Cryogenic Cogeneration System by Hydrogen Absorbing Alloys

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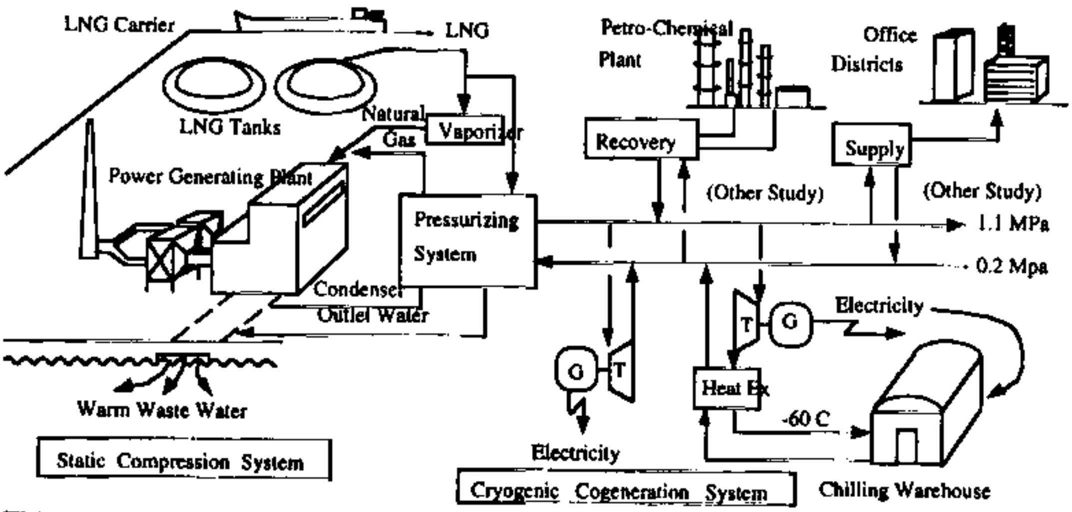
The dual-pressure hydrogen pipeline system might be an appropriate futuristic energy storage, transportation and utilization system, and a cryogenic cogeneration sub-system can offer high quality outputs in both electricity and cold, without any emissions of environmental pollutants such as nitrogen oxides, sulfur oxide and carbon dioxide.

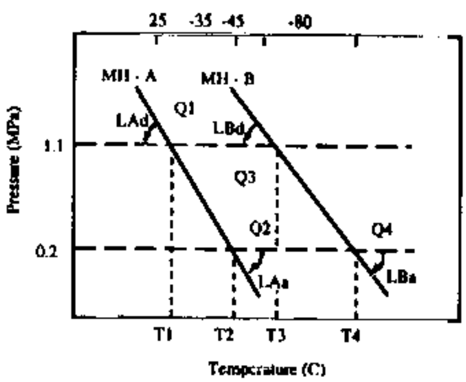



This system is of closed cycle type with hydrogen as working fluid and the capacity of 100kW upto 500kW for both electricity and cold might be a prospective candidate as an independent power unit, since it is an emission-free and simple system.

Keywords:Hydrogen, Hydrogen Absorbing Alloy, Cogeneration, Expander, Refrigeration

## 1. Introduction

The cryogenic cogeneration system acts as a utilization side and the static compression system acts as a storage side of a total energy conservation system. Both systems use hydrogen absorbing alloys.



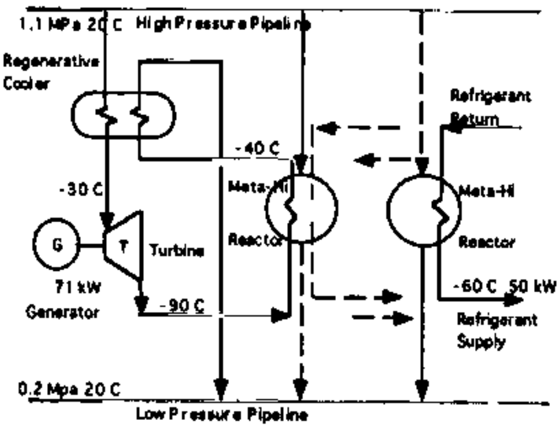

The static compression system adopts double-effective pres-surizing with two different kinds of hydrogen absorbing alloys, i.e., MH-A and MH-B, which compress hydrogen twice from 0.2 MPa upto 1.1 MPa.
Firstly, 0.2 MPa hydrogen is absorbed in MH-B metal hydride at 195K by the cold(Q4:LBa) from LNG heat exchanger and 1.1 MPa hydrogen is desorbed from MH-B at 230K by the heat source(Q3:LBd). Secondly, 0.2 MPa hydrogen is absorbed in MH-A metal hydride at 240K by the heat sink(Q2:LAa) which is conveyed from MH-B

