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MASTER

INVESTIGATION OF PASSIVE COOLING FOR HOT-HUMID CLIMATES

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College of Architecture
Georgia Institute of Technology
Atlanta, Georgia 30332

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Project Director

James M. Akridge
Associate Professor of Architecture
(404) 894-3822

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INVESTIGATION OF PASSIVE COOLING FOR HOT-HUMID CLIMATES

Work the past two months has been devoted toward getting the Brookhaven National Laboratories computer program for modeling ground coil performance operational. This program proved to be much more difficult to get operational than had been anticipated. The problem was finally, with the aid of John Andrews of BNL, traced to a change in TRNSYS from the 8.2 version used by BNL to the 9.2 and 10.1 versions being used at Georgia Tech. John recommended several changes to the TRNSYS main program which were successful. The BNL ground coil simulation program is now operational on the Georgia Tech computer and is presently being used to optimize the field layout.

Arrangements have been made to sink the two 40 ft. vertical wells for soil temperature measurements. These wells should be sunk on May 5th. Figure 1 shows the well location relative to the field location. One well is located remote from the field to measure undisturbed soil temperatures and one well is located in the center of the field to measure the vertical effect of the field. Core samples will be taken during the drilling operation. These samples will be weighed, dried, and reweighed to determine initial soil moisture content. Figure 2 is a cross-section through one of the vertical wells. This figure shows the thermocouple location. The thermocouples are positioned in a sand filled vertical PVC tube with each thermocouple bead projecting through a small hole in the tube and being bonded to the exterior of the tube. Since the PVC tube has a thermal conductivity only 1/10 that of soil, the tube should not affect thermocouple measurements. Once the

FIGURE NO. 1 Plan of Test Site

Figure 2 Crossection of Temperature Wells

TABLE I
THERMOCOUPLE DEPTH

<u>THERMOCOUPLE NO.</u>	<u>DEPTH</u>
1	Surface
2	6"
3	1'
4	2'
5	3'
6	4'
7	5
8	6
9	7
10	8
11	10
12	12
13	14
14	16
15	18
16	20
17	25
18	30
19	35
20	40

thermocouple tube has been located vertically in the 40 ft. holes, the holes will be back filled with a 50/50 mixture of Bentonite and Cement. This mixture has been found satisfactory for such applications because it flows readily and should not subsequently develop cracks which might affect soil temperatures.

Soil temperatures will be measured for the 20 locations in each hole at 1 day intervals beginning as soon as the holes have been filled until the thermocouple temperatures begin to stabilize. Once the effect of the installation has dissipated, the thermocouples will be monitored once each week. Average daily ambient temperatures will also be measured at the test site so that ambient effects on subsurface temperatures can be calculated.

While it would be desirable to have some measurement of soil moisture in the vertical wells, lack of suitable soil moisture probes has precluded installation of moisture measuring equipment. It had been anticipated that the moisture probes developed by the U.S. Forest Products Laboratory at Athens, Georgia, would be satisfactory for soil moisture measurements. J.E. Duff of the Forest Products Laboratory advises that these probes will not be satisfactory for soil moisture measurements. After talking to J. E. Duff, Tom Bligh of M.I.T, Phil Metz of BNL, Jim Hartley of Georgia Tech, and Georgia Power, it has been concluded that no satisfactory remote soil moisture measurement device exists within our operation and budget parameters. Dr. Hartley is working with Georgia Power on the development of a probe and expressed interest in evaluating one of their probes in the coil field. If this probe becomes available, it will be installed with the coil field. At present, periodic vertical core samples appear to be the only reliable moisture measurement technique.

Equipment for simulating the thermal load, for pumping the water, for measuring the water flow rate and for measuring the energy input is being identified and ordered so that it will be available for installation with the pipe field. The pipe field configuration will be dependent upon the results from the computer simulations.

Methods for evaluating the effect of pipe diameter, length, spacing and material have also been under investigation during the past two months. Ingersoll¹ gives an exact solution for energy flow from buried tubes which lends itself well to investigating the effect of each of these parameters. Although far from complete, this investigation permits several conclusions at the present time. Figure 3 shows the temperature difference between the soil adjacent to the pipe and soil remote (undisturbed) from the pipe for a constant energy input of 50 Btu/hr/ft as a function of time. Figure 4 shows the temperature differences if the energy per ft² of pipe is held constant. When one looks at Figure 3, one might come to the conclusion that larger pipe diameters are desirable. Figure 4 shows this not to be the case. A two inch diameter pipe two feet long has much less temperature differential than a four inch diameter pipe one foot long for the same total energy transferred. This becomes even clearer on Figure 5 where energy transfer rate (Btu/hr. ft². °F) is plotted versus pipe diameter. Figure 5 shows that smaller pipes have much higher transfer rates.

Basically Figures 4 and 5 show that smaller long pipes are better than larger short pipes. This is not unpredictable if one recognizes that energy flow to the pipe is essentially radial and that small long pipes are exposed to more undisturbed soil than large short pipes.

¹Ingersoll, L.R., Zobel, O.J., and Ingersoll, A.C., "Heat Conduction with Engineering and Geological Application," McGraw-Hill Book Company, Inc. 1948.

Figure 3 Pipe-Far Field Temperature Difference vs Pipe Diameter (in)

Figure 4 Pipe-Far Field Temperature Difference as Function of Pipe Diameter
(Energy Transfer Per Ft² of Pipe Held Constant)

Figure 5 Energy Transfer Rate as a Function of Pipe Diameter

While the calculations show that the smaller the pipe the better its operation from an energy transfer standpoint, there are other factors, such as pressure drop through the pipe, trenching costs and space available, which will influence pipe diameter selection.

Figure 6 shows the effect of time on energy transfer rate. This figure shows the energy transfer rates to drop quite rapidly during the first 50 hours (2 days), drop less rapidly during the next 100 hours (4 days) and essentially become constant after 168 hours (7 days).

Figure 7 shows the effect of soil thermal conductivity and diffusivity on temperature difference. Comparison of Figure 3 and 7 shows that lower thermal conductivity and diffusivity significantly increase the temperature difference required for a given heat transfer rate. It is believed the values used to calculate the data used to construct Figure 3 are more nearly representative of the soil in Atlanta. As new data becomes available from our tests, we will refine these calculations.

Figure 8 shows the effect of energy withdrawal rate on temperature difference. As one would expect higher withdrawal rates require higher temperature differentials. The equations used to develop these curves have been programmed on a programmable calculator and are being changed to let temperature difference determine transfer rates rather than rates determine temperature difference. The program is capable of superimposing the effect of temperature waves from the surface and from adjacent pipes on the energy transfer rate.

Work during the next month will concentrate on getting the vertical holes installed and instrumented and optimizing the pipe size, material and layout. We are on schedule and do not see problems which might cause delays.

Figure 6 Energy Transfer Rate as a Function of Operating Time

Figure 7 Pipe-Far Field Temperature Difference vs Pipe Diameter (in)

Figure 8 Pipe - Far Field Temperature Difference vs Operating Time