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USE OF FLUIDIZED BED HEAT EXCHANGERS IN HEAT PUMP SYSTEMS FOR IMPROVED PERFORMANCE

Technical Status Report
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PROGRESS REPORT

ABSTRACT

Construction of the test facility including plenum and ductwork has been completed and the heat pump has been operated. In the interest of maintaining comparable test conditions a single compressor with switch-over capability between the fluidized bed and the existing heat exchangers is to be used. A computer program simulation of the York heat pump gives results for COP which are too high. Heat transfer measurements for the design of the fluidized bed heat exchangers using a bare tube show an increase in heat transfer coefficient of about five times for air velocity of 0.5 meters per second using spherical glass beads 245 microns in diameter.

1. INSTALLATION

Construction of the plenum has been completed. Ductwork has been installed between the heat pump and the plenum and the system has been run in the heating mode.

It was planned originally to have two identical separated heat pump units, one of which would use fluidized bed heat exchangers. The performance of the units would only be affected by the difference in the heat exchangers. However, because of possible (unpredictable) differences in the compressors of two different units, it has been decided to run the tests using the same heat pump for both types of heat exchangers. This means that the existing and the fluidized bed heat exchangers will be connected in such a way that the unit may operate with 1) the existing heat exchangers, 2) the fluidized bed replacing either one or the other of the existing heat exchangers, and 3) the fluidized beds replacing both existing heat exchangers. The same compressor will therefore be used for all combinations of heat exchangers. A revised schematic of the systems is given in Figure 1.

2. INSTRUMENTATION

Preliminary pitot tube traverses of the ducts leading from the indoor and outdoor units show good correlation of air flow rate with the manufacturers' figures. Measurements of freon mass flow rate were held up because of a delay in obtaining quick disconnect fittings.

3. SYSTEM MODEL

The first results from the computer model of COP versus heat transfer coefficient have been obtained and give values of COP which are too high by comparison with the manufacturers' values (even when blower, fan and compressor heater powers are included). Most of this is caused because some parameters (pressure drops, temperature differences, compressor efficiency) were estimated. They will be determined more accurately by direct measurement. In addition, improvements in the analytical aspects of the model are necessary and are continuing.

4. HEAT TRANSFER MEASUREMENTS FOR DESIGN OF FLUIDIZED BED HEAT EXCHANGERS

In this report period, tests to obtain heat transfer data for design of the fluidized bed heat exchangers (which is to be substituted in the heat pump system) were begun. A decision was made to obtain initial measurements with a bare tube (without fins). Figure 2 shows a sketch of the instrumented tube used for these initial measurements. A copper tube of 0.95 cm outside diameter was fitted with an internal cartridge heater to obtain a heated length of 10 cm. A sheathed thermocouple was installed in a groove in the copper tube to measure tube wall temperature at the middle of the heated length, as indicated in the sketch. From the measured wall temperature and the measured power input to the cartridge heater, along with an independent measurement of coolant air temperature, it was possible to determine heat transfer coefficient between the tube surface and coolant fluid.

The instrumented tube was installed horizontally in a rectangular bed vessel which provided upward airflow across the tube. Figure 3 shows a schematic sketch of the test assembly. In the initial experiments, the distributor plate was made from a porous plastic plate which had a relatively high pressure drop. Plans call for development and testing of other, low-pressure-drop distributor plates in the coming months. The test heater tube was located with a center line distance (L) above the top surface of the distributor plate. Particles for the fluidized beds could be loaded on top of the distributor plate to any desired packed height (H_0). When fluidized, the depth of the fluidized bed (H) would normally be greater than the tube elevation (L) so that the heat transfer tube is submerged in the fluidized bed. The coolant ambient air temperature was measured by a thermocouple located between the distributor plate and the test tube, as indicated in Figure 3.

Data were obtained first with no particles in the bed. These data, therefore, represent just convective heat transfer to air in cross flow over the test tube. Results are shown in Figure 4, where the different symbols indicate measurements with the tube wall thermocouple at various angular positions (with 0° denoting the top of the tube and 180° denoting the bottom of the tube). It is seen that with air velocities in the range of 0 to 1.2 meters per second, typical heat transfer coefficients were in the range of 40 to 90 $(\frac{W}{m^2 °C})$. There was no significant difference for data obtained at various circumferential locations around the tube, as indicated by the three thermocouple locations.

