SEASONAL HEAT STORAGE IN UNDERGROUND WARM WATER PIT

(Design of a 30.-50.000 m^3 storage)

K.K. Hansen, P.N. Hansen and V. Ussing
Thermal Insulation Laboratory
Technical University of Denmark

Summary

The design, construction and simulated operation of an underground 500 m^3 warm water store preceded this work. The aim of this project has been to design a 30.-50.000 m^3 underground warm water storage as a pilot project for a large seasonal storage. In order to minimize the construction cost the soil interface of pit has been left uninsulated and the lid has been foreseen to float on the water surface. The design data for the project have been taken from a district heating system based on co-generation expressing serious interest in realization of the design assuming that the construction cost will prove to be competitive with different tank storage solutions. The geometrical and geotechnical problems related to the design have partly been reported earlier. This paper gives a resumé of the major points from the final report to be published later in 1984. The design work was finished jointly by the Commission of European Communities and the Danish Council for Scientific and Industrial Research.

1. INTRODUCTION

A seasonal heat storage is a necessity for heating systems based on solar energy. It has been the purpose of this work to design a 30.-50.000 m^3 storage pond using the experience gained from the construction and simulated seasonal operation of a 500 m^3 test facility at the Technical University of Denmark (1). Studies concerning heat storage ponds in the future energy systems (6) have indicated, that only through sufficiently low costs of collectors as well as of storage ponds can solar energy be competitive with other sources of energy. Only through actual construction of a number of full scale heat storage ponds can low priced ponds be developed.

It was of prime importance to base the pilot design of a 50.000 m^3 heat storage pond on data from a large district heating system, expressing serious interest in an early realization of the design, assuming that the cost estimates proved this type of storage competitive against other designs. Insulated new steel tanks are already in operation and serious studies are being done to renovate existing surplus large fuel oil tanks for storage purposes. Speedy realization of the design appeared only possible if the project was designed to serve as storage in a large district heating system based on co-generation. For such systems large heat storage ponds can be shown to be very advantageous. A series of such ponds may help to obtain the experience in construction allowing reduced construction costs required in seasonal storage.

2. REQUIRED CAPACITY AND CHOICE OF GEOMETRY AND LOCATION

The storage is built into a system planned to have a maximum load of 489 MW in 1999. Based on the 24-hour load variations in the system a 6 hour seperation of the generating facility from the district heating system demands a storage of 2905 MWh. Limiting the temperature of the storage to 95°C and having $\Delta t = 47°C$ in the system at maximum load, the required volume can be figured to be 54,539 m^3.

The problems related to choice of geometri and the soil mechanical problems have to some extent been reported earlier (2), (3), (4) and (5).

The storage has been located as close to the electric power plant as possible on an area created by filling in shallow coastal waters with fly-ash. Fig. 1 shows the location of the storage.

3. MAIN FEATURES OF THE CONSTRUCTION

Fig. 2 shows a sectional view of the storage design. By employing a number of bleeder wells and a sheet pile wall the execution of the construction is secured in spite of the fact that the bottom of the pond is 9.2 m below the surface of the sea just south of the pond. The water tightness of the storage is secured primarily by clay. The chemical composition of the water is maintained by a 2mm thick polypropylen sheet covering the bottom, the walls as well as the bottom of the floating lid. The lid is built on the lid bottom liner reinforced by steel wires in the center structure and in the concrete edge beam. The lid consists of insulation, a rubber liner, gravel and top soil placed as the water level is raised. The concrete edge beam and the sheet pile wall are anchored to surrounding ground.

4. CONNECTING THE STORAGE TO THE CO-GENERATION SYSTEM

A principal diagram showing the charge operation for the storage is shown in fig. 3. The storage is connected to the main connection between the power plant and the transmission station of the district heating system. The district heating system is operating at 6 bar. As the storage is planned to function at about 0.9 bar reducing valves (or turbines) and sufficient pumps are used to allow a flow of up to 9.000 m^3/h to and from the storage.

