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"Solar Freeze Desalination"

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These are preliminary lecture notes, intended only for distribution to participants.

SOLAR FREEZE DESALINATION

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ABSTRACT

Efforts to find an efficient and cost-effective solar desalination process have shown that indirect freeze technique has a high potential. The system described in this paper is based on total solar energy concept. High grade heat is used for compression refrigeration and low grade heat to produce absorption refrigeration. CBI's indirect bulkfreeze process is employed for separating water from dissolved salts. Salient features of the system are briefly discussed.

INTRODUCTION

Freeze Separation

Solar energy can be used for water desalination in several ways. The commonest example is the solar still,which serves as both a converter of solar energy to heat and a distiller. Solar stills operate at low temperatures (less than 65 deg.C) and their productivity is low. Alternatively solar concentrating devices can be used to operate conventional distillation plants. Thermal energy at high temperature levels can be used to operate a thermal engine and generate shaft power. The shaft power can be used to drive pumps or compressors directly or to generate electricity. Electricity to provide power for desalination processes can be obtained directly by photovoltaic conversion. Reverse osmosis and electrodialysis by solar-generated power have some advantages over distilation. However these methods are not discussed here.

Freeze techniques for separating water from the dissolved salts have shown great promise in the past few years. Water is the first component to separate by freezing as the temperature is lowered. Freeze desalination has several inherent advantages: low energy requirement, negligible pretreatment, minimal corrosion, low sensitivity to fouling, and ability to handle varying feed conditions[1].

Yanbu Pilot Plant

A solar desalination plant, which uses the freeze technique, was established in Yanbu in Saudi Arabia, under the SOLERAS program. This research program is a joint effort between KACST (King Abdulaziz Center for Science and Technology) and the United States Department of Energy. This is an excellent scientific program committed to the development of solar energy as a viable, cost-competitive energy alternative. The two most prominent items in this plant are: the solar power system and the indirect freeze desalination system. With a subcontract from SOLERAS, the former was designed by Foster-Miller Associates (FMA) and the latter was designed by the Chicago Bridge and Iron Company (CBI)[2].

DESALINATION PLANT

Figure 1 shows the solar power system, which turns solar heat into shaft power to drive the ammonia compressor. Figure 2 shows the desalination system. The power system comprises of four subsystems: energy collection, auxiliary energy, energy storage and energy delivery. The desalination system has two subsystems: the refrigeration system and the process systems of brine and product water[3].

Solar energy is collected by 18,2-axis tracking point focus concentrators with individual tracking controls. Syltherm 800 is used as the heat transfer fluid in the receivers of the collectors. This fluid transfers its heat to molten Partherm salt in the two storage tanks (hot and warm). The stored heat is used to produce superheated steam, which runs a reciprocating steam engine. The engine runs an ammonia compression refrigeration system. Residual heat in the exhaust steam is used to produce additional refrigeration by a lithium bromide cycle. The ammonia refrigerant removes heat from the sea water in the freezers (shell and tube type heat exchangers). High ice fraction slurry is drawn off by a pump to a washer/melter vessel. Draining of the brine from ice creates a pack of ice at the top of the wash column. The pack of fresh ice is melted by direct contact heat transfer with slightly warmer water. A pump draws fresh water from the melter and pumps it out of the plant as product water at less than 500 ppm.

As can be seen from the Figures 1 and 2, the desalination plant comprises of several subsystems and several components in each subsystem. The role of each component is not discussed here in order to make the paper brief and concise.

PERFORMANCE

The research group met with several problems while running the plant. The flux traps at the receivers melted now and then indicating the problem in getting proper focus on the receivers. Innovative approaches were made to reduce this problem. Freezer performance was hindered due to the fouling of the freezer tube surface by dirt, corrosion products and oil from the ammonia compressor (carried by liquid ammonia). Despite these drawbacks, the system performed very effectively, with the production of fresh water reaching 162 cubic meters per day (24 hour period).