A second series of experiments were performed with glass bead particles (245 micron mean diameter) as the fluidized bed medium. The particles were loaded to a packed height (H) of 3.8 centimeters. The center line tube elevation (L) was 2.2 centimeters. Results are shown in Figure 5 where again the different symbols indicate measurements made at different circumferential locations around the tube. As seen from Figure 5, there is a noticeable, though small (approximately 10%), variation of the heat transfer coefficient around the tube in this fluidized bed mode. More significantly, we note that with the tube in the fluidized bed, the heat transfer coefficients were indeed greater than those obtained with just air convection. Comparing the results of Figures 4 and 5 at an air velocity of 0.5 meters per second, the heat transfer coefficients for this particular fluidized bed were approximately 500% greater than those for air convection at the same velocity.

These experiments are continuing in the coming months. Additional data will be obtained for different types of bed particles and for different tube elevations and packed bed heights. In addition, development of low-pressure-drop distributors will be initiated.

5. PERSONNEL

Since the beginning of the current term of the project, Professor John C. Chen has devoted ten percent of his time to the project and Professor Robert G. Sarubbi, fifteen percent. These percentages of participation have continued at the same rate through May 1978. Professor John C. Chen will continue at a rate of twenty-five percent for two summer months and Professor Sarubbi at fifty percent for two summer months, through August 1978.

