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EXPLOITATION OF LOW TO MODERATE TEMPERATURE ENERGY SOURCES BY ORGANIC RANKINE CYCLE

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ABSTRACT

This paper reports the status and experience in exploitation of low to moderate temperature energy sources by using the organic Rankine cycle (ORC) in China. Several experimental demonstration installations of ORC in our country are described, in which two geothermal power stations, one in Jiangxi province and the other in Liaoning province, are emphasized in this paper. The authors indicate that the potential application of ORC in industrial waste-heat recovery is very widespread, so that attention should be paid to the development of ORC technology.

INTRODUCTION

Exploitation and utilization of new energy sources (eg: geothermal and solar energy) and saving conventional energy (eg: recovery of waste heat) have become the most important problem in the world. These resources of energy are very abundant and can easily be converted into electric power by using the ORC or flashed steam cycle (Lu and others, 1975; Lu and Wei, 1983). Our government, realizing the potential importance of application of the ORC, has initiated a program directed toward the design, development and demonstration of several ORC systems. Since early 1971 a small ORC experimental installation with 1 kW capacity has been established in Tianjin University. Up to now four geothermal power stations have been set up in different places of our country such as the provinces of Jiangxi, Liaoning, Guangdong and Hebei. Similar experimental installations have been constructed for power generation to the generators or compressors of refrigerators, using waste heat from industrial factories in Shanghai and Suzhou. Nowadays ORC power generation systems are under construction using thermal oil from refinery processes in Beijing and Shanghai.

A SMALL EXPERIMENTAL INSTALLATION

The first experimental installation in our country was established in Tianjin University. An electric boiler produces thermal water or oil with a temperature of 60 to 120° C to simulate geothermal, solar or waste-heat sources. The heat transfer and power generation performance of simple common fluids such as isobutane, ethyl chloride, normal butane and freon R11 and R113 have been tested in this installation. It can easily be changed from a binary cycle (water-organic working fluid) to a triple cycle (water-oil-organic working fluid) to perform different energy-source tests. The performance tests of the turbine and different types of exchangers, including evaporators and condensors, have been completed. The testing details and experience of the installation have been provided for construction and operation of ORC power stations, established later in our country.

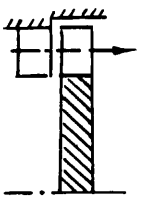
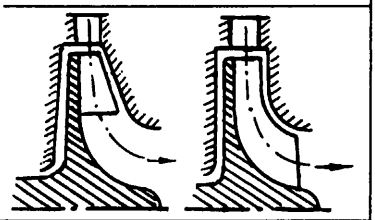
GEOTHERMAL POWER STATIONS

Since 1971 in China four binary cycle demonstration stations have been constructed and operated to test the validity of applying the ORC to geothermal electric power generation (Lu, 1984). Their major properties are summarized in Table 1.

Table 1. Properties of Binary-Cycle Demonstration Stations

Properties	Station Location			
	Wentang Jiangxi	Huailai Hebei	Xiongyue Liaoning	Dengwu Guangdong
Capacity, kW	50	200	100	200
Geo. temp., °C	66	85	82	91
Working fluid	Ethyl chloride	n-butane	n-butane	i-butane
Time of operation	1971,9	1971,9	1977,9	1977,9

Table 2. Types of Turbines Examined in China and Their Parameters

Parameters	Type of Turbine		
	Axial	Radial Inflow	
			
Working fluid	Ethyl chloride	Ethyl chloride	n-butane
Capacity, kW	50	50	100
Rated speed, rpm	3000	4500	5500
Isent efficiency	0.67	0.80	0.87
Time of operation	1971,9	1978,5	1982,7
Name of station	Wentang Jiangxi	Wentang Jiangxi	Xiongyue Liaoning

Wentang geothermal power station has the following features:

(1) The temperature of geothermal water to the station is only 66°C, which is the lowest among the geothermal power stations of China;

(2) Both geothermal and cooling water can be selfdischarged because of the local geologic and topographic aspects. This eliminated the need for a deep well pump and a condenser cold pump. Only the pump for the working fluid is required, using about 5 kW. This tiny power station has been generating electric power for the local residents continuously over the years;

(3) More efficient exchangers (eg: spiral fluted tube condensers) and radial inflow turbines have been adopted;

(4) Two evaporators can be operated in either parallel or series system, so that the station is able to operate in one or two staged evaporation to perform various tests;

(5) The station is independent of outside electric power sources for its start-up. This character is of practical significance especially for the nonelectric supplied places.