CONCLUSION

Taking into consideration all the factors relating to new concepts, design, construction, operation and performance of the pilot plant at Yanbu, it can be said that the indirect freeze desalination by solar power, using the CBI technique, has proved to be a very useful scientific effort, and would serve as a forerunner to new developments and advances in this field of scientific endeavour.

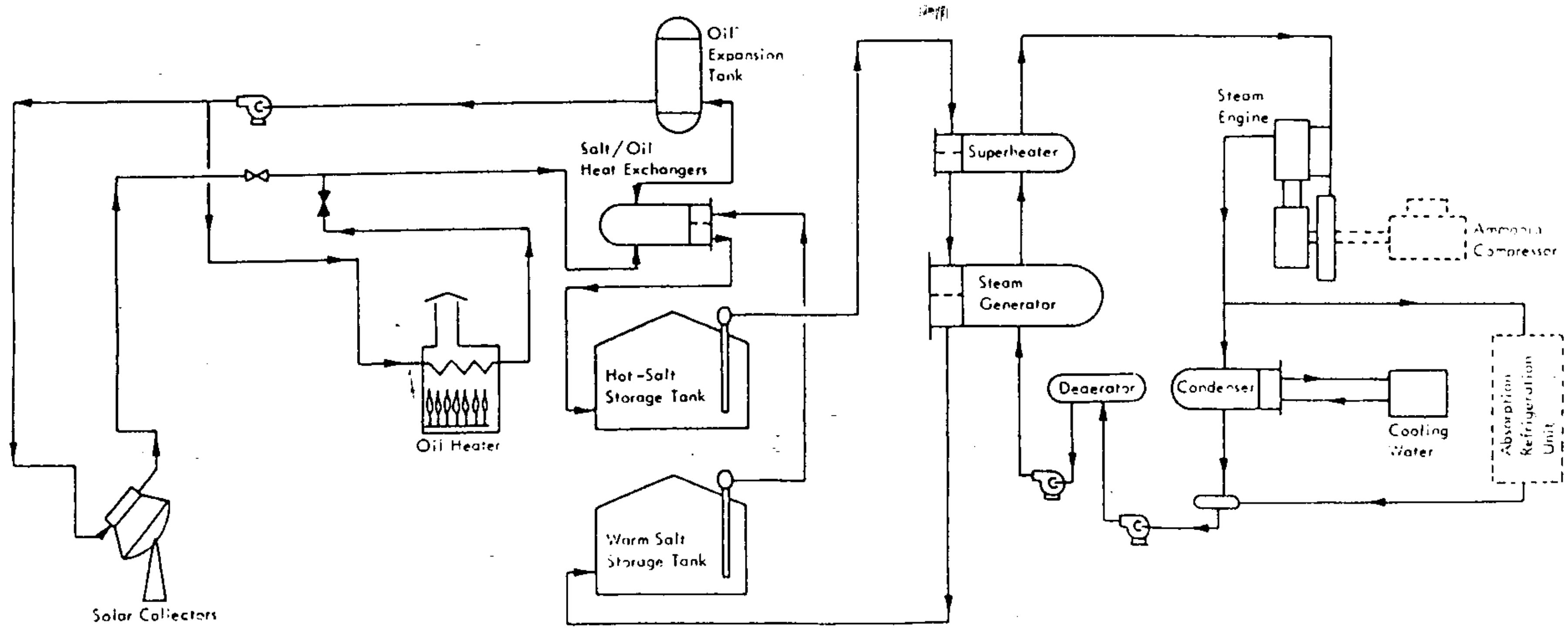

Figure 1. SOLAR POWER SYSTEM COMPRISING OF FOUR SUBSYSTEMS: ENERGY COLLECTION, AUXILIARY ENERGY, ENERGY STORAGE AND ENERGY DELIVERY [Ref.3]

