inventory of up to 140 kg (308 lb) of salt, although during normal operation the tank only contains 70 kg (154 lb) of salt. The entire transport loop is heat traced using a mineral insulated heat trace cable operating at less than 164 W/m (50 W/ft). The cable is rated at 656 W/m (200 W/ft). All the pipes and tanks have 7.6 cm (3 inches) of insulation. The valves in the PRE system all use an extended bonnet with bellows seals. The valves are heat traced with the rest of the transport loop.

Two calibration tanks are located in the flow loop to measure the salt flow rate at the outlet of the panel. Because of accuracy problems in previous tests with flow meters, the calibration-tanks were installed to provide a secondary measure of flow rate. Vortex flow meters are used for the primary flow measurement.

Absorber Panel Design

The absorber panel consists of the panel, support frame, and the pneumatic cylinders. An important requirement in the design of the panel is that it remain flat during operation. Previous testing [9] showed that warping of the panel can cause additional fluid stability problems.

Simulating the commercial panel design on this size of a panel test was difficult because of the thermal stresses the panel is expected to encounter. The panel, shown in Figure 4, is made of 3-mm thick 316 stainless steel 1-m wide and 7.08-m long. Only 5.9 m of the panel is exposed to the molten salt; the other 1.2 m is covered by the fluid manifolds. In order to approximate the commercial absorber design, in which the absorber is suspended from the top and vertically tensioned and loaded outward from the inside to provide horizontal pretensioning, the panel is held in tension vertically and horizontally and supported in the back by an insulation block. The tensioning devices are pneumatic cylinders. Not only do the cylinders have to keep the panel in tension, but they must take up the thermal growth in the panel as it heats up from ambient temperature to salt temperature. The attachment lugs on the panel by which the tensioning devices are attached were designed to transmit the tensioning load uniformly without causing stresses of their

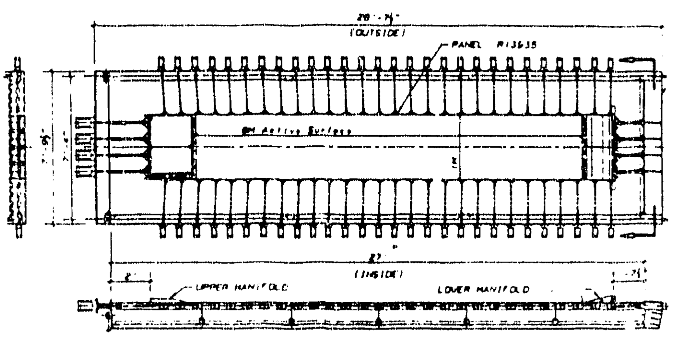

Figure 4
Drawing of the Panel

own. The conceptual design by Foster Wheeler called for vertical tensioning of 2102 N/cm (1200 lb/in) and horizontal tensioning of 525 N/cm (300 lb/in). These loads were required to keep the panel flat in the presence of thermal stresses caused by severe off-axis flux gradients that might be possible in the PRE. These tensioning loads were considered excessive (in design reviews); consequently, the tensioning loads were reduced to 1051 N/cm (600 lb/in) vertically and 175 N/cm (100 lb/in) horizontally. The flux gradients during testing are also to be reduced. A picture of the panel, prior to mounting, is shown in Figure 5.