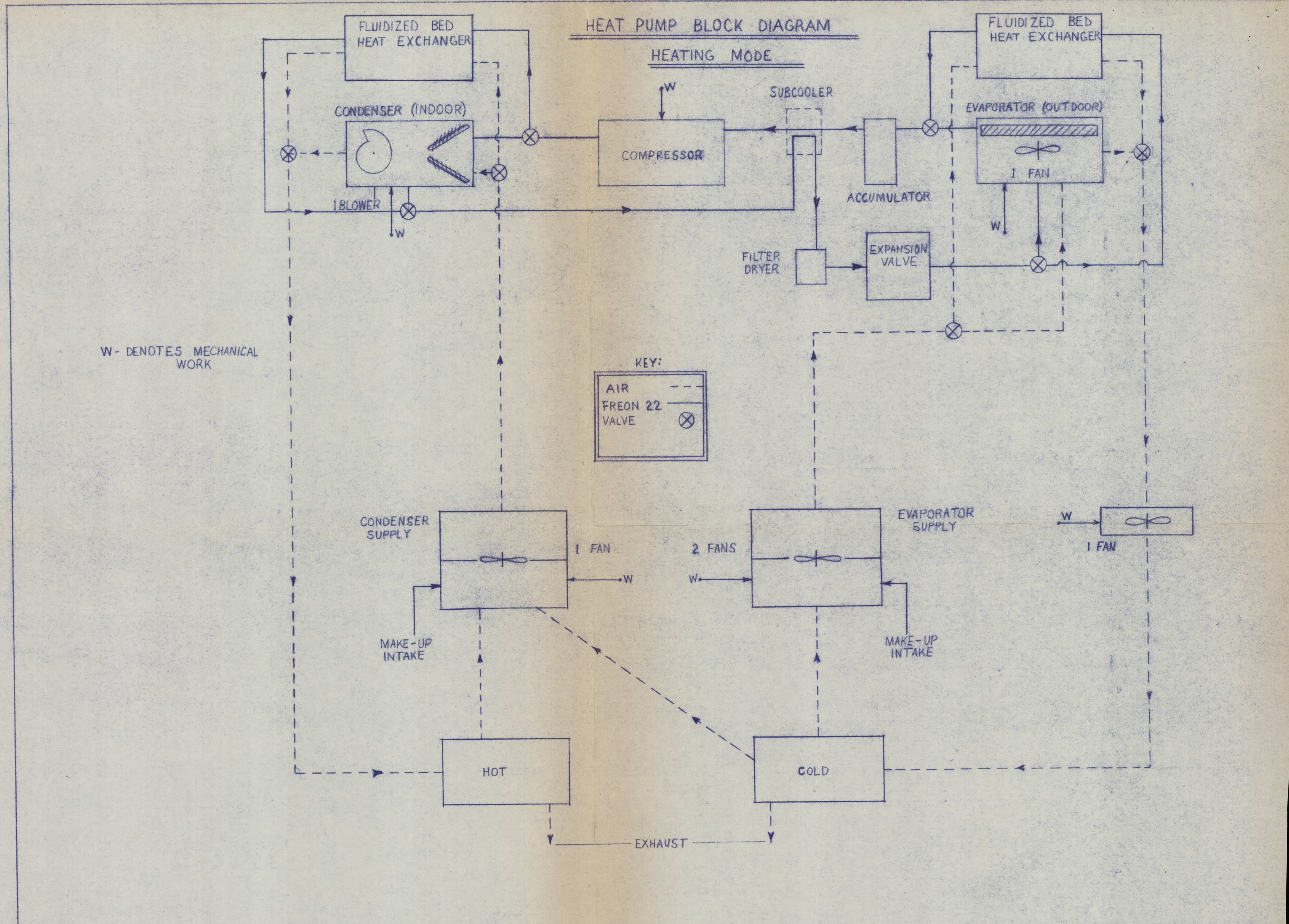

FIG. 1

DUANE ISING 6-12-78
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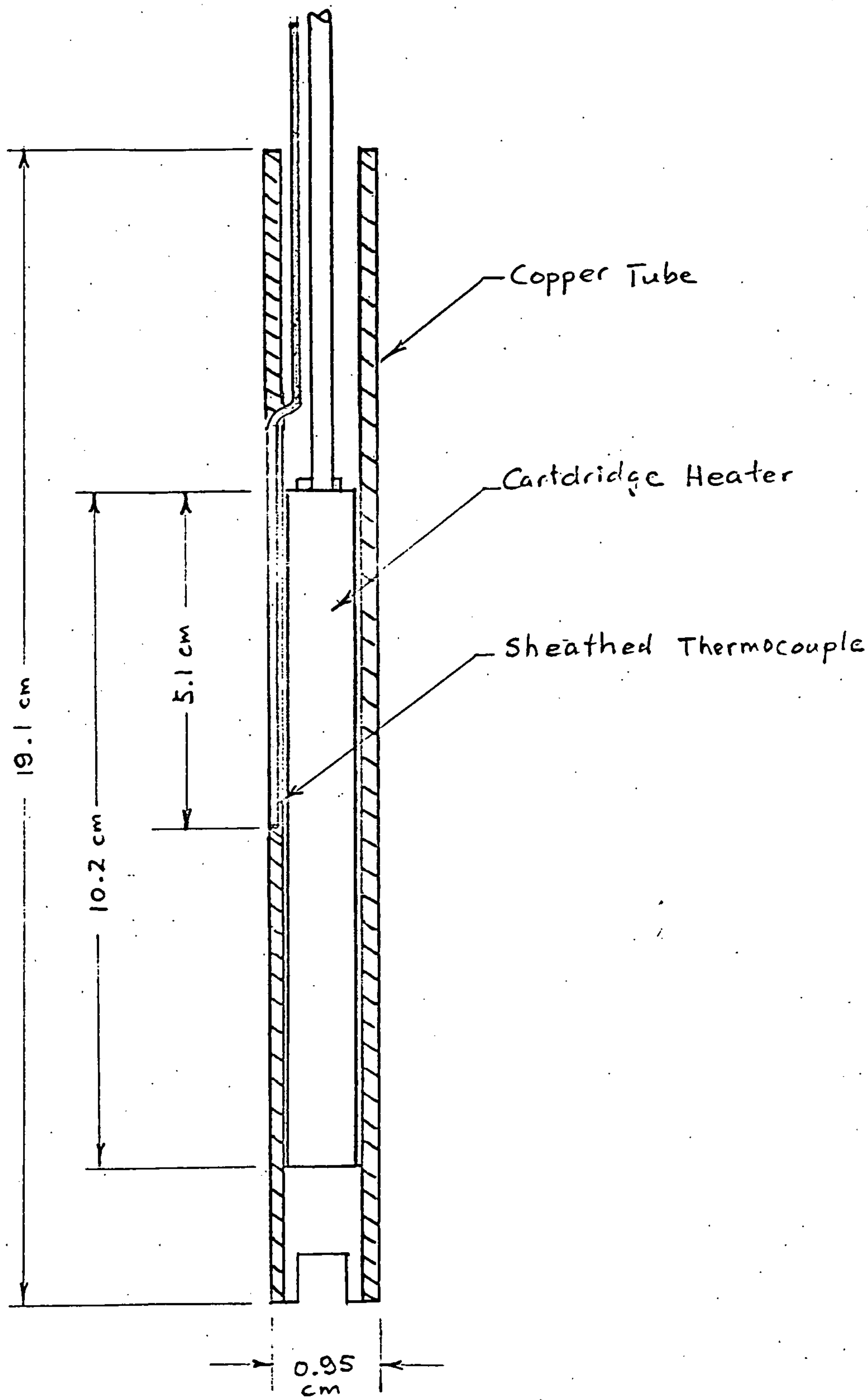
Instrumented Test Heater Tube

