6.15 Plant Concept of Heat Utilization of High Temperature Gas-Cooled Reactors

—— Co-generation and Coal-Gasification ——

HTR-HUC (HTR Heat Utilization Core Group in FAPIG*)
M.Tonogouchi, S.Maeda,(Ube Ind.), A.Ide, H.Hayakawa, T.Yasuno(Fuji Electric),
Y.Takenaka, S.Hayashi, T.Kobayashi(Kawasaki Heavy Ind.), M.Takeda(Shimizu Corp.)
M.Horie(Kobe Steel), K.Handa, Y.Nakamura(Furukawa Elec.),
M.Kaneko(Nuclear Fuel Ind.), T.Masuda(Nippon Light Metal),
M.Ikehara(Nissho Iwai), Y.Takase(Asahi Denka), M.Ishiwatari(FAPIG)

*FAPIG(The First Atomic Power Industry Group) is a supplier group of nuclear plant and consists of 22 companies representing variety of industries such as Electric, Chemical, Steel, Heavy industries etc..

ABSTRACT

The world energy demand is increasing along with the increase of population and rise of the standard of living and if this would be supplied only by the fossil fuels, much limitation will be imposed on human activities by the environmental problem.

The use of nuclear energy for generating electricity is now well established all over the world. Because more than 50% of the energy cunsumed in nonelectrical energy, it is important to develop methods to apply nuclear energy to the fields other than generating electricity. Since the modular high Temperature gas-cooled reactor (M-HTR) can supply high temperature energy of 700℃ to 1000℃ and possesses high level inherent safety, the M-HTR seems to be most suitable to apply the industries that need high temperature energy.

In Japan, JAERI is now constructing the High temperature Engineering Test Reactor (HTTR) and the new era is coming for the development and utilization of HTR.

Recognizing that the heat utilization of HTR would mitigate problems of environment and resources and contribute the effective use and steady supply of the energy, FAPIG organized a working group named " HTR-HUC " to study the heat

utilization of HTR in the field other than electric power generation.

We chose three kinds of plants to study, 1)a co-generation plant in which the existing power units supplying steam and electricity can be replaced by a nuclear plant, 2)Coal gasification plant which can accelerate the clean use of coal and contribute stable supply of the energy and preservation of the environment in the world and 3)Hydrogen production plant which can help to break off the use of the new energy carrier HYDROGEN and will release people from the dependence of fossil energy.

In this paper the former two plants, Co-generation chemical plant and Coal-gasification plant are focussed on. The main features of these plants are as follows.

(1) Co-generation chemical plant

A typical chemical plant in Japan was selected as the reference plant. The reactor system consists of 2 modules of HTR with the thermal output of 450MWt each and the reactor outlet temperature of 700℃. 640ton/hr of steam of 200 ℃ to 450℃ and 210MW of electricity are supplied to the chemical plant in which 1800ton/day of ammonia, 1200ton/day of methanol, 1700t/day of ammonium sulphate and so on are produced. The total heat untilization efficiency in this plant comes up to 74%.

(2) Coal-gasification plant

The coal gasification/ammonia production plant was selected as the reference plant of coal gasification. The reactor system consists of 4 modules of HTR with IHX, with the thermal output of 170MWt each and the reactor outlet temperature of 950℃. The coal is gasified by the steam gasification process using fluidized bed gasification furnace with gasification temperature of 750 ℃ and the product gas is supplied to the ammonia plant of the capacity of 1700ton/day. The amount of CO_2 emission from this plant is reduced by 20% than that from current coal-gasification plant.

1. INTRODUCTION

The FAPIG(First Atomic Power Industry Group) joined in the construction of two Japanese gas-cooled reactors. Through these experiences, FAPIG has the confidence with usefulness of the gas-cooled reactors. In this paper, we introduce the two types of heat utilization plant of HTGR.

2. PLANT SELECTION

We have started this work by getting information on energy consumption status of energy utilizing plant from our group companies to image a realistic model plant for the study.

Among the 10 companies who answered, 4 companies consume energy more than 100MW in a plant. They are a steel making, aluminium refining and cement & chemical production companies.

Considering the purpose of the present study, we have selected two types of plant:1)Co-generation plant to substitute the existing power plant in the chemical plant. 2)Coal gasification plant to produce ammonia by using reformed H2 from coal.