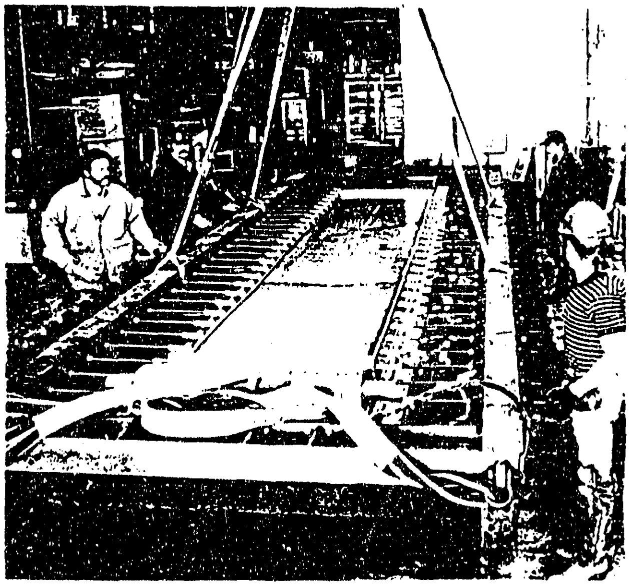

Figure 5
Picture of the Panel Prior to Mounting

A large support frame is used in conjunction with the pneumatic cylinders to tension the panel. The panel is fixed to the bottom of the frame. At the top of the panel four pneumatic cylinders are used to take up the maximum thermal growth of 10 cm (4 inches) and keep the panel tensioned to 1051 N/cm. Horizontal tensioning is provided by 52 pneumatic cylinders (26 per side).

A shim stock edge piece is used to keep the fluid on the panel. A thin, 0.25 mm (10 mils) stainless steel shim stock material was selected for the edging because of its ability to grow with the panel as it heats up. In addition, the shim stock can be easily bent and it has a sharp edge that will contain the molten salt. The actual flow width on the panel constrained by the edge pieces is 0.939 m (3.1 ft). The flow length between the inlet and collection manifolds is 5.9 m (19.4 ft).

Manifolds

The inlet, intermediate, and collection manifolds are critical to the DAR operation because they provide the uniform flow on the panel and collect the fluid. The design of these manifolds is based on water flow testing conducted at Sandia [8,9]. One criterion for the manifolds is that they not affect the thermal growth or introduce thermal stresses on the panel.

The inlet distribution manifold is used to uniformly distribute the fluid onto the panel without misting or splashing. In a commercial DAR the inlet manifold would need to accommodate salt flow rates of 10-28 kg/m.s (27-75 gpm/ft). A schematic of the inlet distribution manifold is shown in Figure 6(a) and a picture of the manifold mounted on the panel is shown in Figure 6(b). This manifold is an independent tank mounted on the front of the panel. The tank has two sections, one for each control zone on the panel. The fluid flows into the tank and then spills out onto the panel through a perforated plate. The perforated plate was designed to provide a uniform flow distribution over a wide range of flows, from 6 kg/m.s (16 gpm/ft) to 19.5 kg/m.s (52 gpm/ft), and keep the manifold to a reasonable size. At the bottom of the manifold, 15 layers of woven stainless steel mesh fill the gap between the panel and the manifold. The layers are tapered to transition the flow and more uniformly distribute the fluid on to the panel. The inlet manifold is attached to the panel with bolts at the top and bottom of the panel.

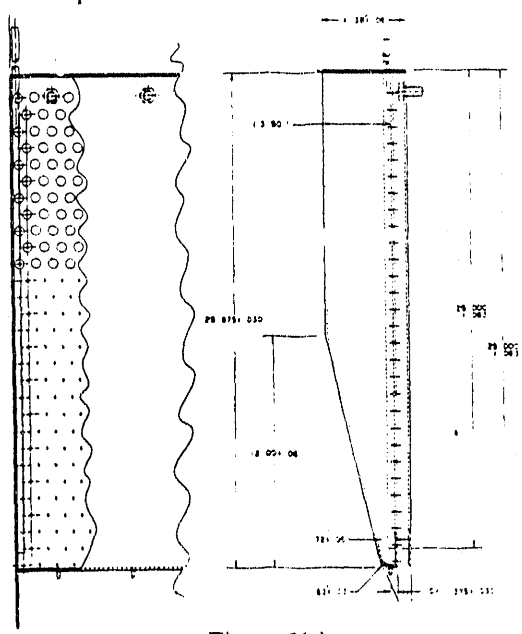

Figure 6(a)
Schematic of the Inlet Distribution Manifold

Figure 6(b)
Picture of the Inlet Distribution Manifold

After the molten salt is heated it is collected at the bottom of the panel in the collection manifold. The manifold must not cause the fluid to mist or splash and yet minimize thermal losses. The collection manifold is attached to the panel with two sets of mounting bolts. Fluid is diverted into the collection manifold with a 0.25 mm (10 mil) stainless steel shim stock deflector which is roll resistance welded to the panel.