FIGURE 2



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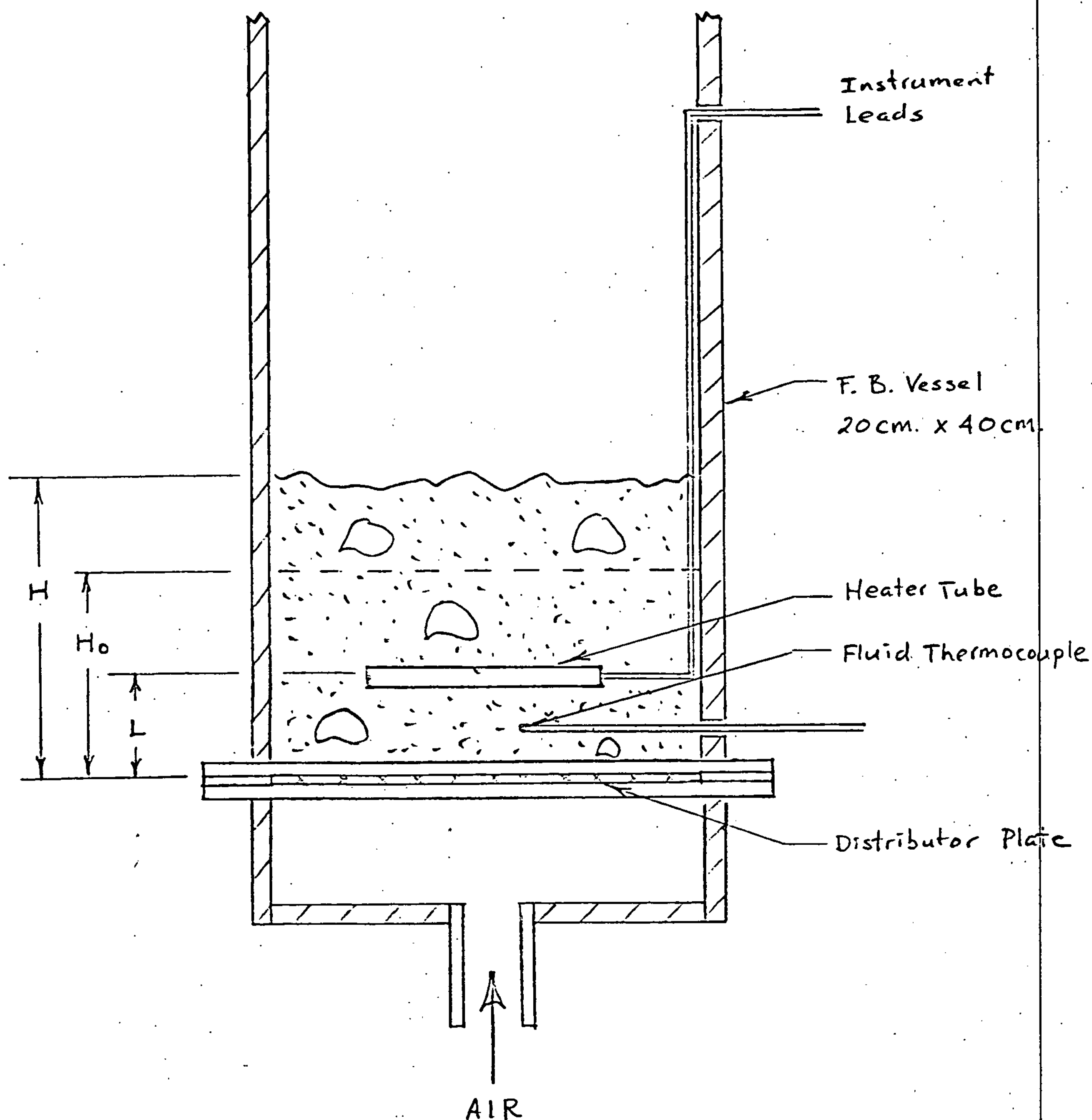
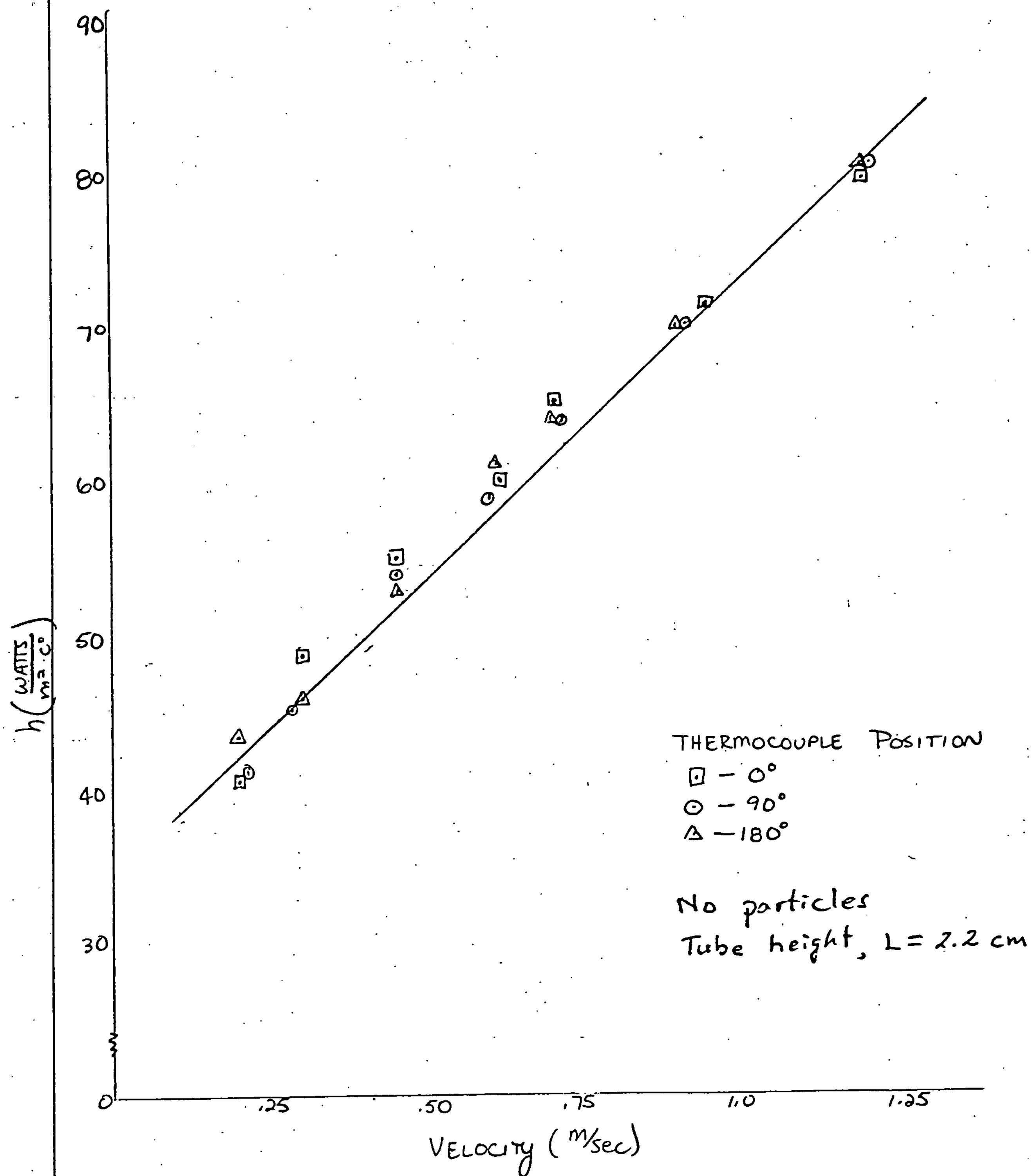
Fluidized-Bed Heat-Transfer Test Apparatus

FIGURE 3



Air Convection Heat Transfer

FIGURE 4



Fluidized-Bed Heat Transfer

FIGURE 5