Proceedings of the 6th Asian Geothermal Symposium, Oct. 26-29, 2004
Mutual Challenges in High- and Low- Temperature Geothermal Resource Fields, 5-7

POWER GENERATION TECHNOLOGY BY HOT WATER HEATING OF LOW TEMPERATURE POWER GENERATIONS USING AMMONIA AND AMMONIA-WATER MIXTURE AS WORKING FLUID

Takumi HASHIZUME
Waseda Univ., 17 Kikui-cho, Shinjuku-ku, Tokyo, 162-0044, Japan
e-mail:hasizume@waseda.jp

1. INTRODUCTION

The heat discharged without being used for surroundings including the factory waste heat is not a little. It is widely used when the temperature of the heat source is high, and it is used comparatively effectively. On the other hand, the heat is not effectively used for the heat source of a low temperature of 100℃ or less. As for the geothermal energy, this is similar. It is used as a geothermal power generation when the steam of the high temperature and high pressure is obtained, and the usage is not wide for the steam and the hot water of the low temperature and low pressure. If the use as heat in the hot spring, the indoor air-conditioning (heating), the greenhouse, and the road heating, etc. is excluded for the hot water of 100℃ or less, it is hardly used in Japan. In this paper, it introduces the power generation technology which obtains electricity from the hot water of 100℃ or less by using the power generation cycle when the medium with a low boiling point (low boiling point medium) is made an working fluid.

2. HEAT RECOVERY AND RANKINE CYCLE BY LOW BOILING POINT MEDIUM

Rankine cycle consists of the pump, the evaporator, the turbine, and the condenser, and the working fluid circulates around each equipment in this order. The heat supply from the hot spring to the working fluid is done with the evaporator. The working fluid is cooled with the condenser by the river water and atmosphere, etc. Therefore, the high temperature side of the cycle becomes about 100℃ and the low temperature side becomes about 25℃. The temperature difference of the working fluid of the cycle becomes small more than this though the temperature difference of the high and the low temperature heat source becomes about 75℃. The sensible heat (liquid and gas) and the latent heat (steam) are enumerated in the type of the high temperature heat source and the low temperature heat source. Heating with the hot spring water and cooling with the river water are assumed, and the former is taken up here. The pinch point can be obtained by evaluating the temperature transition of the heat source fluid and the working fluid in the evaporator and the condenser. The pinch point shows a point where temperature difference is the smallest between both fluids. The ratio of the sensible heat and the latent heat in the heating rate that the working fluid obtains greatly influences the pinch point in the evaporator. It is preferable that the ratio of the sensible heat is large to increase the heating rate from the heat source. If it says by the heat physical properties, it is preferable that specific heat is large to the latent heat. The outlet temperature of the heat source lowers by the ratio of the sensible heat growing, and the heating rate increases. In the condenser, the flow rate of the cooling fluid is taken very greatly generally. Therefore, the restriction of the pinch point is comparatively eased.

3. FEATURE OF WORKING FLUID AND AMMONIA

A natural refrigerant has come to be used from the viewpoint of the global environment protection (control and prevention to depletion of ozone layer and global warming) in place of the fluorocarbon refrigerant which has been used as a working fluid of the turbine system by the low temperature heat source. A suitable medium is a medium whose boiling point is lower than water as the working fluid of the turbine system by the low temperature heat source. When the performance of an actual equipment is noted, the hydrocarbon, ammonia, ammonia-water mixture (AWM), and CO_2, etc. are enumerated as a low boiling point medium of possible practical use. The low boiling point medium is suitable at the power generation system by the low temperature heat source as the working fluid. The reason for the low boiling point medium is that it becomes the vapor of the high pressure, making the working fluid high density is brought, and the miniaturization of the equipments is achieved. Furthermore, this high-pressure vapor becomes a dry saturated vapor easily, and the isoentropic curve is comparatively along the dry saturation vapor line. Therefore, the vapor at the turbine outlet does not become excessive wet vapor easily. When the feature and physical properties of a typical, natural refrigerant are evaluated, it is understood that ammonia is suitable as the working fluid of the power generation system. Especially, because combustion is low, it is suitable for the working fluid of the distributed power generation system for a general house area. Toxicity becomes a problem when a large amount of leaking even if it is ammonia. Such an accident can be prevented enough by dealing with an initial stage of the leakage. The stench strength means detection at an initial stage of the leakage is easy. Using it for all-round highly effective becomes possible by using ammonia as mixed media with water. This respect is described later.