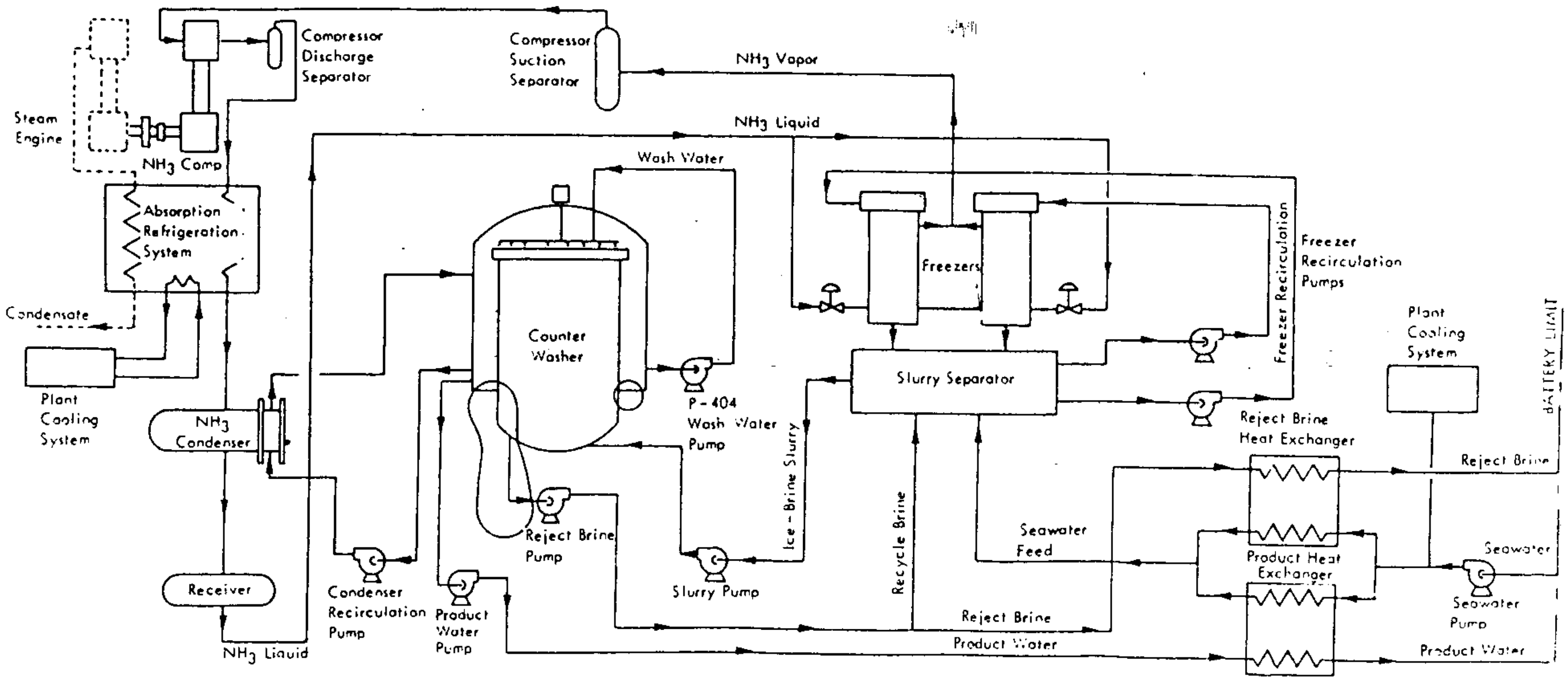

Figure 2. FREEZE DESALINATION SYSTEM COMPRISING OF TWO SUBSYSTEMS: REFRIGERATION SYSTEM AND BRINE AND PRODUCT WATER PROCESS SYSTEMS [Ref.3]

REFERENCES

1. R. Demler, G. Engdahl, M. Husain, S. Mukherjee and T. Nowak, Design of a Solar Energy Powered Freeze Desalination System, Proceedings of the Second SOLERAS Workshop, published by the Midwest Research Institute, Kansas City, MO, USA.