An intermediate manifold (IM) may be needed to stop the wave formation, and associated fluid ejection, which occurs as the fluid travels down the panel. Previous testing [7-11] showed that droplet ejection from the waves begins to occur at approximately 4-m down from the inlet. The purpose of the IM is to collect and redistribute the fluid (a combined collection and inlet manifold) back on to the panel. Design of the IM is based on a series of water flow tests [5]. This design is similar to the inlet manifold, except that it is much smaller at 20 cm (8 inches) compared to 73.5 cm (29 inches) for the inlet manifold. The IM is an independent component that can be mounted at any location on the panel (although it will first be mounted at 4-m), using a mounting system independent of the panel; it is not bolted to the panel like the inlet or collection manifolds. The perforated plate uses a denser hole packing than the inlet manifold to allow for the flow range. The wire mesh pack is the same design as used in the inlet manifold. The purpose of this design is to demonstrate that the IM concept will work for eliminating the droplet ejection phenomenon.

Heat Rejection System

During solar testing, the heat rejection system used to remove heat from the salt is an air-cooled molten salt heat exchanger with a nominal rating of 3 MW_t. The heat exchanger is placed directly in the flow loop as explained earlier. The heat exchanger is equipped with two variable-frequency, fixed-pitch, 4-kW (5-HP) electric-motor-driven fans. Air louvers are provided for more precise outlet salt temperature control, if needed. The entire heat rejection system is electrically heat traced.

Water-Cooled Spillage Panels

The PRE was designed to be tested with high flux limits, greater than 1000 kW/m^2. In order to test with high fluxes on the 1-m wide panel there will be a significant amount of spillage, up to 2 MW_t. The water-cooled spillage panels will be used to protect the panel frame, pneumatic cylinders, and remainder of the PRE system from the flux spillage. The design of these panels is not complete at this time; however, the panels will be painted with a high-temperature flat-white paint to provide a diffuse reflector for measuring flux levels using the beam characterization system at the NSTTF. (The location of the spillage panels are shown in Figure 3.)

Instrumentation

This experiment is instrumented to provide adequate data to characterize the performance, evaluate the capability, and determine the engineering feasibility of the DAR concept. The process and instrumentation diagram shown in Figure 3 details the instrumentation used (or to be used) on the PRE. Instrumentation consists of temperature, pressure, fluid level, flow measurement, and flux measurement. The control of the PRE is provided by the Bailey control system installed at the NSTTF. All data acquisition is initiated by the Bailey system and recorded on an HP-1000 computer.

Temperatures are measured using stainless-steel-sheathed type-K thermocouples. Thermocouples (TCs) are used for data measurement, heat trace control, and system safety indicators. Thermocouples (SS sheathed 1.6 mm (0.0625 inch)) are attached to the back of the panel to provide temperature data on the panel. There is no satisfactory method of measuring the fluid temperature as it travels down the panel; however, the panel temperatures will be used to infer the fluid temperature. The salt temperature is measured in the inlet manifold (in both zones) and in the collection manifold. Temperature changes across the panel are measured using both differential TCs, to provide better accuracy, and by differences in absolute TC measurements.

Pressure transducers for measuring salt pressure at the inlet to the heat exchanger utilize a sodium/potassium (NaK) working fluid to provide the best accuracy and allow operation of the system at temperatures greater than 400°C. The air pressure is measured in the accumulator tank to maximize the reliability of the system. A pressure transducer using siltherm oil is used for this transducer. Fluid level is measured in the pump sump, inlet manifolds (both zones), and calibration tanks. Relatively simple air bubblers are used in all cases since all these locations are vented.

Salt flow rates are measured with two different systems, a vortex shedding flow meter and the calibration tanks. The vortex shedding flow meters are located a four locations (see Figure 3) in the flow loop for measuring total flow, flow up to the accumulator tank, and flow to each zone of the inlet manifold. The calibration tank is a "bucket and stop watch method" of measuring flow. The level indicators are used to calculate the flow rate at the outlet of each zone. The calibration tank measurements can be compared to the vortex flow meters and provide a backup in the event that the vortex flow meters do not work as expected.