5. OPERATION LOSSES

Based on geotechnical investigations and numerical computations the heat loss in % of maximal theoretical heat content at a ΔT of 44°C is shown in fig. 4 as function of the time elapsed in the fourth year of operation. Underground hot water storage ponds with large volumes can be constructed assuming that suitable layers of clay can be found in the vicinity of the power station or clay can be obtained at a reasonable cost from other locations.

A number of large storages primarily serving load management purposes in a co-generation system will prove to be very economical and will constribute to rapid development of low construction cost for large seasonal storages, which is a condition for use of solar energy on a large scale.

6. REFERENCES

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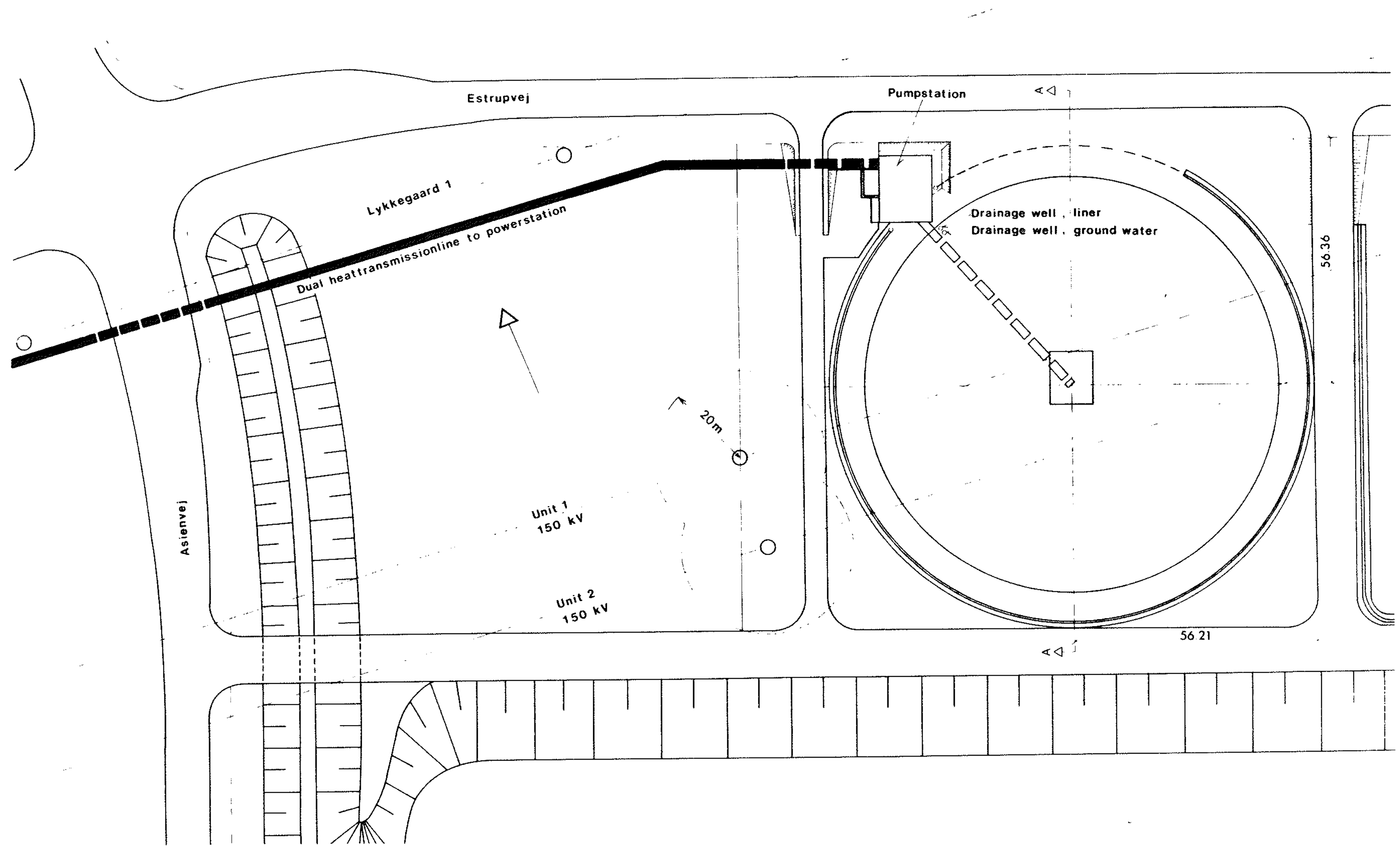