Xiongyue geothermal power station was constructed on the basis of previous technical experiences of geothermal power stations in our country. A more efficient radial inflow turbine has been adopted. This station was considered for more economical and effective utilization of geothermal water. After passing through the power generation equipment, the warm water, at 50 to 55°C temperature, is used for direct utilization such as space heating, sanatorium, greenhouse, fish and plant cultivation and so on. Xiongyue geothermal power station becomes an outstanding example of the comprehensive utilization of geothermal energy in our country.

Possibly there is nothing more important to the cycle equipment than the turbine, because a small drop of turbine efficiency substantially affects station cost. In Table 2 the types and parameters of turbines examined in our country are summarized. Figures 1 and 2 provide the results of the turbine efficiency tests. (Hu and others, 1980; Hu, 1984).

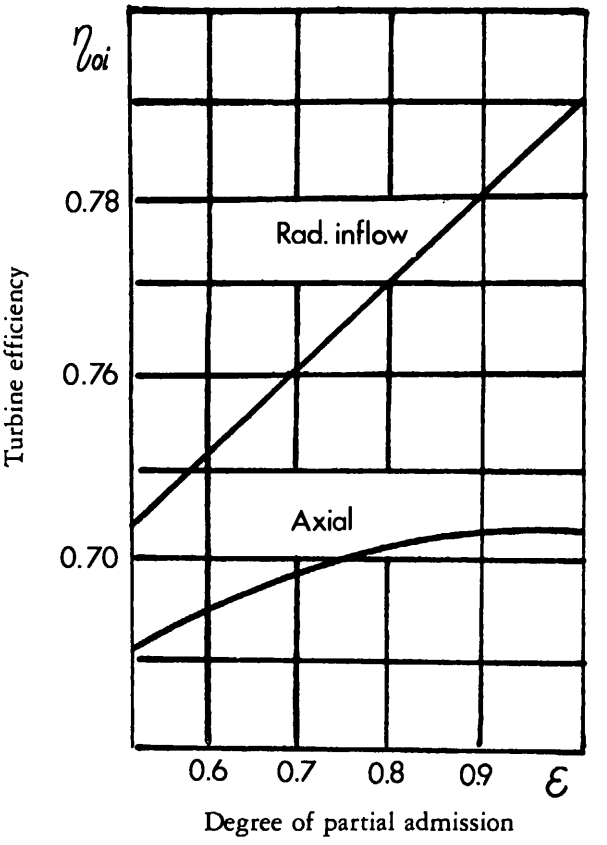


Figure 1. Isentropic turbine efficiency of Wentang geothermal power station

WASTE HEAT POWER INSTALLATION

In China the first experimental ORC power installation using waste steam was completed in 1981. The mechanical shaft power (75 kW) of the radial inflow turbine, similar to that of the Wentang station, is used to drive the compressor of a refrigerator. In this year, another

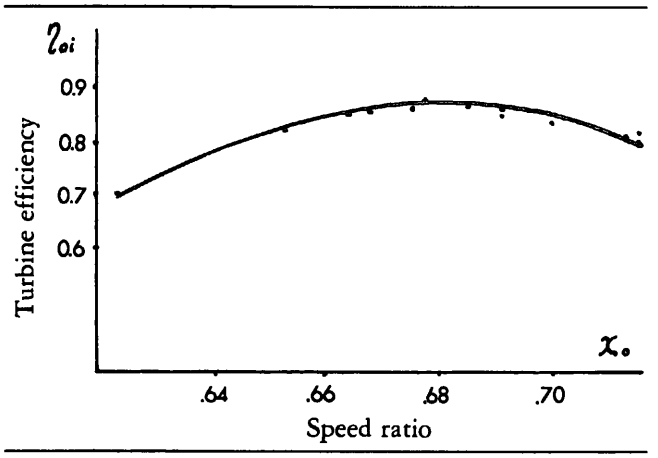


Figure 2. Isentropic turbine efficiency of Xiongyue geothermal power station

similar power installation was constructed in a Suzhou chemical factory, having a capacity of 150 kW. Now two waste-heat power stations are under construction at the Shanghai and Beijing oil refineries. Their capacities will be 680 and 750 kW respectively. The temperature of oil as the thermal energy resource is 120 to 160°C. The type of turbines is similar to that of the Xiongyue station. Freon R11 will be selected as the working fluid.

SUMMARY

Operating experience shows that the ORC can be used to exploit low to moderate temperature energy resources technically. For these temperature geothermal resources, the ORC can be superior to the flash steam methods, both technically and economically, and it will be more economical and effective if comprehensive uses for industry and agriculture, as well as therapeutic uses, are considered. With the increased discovery of abundant low to moderate temperature energy sources, we expect that a greater utilization of the ORC for power generation will be seen in our country.

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