During solar testing, the incident flux will need to be measured to evaluate the performance of the PRE. The incident flux will be measured using the beam characterization system and the spillage panels (described earlier). In addition, plans for the water-cooled spillage panels call for them to be instrumented with flux gages to provide point flux measurements. Since the spillage panels are adjacent to the PRE panel the aim point(s) can be simply shifted from the PRE panel to the spillage panel and back to get flux measurements. The flux gages to be used will be determined at a later date.

4.0 TEST PLANS

Testing of the PRE will be conducted in three phases: water flow testing, salt flow testing at the base of the tower, and solar testing at the top of the tower. An overview of the test plans is provided in Table 2.

Table 2
Test Plans for the PRE

TESTS	PURPOSE
Water Flow Testing	
Checkout Testing	evaluate system integrity
Fluid Characterization	evaluate fluid stability
IM Testing	test IM performance
Salt Flow Testing	
Checkout Testing	evaluate system performance
Flow Characterization	evaluate fluid stability
Wind Effects Testing	determine effects of wind on fluid stability
IM Testing	test IM with salt
Zone Flow Testing	evaluate effects of zone variations
Thermal Loss Testing	determine thermal performance of the PRE

Table 2 Continued
Test Plans for the PRE

TESTS	PURPOSE
Salt Flow Testing	
Cold Start Testing	evaluate PRE cold startup
Solar Testing	
Checkout Testing	validate system operation
Control Verification	verify operation of the control system
Wind Testing	evaluate the effects of wind on fluid stability with solar flux
Loss Measurement	determine the thermal performance of the PRE
Blackener Performance	evaluate the effect of the blackener on thermal performance
Transient Testing	evaluate the PRE response to transients
IM Testing	investigate the performance of the IM in the solar environment
Power Production	determine ability to daily produce power
Cyclic Fatigue Testing	investigate cyclic fatigue effects

5.0 RESULTS OF PRELIMINARY TESTING

The fabrication of the PRE was completed in July 1990. A picture of the completed PRE is shown in Figure 7. The water flow testing was initiated before the entire PRE was completed. Salt flow testing on the PRE panel was initiated in August 1990. We are currently in the middle of the salt flow test plan. Once the salt flow testing has been completed, and a technical evaluation of the concept determines that the solar testing is justified, the PRE will be raised to the top of the CRTF for solar testing.

The results discussed are preliminary.

Water Flow Testing

Initial water flow testing demonstrated the integrity of the system. Testing was initiated with the panel tilted back to 10° from vertical. There were no significant problems with the flow loop. However, one minor deficiency identified was that the pump did not have the capacity expected. When water was flowing through the recirculation loop, the pump capacity was approximately 6.61 kg/s (105 gpm). However, when pumping up to the accumulator tank, the maximum capacity of the pump was 5.86 kg/s (93 gpm). This was below the design specification, and the maximum flow will be less with salt because of its higher density. The lower pump capacity will reduce the flow range which can be tested.

Much of the water flow test time was spent optimizing the inlet manifold operation. The wire mesh pack had to be modified to achieve the designed flow range of 6-19.5 kg/m.s, which would allow operation in film Reynolds number ranges up to 75,000 with hot salt.

The operation of the IM was also tested during the water flow testing. A picture of a test with the IM in place is shown in Figure 8. This picture demonstrated the effective operation of the IM in stopping the flow (and wave development) and reintroducing the flow uniformly back on to the panel. The IM wire pack configuration also had to be modified during the water flow tests to allow operation over the desired range.