Figure 1. Plan view.

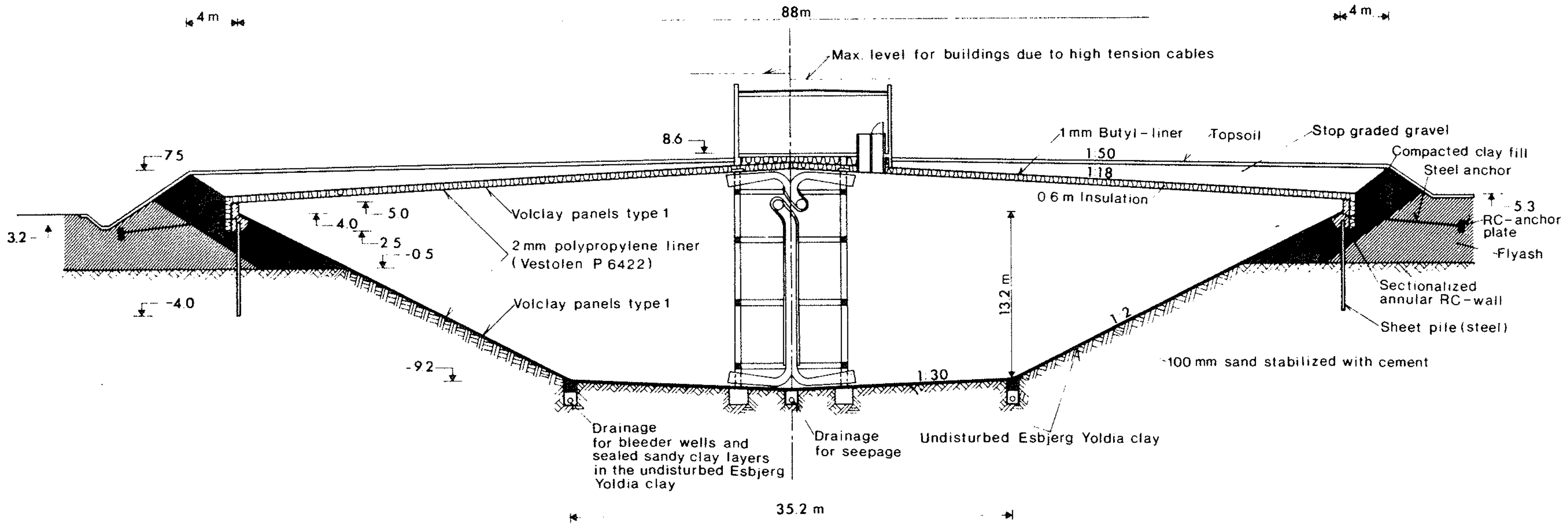

Figure 2. Sectional view of the 50,000 m^3 warm water pond.

