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SEASONAL STORAGE TEST PIT. TESTING OF A 500 M³ STORE

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Summary

The aim of the work has been to show, that warm water pits, uninsulated towards the soil, are well suited for seasonal heat storage. Limiting the insulation to the top surface will contribute to a construction price reduction, which is so important, if seasonal storage shall be economically feasible.

The design work was based on the geotechnical investigations of the site selected at the laboratory test grounds on the university campus. The thermal properties of the soil were determined to form the basis of the computed analysis of the heat flows.

Upon construction of the pit, charge and discharge operations varying the water temperature ± 15 °C in a sinoidal pattern with mean temperatures of 45 °C and 65 °C have been performed. Measurement from the initial 210 days reported earlier showed good agreement with analytical and numerical predictions of the efficiency of the pit.

The measurements of 330 subsequent days reported now continue to agree well with numerical simulations. The durability of the high density polyethylene liner has so far given no reason to complaints and the vapour transmission through the floating lid has taken place without measurable accumulation in the insulation.

1. INTRODUCTION

In a joint venture between the Danish Ministry of Energy, the Danish Council for Scientific and Industrial Research and the Directorate General for Science and Development of the Commission of the European Communities the design and construction of a 500 m³ underground warm water store was undertaken during 1981-82. Previous theoretical studies (1), (2) had indicated that underground warm water stores would show an acceptable efficiency even if the soil interfaces were left uninsulated. As studies and experiments with solar collectors had indicated, that only sufficiently low construction costs for solar collectors as well as for underground warm water stores would secure competitive prices for solar energy, the verification of the above mentioned theoretical studies was highly desirable.

Financed by the Danish Ministry of Energy the design and construction of the 500 m³ underground warm water store was undertaken. The design did not attempt to make the experimental facility a model of future full scale warm water stores, but attempted to make the verification of the theoretical investigations as easy as possible. Thus the store for instance was placed completely underground in stead of partly underground.

Simarily the store was placed adjacent to an existing building in spite of certain inaccuracies in the verification was to be expected from this location in order to facilitate the installation of the datalogging at a short distance from the point of measurements, which would secure recording at an acceptable accuracy.

2. CONSTRUCTION OF THE STORE

The store with a pyramidal geometry was dug into the ground from the ground level. The store/soil interfaces are made waterproof by use of a 2.5 mm polyethylene plastic liner.

The floating lid is heat insulated by 0.5 m polystyrene and protected against evaporation from the store and against climatic conditions by use of a 2.5 mm polyethylene plastic bottom liner and a 1.0 mm butyl rubber liner for the topside. The lid was constructed in a "dry dock" next to the pit and was easily floated to the final position. A photo of the final plant is shown in figure 1. The construction was completed in 3 months during the summer of 1982 and are explained in more details in [3].

The ground water level is 40 m below the ground level.

Figure 1. The final plant. The "dry dock" where construction of the lid was undertaken, is partly seen to the left.

3. EXPERIMENTATION

Approximately 80 copper constantan thermocouples are being used to measure temperatures in the water and in the soil under and around the pit. The thermocouples are arranged in chains which are located in two planes. The location of the thermocouples in the ground in one of the planes is shown in figure 2.

The temperatures are scanned automatically once an hour. Every day the data logger system prints all the daily mean temperatures on paper and on tape (for later transfer to our computer center).

The heat input to the water in the store is generated by two gas boilers. The first charge period started in September 1982 with a water temperature of 15°C.

Because of the limited time being available for experimentation in this project, it was decided to accelerate the testing by reducing the charge/discharge cycle from 365 days to 70 days. Further it was decided to have total temperature mixing of the water in the store. The charge and discharge cycles can be seen in figure 3.

4. COMPUTER MODEL

A computer program has been constructed based on the method of finite differences. The program treats the geometry of 1/8 of the store and the surrounding soil as indicated in figure 2. The computer code has been constructed to be truly 3-dimensional. The enmeshment is shown in figure 2. The centre points of the volume elements shown are the meshpoints used in the simulations.

5. SIGNIFICANT RESULTS

The temperature range in the water was originally 30°C-60°C and the first period of 210 days of the measurements with this temperature range is reported earlier [3], [4]. Here the calculated temperatures in the 51 thermocouples in the ground coincide very well with the temperatures measured.

From April 1983 and during the summer the temperature range in the water was changed to 50°C-80°C while the sinoidal relative temperature change was maintained, see figure 3. In the winter 1983-84 the temperature range once more reverted to 30-60°C. As indicated on figure 4 the calculated temperatures at the position of the 51 thermocouples in the ground still coincide very well with the temperatures measured.

6. CONCLUSIONS

By the termination of the measurements in the fall of 1984 it is expected that the calculated temperatures in the soil will continue to coincide with the temperatures measured as has been the case so far.

It is also anticipated that no visible reduction of the quality of the high density polyethylene liner which was used as water barrier on the sides and the bottom of the pond as well as on the bottom of the floating lid will be observed.

It is also expected that the efficiency of the storage will have improved as envisaged theoretically corresponding to the number of cycles of operation performed.

7. REFERENCES

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► indicates thermocouple locations.

Figure 2. Position of the grid points in vertical plane to the left and horizontal plane to the right.

Figure 3.

Figure 4.