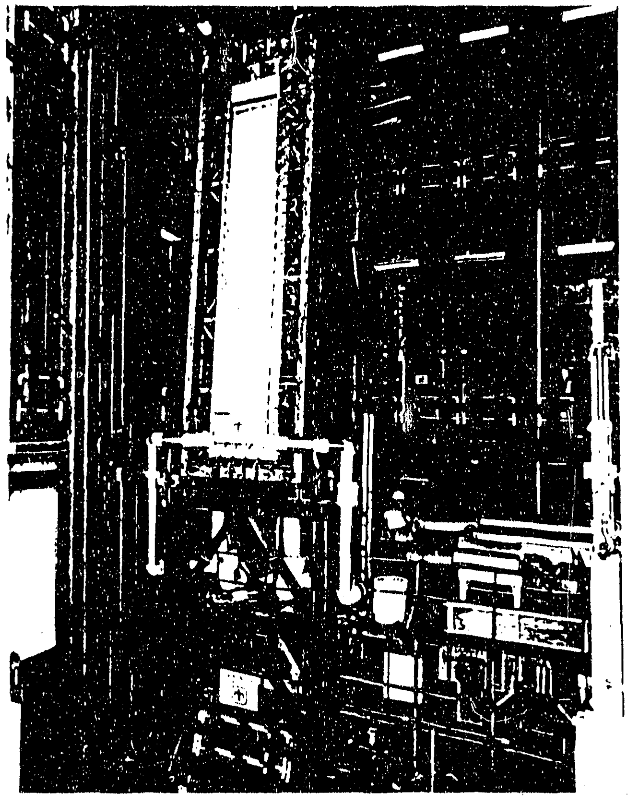

Figure 7
Picture of the PRE in the Base of the Tower

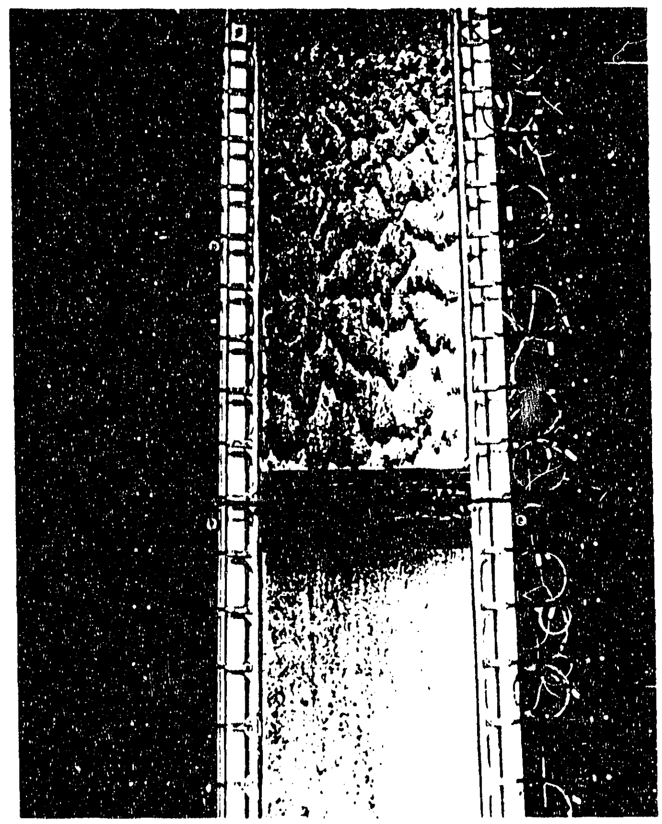

Figure 8
Intermediate Manifold During Operation

The water flow tests were also used to conduct fluid characterization testing. In particular, wave height measurements were made at 3 through 5 meters down the panel. These measurements were the same as those conducted by Chavez [8] in earlier water flow testing. The measurements taken on the PRE included testing at higher flow rates (and Reynolds numbers) than conducted previously. The measurements, with the panel tilted back to 10°, compare favorably with previous results. Peak wave heights of 12 mm were measured at Reynolds numbers of 35,000. In observing, the flow there appeared to be little droplet ejection in the absence of wind. The droplets that did develop at the tips of the waves tended to fall back onto the panel.

Salt Flow Testing

The salt flow testing is being conducted with the PRE on the elevating module in the base of the tower. For this phase of testing the molten salt will not be darkened with the colbalt oxide. The initial testing is being conducted with the panel tilted back 10° from vertical and no intermediate manifold on the panel. Salt flow testing on the PRE was initiated on August 15, 1990.