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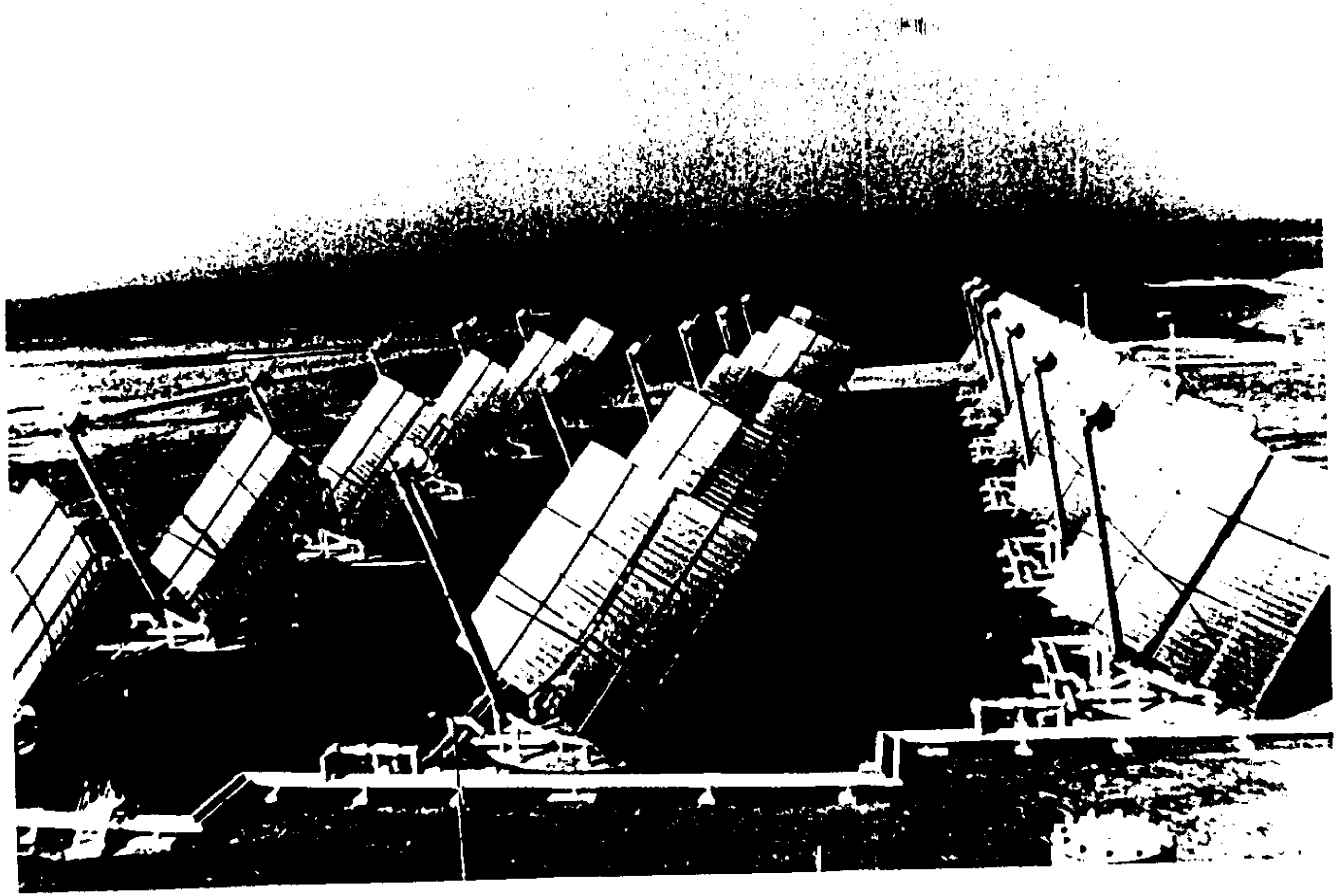