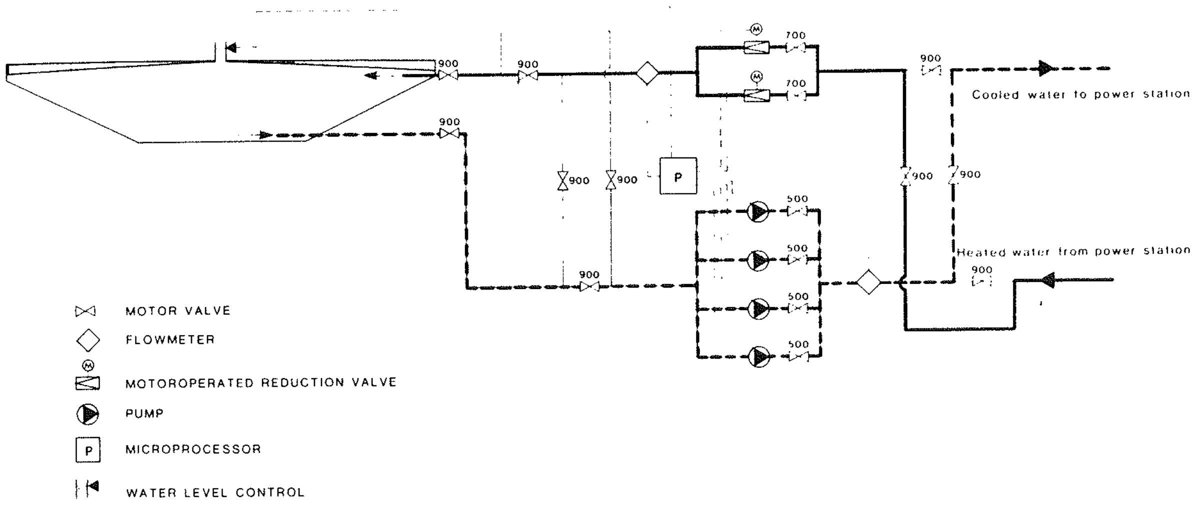

Figure 3. Pumpstation. Principal diagram. Charge operation.

HEAT LOSS IN % OF THE MAXIMAL THEORETICAL HEAT CONTENT BASED ON A TEMPERATURE AMPLITUDE OF 44 °C.
THE TEMPERATURE OF THE STORED WATER IS 73 °C (CONSTANT), AND THE PERIOD IS THE 4. YEAR.

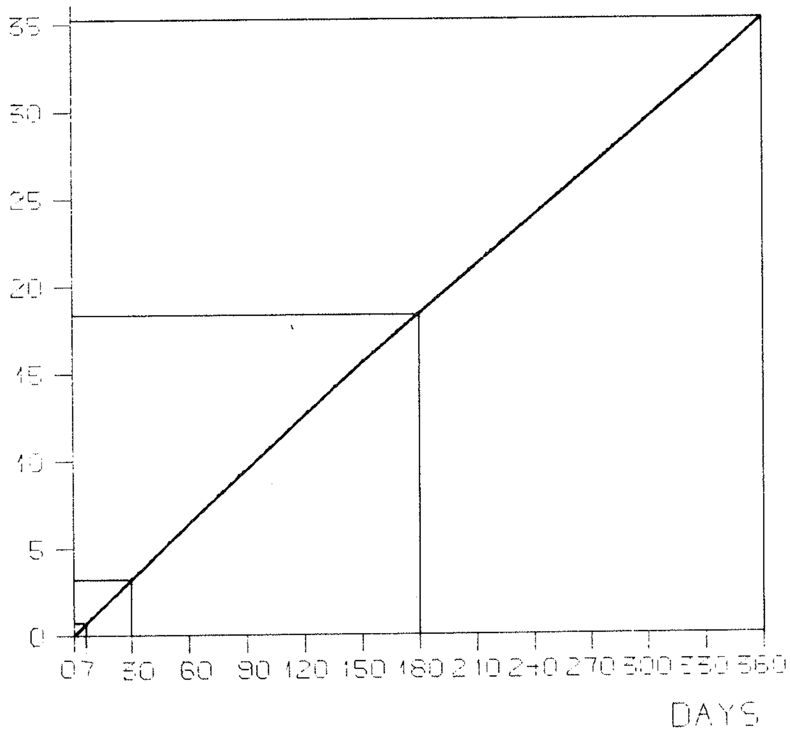

Figure 4. Heat loss calculation.