4. HOT SPRING POWER GENERATION WHICH MAKES AMMONIA WORKING FLUID

It introduces power generation (it is called the hot spring power generation) of which the heat source is the hot spring heat in the background of the hot spring in Japan. The temperature of the hot spring water drawn up in the hot spring extends widely from an atmospheric temperature to 100℃. The hot water of 80℃ or less is most. It is requested to the hot spring of 60℃ or less to heat it up to 60℃ with the boiler etc. for the prevention of the infectious disease. On the other hand, to lower up to the bathing temperature (about 55℃) in the hot spring of 80℃ or more in water temperature, water is added. When water is not added, an indirect cooling by the river water and atmosphere is done. This is not to limit to the hot spring, and to be able to say to the heat system whole which uses the hot spring heat. The energy resource of the hot spring is not used enough though the hot spring heat is rich like this. Then, the hot spring power generation introduces here is the one that electricity is generated by using temperatures difference up to the bathing temperature for the hot spring of the high temperature. When the performance of the practical machine is noted as a hot spring which can be used to generate electricity, it is preferable that the temperature and flow rate exceed 85℃/200l/min respectively. The type at this power generation system is corresponding at Rankine cycle. Ammonia which is the working fluid evaporates by the hot spring heat in the evaporator, becomes the vapor of the high pressure, and flows into the ammonia turbine. The ammonia vapor which exhausted from the ammonia turbine is cooled with the river water in the condenser, becomes ammonia liquid, and is supplied to the evaporator again with the ammonia pump. The hot spring water comes to be cooled from 85 to 55℃ with the evaporator at the suitable temperature and is supplied to the hot spring facilities. This energy has been uselessly consumed so far. The energy thrown away is converted into electric energy by introducing the hot spring power generation, and it is possible to use it effectively. The hot spring resource does not dry up along with the operation of the hot spring power generation. The power generation of about 10kW is possible from the hot spring of 85℃/200l/min. It is not a big output at all compared with distributed power generation systems of wind power generation and the photovoltaic generation, etc. However, electricity cannot be generated for instance for wind power generation when it is necessary. On the other hand, electricity can be generated arbitrarily with stability in the hot spring power generation.

5. OTHER POWER GENERATION TECHNOLOGIES WHICH MAKE AMMONIA WORKING FLUID

Industrial use is mainly used for the power generation system which makes ammonia a working fluid than before. In this case, ammonia is not necessarily used in the single but being used as mixed media with water (AWM; Ammonia-Water Mixture) is not a little either. The Lorenz cycle and the Kalina cycle are enumerated as a typical turbine system which makes AWM a working fluid. The heating rate obtained from the heat source by making mixed media a working fluid increases. When we evaluate the temperature transition of mixed media in the evaporator, because nonisothermal evaporates, mixed media present a similar temperature transition to a sensible heat medium. Therefore, the energy loss decreases remarkably when the fluid to be heated is mixed media, and mixed media can obtain heat from the high temperature fluid efficiently. As a result, the high temperature fluid (heating fluid) is cooled to the low temperature or more, and the low temperature fluid (fluid to be heated) is heated to the high temperature or more. When the heating fluid is a sensible heat fluid like the hot water, this is effective. This effect cannot be expected for a latent heat fluid like steam. The Lorenz cycle is gotten by substituting the working fluid at Rankine cycle for mixed media. Moreover, the Kalina cycle is enumerated to a highly effective system which makes AWM a working fluid. Authors designed the cycle (we call AWM turbine system: 60kW) used AWM as the working fluid. The heat source of this system is steam from the cogeneration system (800kW/100USRT). It is constructed at Waseda University, Tkyo/Japan as a practical system. Heat is efficiently recovered from the heat source within the range from 100 to 300℃ to which heat source of steam and the hot water by using this system, and electricity can be generated well. It becomes a more highly effective system by combining with the ammonia absorption refrigerator though AWM turbine system can be used alone as a power generation system. Because the working fluid of both system is AWM, making the AWM turbine system and the ammonia absorption refrigerator a hybrid becomes possible. The ammonia absorption refrigerator uses ammonia in the refrigerant and uses water for the absorbent. The working fluid existing as ammonia is in the condenser and evaporator, and, besides, exists as AWM. The performance of the ammonia absorption refrigerator greatly depends on the reduction of heating rate with the rectifying tower where ammonia is refined. The operation from the outside of the cycle is hoped for to an effective adjustment of the operation point at the cycle. Similarly, to obtain a bigger output, some operations from the outside of the cycle are needed in the AWM turbine system. Then, high density AWM is supplied from the AWM turbine outlet side of the AWM turbine system to the rectifying tower inlet side of the ammonia absorption refrigerator, and, on the other hand, AWM of a low density is supplied from the absorber outlet side of the ammonia absorption refrigerator to the low-pressure condenser of the AWM turbine system. As a result, the efficiency of the system improves. In the ammonia absorption refrigerator COP is improved, and the input energy is reduced. On the other hand, in the AWM turbine system the output of the AWM turbine increases depending on the surplus energy from the ammonia absorption refrigerator and the decrease of the exhaust pressure in the AWM turbine system. Thus, the efficiency of the system improves by 15% by simply adding three pipings to connect both systems. However, this system configuration is very complex. To apply it to the small-scale distributed power generation system which uses the hot spring heat, a further simplification is needed. Now, it is thought that the system by Rankine cycle is preferable.