As a reference reactor, we chose 450 Mwt MHTGR and 200 Mwt HTR-M.

3. CO-GENERATION PLANT

The theme of this study is the utilization of nuclear energy for industrial plant as steam and electricity.

3.1 Plant Specification

We studied best match of HTGR co-generation system with chemical plant and got the result as follows.

(1) Nuclear reactor system

Type of Reactor	MHTGR
Thermal Output of Reactor	450 MW x 2
Inlet and Outlet Coolant Temperature	288 / 704 ℃
Coolant Pressure	7.09 Mpa
Steam Temperature	540 ℃
Steam Pressure	17.8 Mpa
Power Generated	117 Mwe x 2

(2) Chemical plant

a.Extracted Steam Conditions

Pressure (Mpa)	10.6	3.6	1.1
Temperature (℃)	490	330	220
Flow Rate (t/h)	264	108	269

b.Products

Ammonia	1,800 t/d
Methanol	1,200 t/d
Nitric Acid	430 t/d
Sulfuric Acid	1,200 t/d
Caprolactum	290 t/d
Nylon	220 t/d
Ammonium Sulfate	1,670 t/d

3.2 PROCESS FLOW

Process flow is showed in the attached Fig.1.

4. COAL GASIFICATION PLANT

The theme of this section is the utilization of high temperature helium from HTR-M for coal gasification.

4.1 Plant specification

The most important problem to be discussed is how to utilize the helium enthalpy for coal gasification. For heating indirectry, outlet temperature of helium shold be higher. We adopted two step gasification that has pre-reforming fluidized bed to use as much energy of helium as possible for gasification.

(1) Nuclear Reactor System

Type of Reactor	HTR-M
Thermal Output of Reactor	170 MW x 4
Inlet and Outlet Coolant Temperature	300 / 950 ℃
Coolant Pressure	4.05 Mpa

(2) Intermediate Heat Exchanger

Helium Flow Rate (kg/s)	50.3	47.3
Inlet and Outlet Gas Temperature (℃)	950/292	200/900
Inlet and Outlet Gas Pressure (Mpa)	4.04/4.02	4.44/4.25

(3) Coal Gasification / Ammonia Synthesis System

Ammonia Production Rate	1,500 t/d
Coal Gasification Rate	2,200 t/d
Number of Gasifier	4
Type of Gasifier	Flidized Bed
Helium Temperature at Gasifier (Out/In)	900/650 ℃
Gasifier Operating Temperature	750 ℃
Gasifier Operating Pressure	1.01 Mpa
Steam Carbon Ratio	3

4.2 PROCESS FLOW

Process Flow is showed in the attached Fig.2

5. SAFETY ASSESSMENT

We are studying on the following items for the safety assessment.