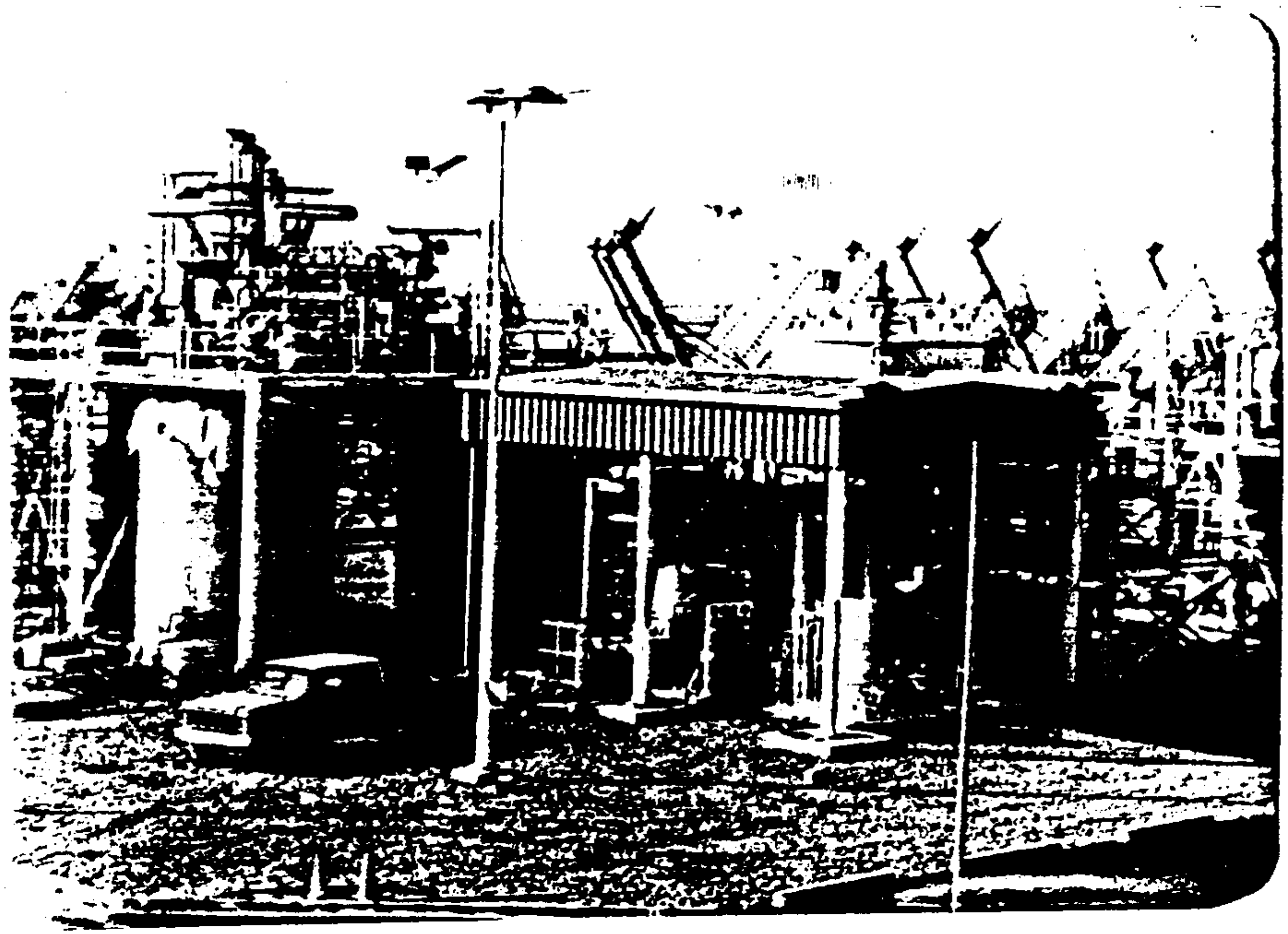


A VIEW OF THE SOLAR COLLECTOR FIELD



A VIEW OF THE DESALINATION PILOT PLANT