In order to reduce the thermal shock to the panel and prevent salt from freezing on the panel when salt flow is initiated, a procedure was developed for using heliostats in the field to preheat the panel. Normally four heliostats are used to preheat the panel; these heliostats provide approximately 75 kW_t to the panel. The temperature near the outlet of the inlet manifold is the most critical. The temperature in the wire mesh pack must be over (220°C) 430°F so that the salt does not freeze in the wire mesh and block the flow. Two cartridge heaters are located on the back side of the panel at the location of the wire pack. The panel is heated to approximately 260°C (500°F), then salt flow on the panel is initiated.

The salt flow looks very much like water flowing on the panel. The inlet salt temperature is 330°C (625°F). Flow out of the inlet manifold appears to be satisfactory, although, there is some minor leakage around the edges of the manifold. The edge containment pieces work well. However, the salt leakage out the edges of the manifold tend to cause salt to ride on the top of the edge containment pieces. The collection manifold appears to work well in collecting most of the salt flowing down the panel. The maximum flow capacity of the inlet manifold is 9.4 kg/m.s (25 gpm/ft). This is far below the maximum expected, and the reason for the lower flow rates with salt is not known. However, various causes are being investigated.

All characterization testing and observations have been conducted with the salt at 330°C. With salt flow rates of 5 kg/m.s (13.5 gpm/ft) and no wind there is light misting off the panel and no observable droplet ejection off the panel. Observations taken from high-speed movies of the flow, at flow rates of 6.2, 7.5, and 9.4 kg/m.s (Reynolds numbers up to 12,000) show that the droplet from the tips of waves does occur at all flow rates beginning at approximately 4-m down from the inlet. However, most of the droplets appear to fall back onto the panel since the panel is tilted back 10°. The wave heights and droplets increase with higher flow rates. In the few wind effects tests that have been conducted, a wind of approximately 20 mph blowing at an incident angle of 45° to the panel causes a significant amount of misting and observable droplet ejection from the panel at all flow rates. Further testing is to be conducted in an attempt to better quantify the droplet ejection and the effects of wind.

During the preheating of the panel and bottom manifolds, there are large temperature gradients near the top and bottom manifolds. These gradients caused severe thermal stresses on the panel which were noticed after the panel cooled down. During subsequent testing and heating of the panel all the deformations in the panel appeared to pull out while it was hot (it appeared to be flat). The deformations in the panel occurred at the edges of the panel in the form of sin waves in the panel. The pneumatic cylinders appear to be working as designed in accommodating the thermal growth in the panel and keeping the panel tensioned and flat while it is operating. However, the warping of the panel as it cools down may be an indication that more tension is needed to keep the panel flat during cool down.

Molten salt flow testing of the PRE is continuing. Salt flow testing to quantify and evaluate the DAR concept will be completed in December 1990.

6.0 CONCLUSIONS

As part of the program to develop the molten salt DAR, a panel research experiment (PRE) was designed and built as a scaled-down model of a commercial DAR. The PRE is a 3-MW_t DAR experiment that will allow flow testing with molten nitrate salt and provide a test bed for DAR testing with actual solar heating. The PRE has been tested with water flow and molten salt flow. Flow testing has demonstrated that the PRE works as designed.

The testing conducted to date is limited, and the results are preliminary. All the PRE components work as designed, although the maximum flow rate from the inlet manifold is lower than expected. Also, the panel does warp slightly during cool down; yet, this does not affect the PRE operation. Preliminary test results show that there is salt droplet ejection from the panel, particularly with windy conditions. However, the amount of salt lost does not appear to be significant.

Testing of the PRE is being continued to evaluate the engineering feasibility of the DAR concept. The testing to date indicates that the DAR can be made to work. That is, the higher flow rate can be achieved with the inlet manifold, the salt misting and droplet ejection can be controlled, and the panel warping can be eliminated. These problems can be eliminated with a new inlet manifold, wind screen and air curtains to eliminate the fluid loss, and higher tensioning and different manifold attachment to keep the panel from warping. Once the engineering feasibility of the DAR concept has been proven, the question then becomes: are the benefits of the DAR still great enough that the concept should be pursued? We are attempting to resolve this question.

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