a. Safety improvement for adjacent demand plant

b. Discussion on reactor safety system

c. Possibility of adaptations for adjacent demand plant

d. Protective consideration against the gas explosion at demand plant

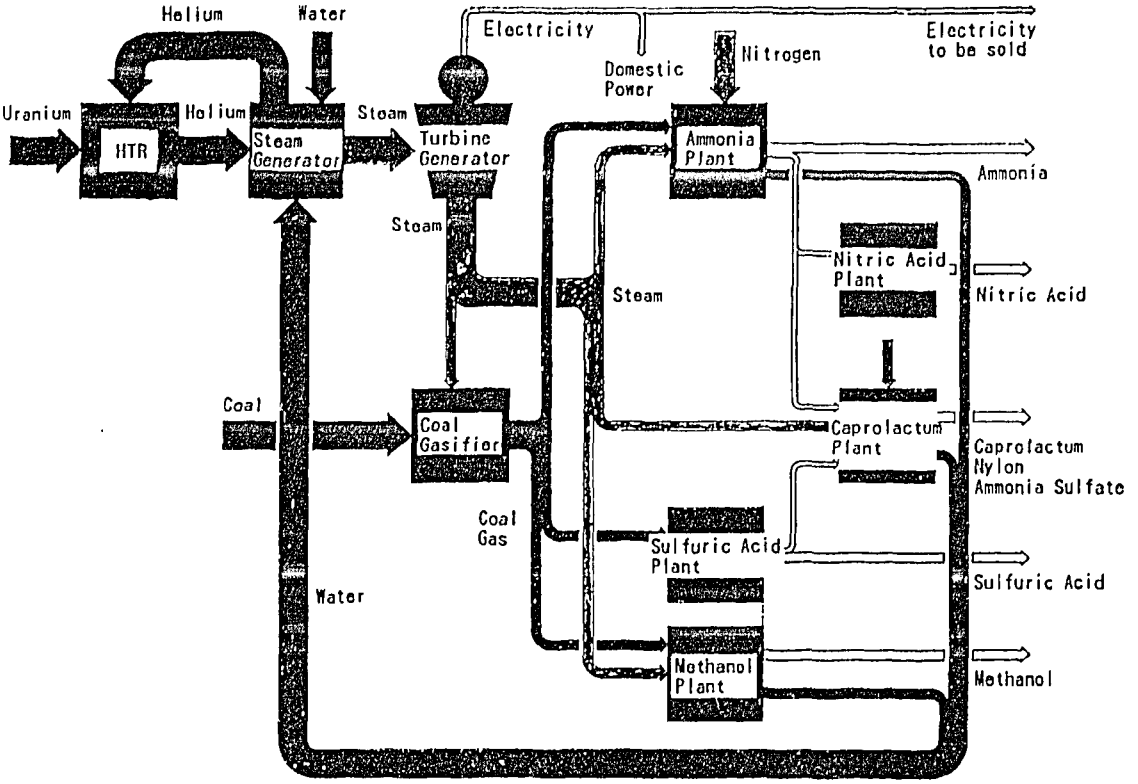

Fig.1 Diagram of HTR Co-Generation Plant

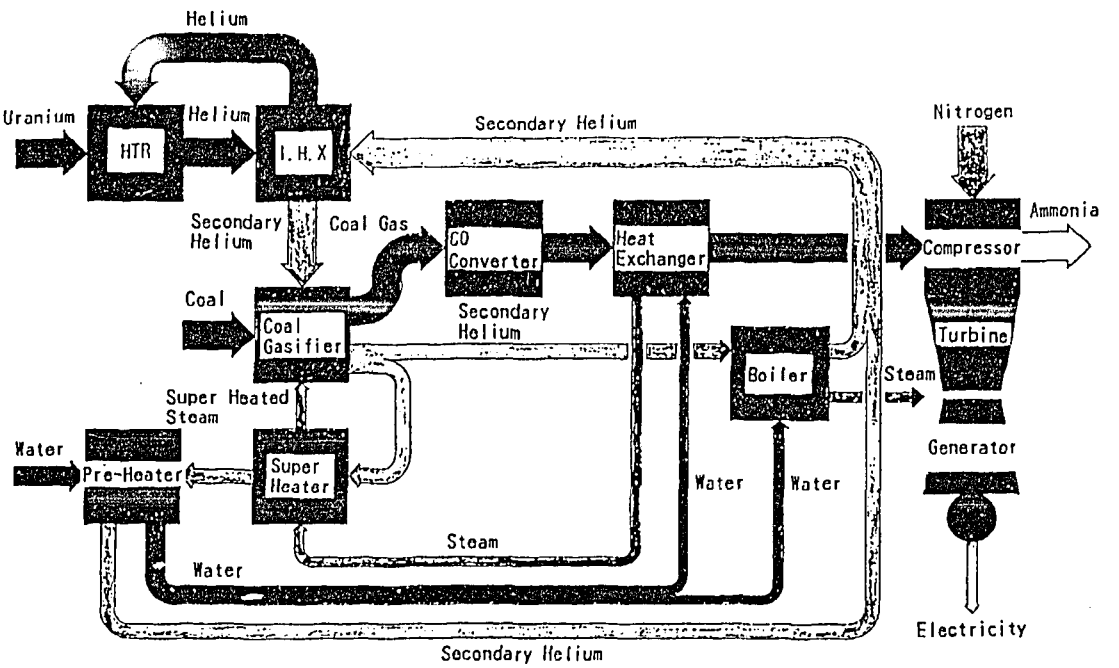

Fig.2 Diagram of HTR Coal-Gasification Ammonia Production Plant