heat source(Q3:LBd), and 1.1 MPa hydrogen is desorbed from MH-A at 300K by the heat source(Q1:LAd) of warm water from a steam condenser. This system has a feature of hydrogen pressurizing without any mechanical compressors, in other words, without any driving power.

A desk-top model test of 500W class was successfully tested, demonstrating the compression at 240K and 195K, respectively.

Effective heat transmission in reactors containing metal hydrides MH-A & MH-B, especially heat transportation from Q2 to Q3, must be considered. As the result of comparison study, the heat transmission by using latent heat is recognized to be more suitable than that by sensible heat due to less working fluid circulating power.

The cryogenic cogeneration system offers electricity and cold supply for remote sites, via an underground dual hydrogen pipelines. This study is in a preliminary design stage without any model testing. The interim status is summarized in the following.




1)SystemEfficiency:Energy conversion efficiency was evaluated as 38%.

System efficiency is defined as follows.
(Gene. Output+0.3~0.4*Cold Supply)
/(Hydrogen Enthalpy between 1.1 and 0.2 MPa)

2) Hydrogen Turbine:Efficiency of 70 kW class turbine was evaluated as 68 %.

Turbine efficiency is defined as follows.
(Turbine Output)
/(Isentropic Enthalpy Drop)

2. Description of Cryogenic Cogeneration System

The system is to expand 1.1 MPa hydrogen gas down to 0.2 MPa, producing electric power(100kW to 500kW) during expansion and supplying cold by expanded gas.

1.1 MPa hydrogen gas from high pressure pipeline is fed to a regenerative cooler, where the gas is cooled down to 243K, and is flown to the turbine, where the gas is expanded down to 0.25 MPa and discharge temperature is approx. 184K.

The exit gas from the turbine is supplied to a metal hydride reactor[3] as heat sink to absorb 1.1 MPa hydrogen via another small branch line. The outlet gas at 233K is fed to the above mentioned regenerative cooler and warmed up to 283K, and then returned to a low pressure main pipeline(0.2 MPa).

Corresponding to one (1) set of continuous operated turbine, two (2) sets of metal hydride reactors are necessary to overcome intermittent duty of absorbing/desorbing processes.

The refrigerant return at 218K acts as heat source to desorb hydrogen gas, getting cold to make the refrigerant supply temperature down to 213K. In the course, the desorbed hydrogen gas is returned to the low pressure main pipeline, via a small branch line.

In this study, the hydrogen mass flow of 1.0 kg/s can produce 71kW electricity and 50kW cold, simultaneously. The rated flow of small branch line is to be 0.006 kg/s.

3. Conceptual Design of a Turbine/Generator

The key concept of a turbine/generator design to meet this system is to make a machinery highly reliable and compact. Under activities, the following criteria were selected.

a. Direct connection of an expander and a generator

b. Possible application of proven space technology for expander type selections[2]

c. Application of cryogenic helium related technology for bearing designs[1]

The turbine of axial flow type, with magnetic bearings were selected to meet reliable and compact requirements. The directly connected generator shall be of claw-pole type or permanent magnet type to match higher speed capability.

4. Conclusions and Improvements

The energy conversion efficiency of cogeneration system exceeds 35%, which would be equivalent to other systems, however the presented system is a freon-free thermal system, i.e., consumes no electricity.

The better economic feasibility for futuristic broad applications would be able to be expected by the lower opearting cost from less expensive hydrogen absorbing alloys and higher output.

Improvement plans, therefore, should be concentrated for development of optimum hydrogen absorbing alloys of longer lives, higher heat transmission reactor, and more efficient turbine. Modified system without cold supply have to be designed for the customers who need electric power only.

5. Acknowledgment

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References:

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