6. DEVELOPMENT IN THE FUTURE

A suitable region (hot spring water of 85℃ or more) for the hot spring power generation exceeds 150 places in Japan. It seems that it goes up to several times in a suitable region if a detailed investigation is done. Authors are aiming at the practical use of the hot spring power generation of 10kW class under such a background. Equal power generation becomes possible in low temperature and small flow rate according to use of the hot spring though the hot spring of 85℃/200l/min is needed for the power generation of 10kW as previously stated. The user who drives and manages this kind of small power generation system is not often a professional skill person. Therefore, an excellent technology in higher perfection and operativeness than the latest and advanced technology is hoped for. Additionally, cheapness is also important. Moreover, the establishment of a remote monitoring system which enables an abnormal diagnosis is needed for the spread of the system.

7. SUMMARY

As for the hot spring power generation described above, the point which should make a special mention from a technical, economical viewpoint is less than a large-scale power plant. However, effective use for energy is top priority to correspond to environmental problems which become problems globally. It does not depend on the fossil fuel, and the use of the energy resource not to be accompanied by the exhaust of so-called CO_2 has an important meaning. It has never been effectively used up to now though the hot spring heat enumerated to the one is an extremely familiar energy resource. Because it is an energy resource which can be acquired with stability, and arbitrarily compared with solar energy like the wind power, the quality is extremely high. The spread the hot spring power generation as the electric power infrastructure is expected.

REFERENCES

Yoshiharu AMANO, Keisuke TAKESHITA, Takumi HASHIZUME, Masashi AKIBA, Akira USUI, Yoshiaki TANZAWA,"*Experimental Results of An Ammonia-Water Mixture Turbine System*", 2001 Int. Joint Power Generation Conf., New Orleans／USA, (2001.6), ASME, PWR-19004, pp.1-7.

Keisuke TAKESHITA, Yoshiharu AMANO, Takumi HASHIZUME, Akira USUI, Yoshiaki TANZAWA, "*Experimental Results of An Ammonia-Water Mixture Turbine System* (Part 2 : Effects of the Ammonia Mass Fraction)", 2002 Int. Joint Power Generation Conf. (IJPGC'02), Phoenix／USA, (2002.6), ASME, IJPGC2002-26064, pp.1-6.

Keisuke TAKESHITA, Yoshiharu AMANO, Takumi HASHIZUME, Akira USUI, Yoshiaki TANZAWA, "*Flexible Heat-to-Power Ratio Co-generation System with Ammonia-Water Mixture Cycles at Bottoming*", 2003 Int. Joint Power Generation Conf., Atlanta/USA, (2003.6), ASME, pp.1-6.

Keisuke TAKESHITA, Masao TOMIZAWA, Yoshiharu AMANO, Takumi HASHIZUME, Toshitaka TAKEI, "*Measurement Method of Refrigerant Mass Fraction in Ammonia Absorption Refrigerator*", 6th Int. Conf. on Power Engineering -03 (ICOPE-03), Kobe/Japan, (2003.11), JSME/ASME/CSPE, Vol.2, No.03-204, pp.2.141-2.144.

Masao TOMIZAWA, Keisuke TAKESHITA, Yoshiharu AMANO, Takumi HASHIZUME, "*AVAILABILITY OF ICE STORAGE SYSTEM IN THE OPERATIONAL PLANNING OF ACGS BASED ON MODELING COMPONENTS WITH DELAY*", The 6th Int. Conf. on Power Engineering -03 (ICOPE-03), Kobe/Japan, (2003.11), JSME/ASME/CSPE, Vol.2, No.03-204, pp.2.49-2.53.