● Hydrogen Production by Reaction Integrated Novel Gasification Process Technology (HyPr-RING)

1. Outline of the Technology

Regarding the fossil fuel conversion method to produce hydrogen, numbers of proposals have been presented up to now. But this is a unique technology called, **HyPr-RING process which stands for Hydrogen Production by Reaction Integrated Novel Gasification process, which can use coal and other fossil fuels, as well as, some chemical energy contained in general organic wastes to produce hydrogen, selectively and efficiently, by thermo-chemically analyzing water**.

Different from other conventional coal combustion or gasification, coal with other organic materials, etc. is treated in a high temperature, high pressurized water (650 ~800℃, above 60 atm), and the produced CO_2 reacts with such absorbing reagent as CaO etc., to generate extremely much amount of hydrogen gas efficiently. Simultaneously, CO_2 as by-product is easily separated and recovered. Most of the hydrogen produced by the HyPr-Ring technology comes from water. It enables us to produce a large amount of hydrogen based on coal as its clean energy source. The produced gas is almost pure hydrogen, and it contains no coal ash or sulfur, etc. And it requires no gas refining at all either for feeding those Fuel Cell, gas turbine, hydrogen fueling automobile or manufacturing some other chemical raw stuffs because it can be used as a cleanest energy from the beginning.

2. Principle of Hyper-Ring process

Regarding the representative chemical reaction of Coal Gasification, there are four such major chemical formulas as follows,

$$C + O_2 \rightarrow CO_2 \quad (1)$$

$$C + 1/2\,O_2 \rightarrow CO \quad (2)$$

$$C + H_2O \rightarrow + H_2 + CO \quad \text{(Hydro-gasification Reaction)} \quad (3)$$

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \text{(Shift Reaction)} \quad (4)$$

Hydrogen production is undertaken by both reactions of the hydro-gasification (No.3) and the shift reaction (No.4). In case of the HyPr-RING process, a large amount of extremely pure hydrogen gas can be produced by removing the by-produced CO_2, which is occurred in one of the reaction vessel through the above mentioned shift reaction (No.4), then to let the chemical reaction shift towards the right side of the formula (that is towards the product side).

The actual reaction occurring in the HyPr-RING process is presumed to occur additionally along with the reactions of (No.3) and (No.4) as follows, either

$$CO_2 + CaO \rightarrow CaCO_3 \quad (5)$$

or

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O \quad (6)$$

Then, if those (No.3), (No.4) and (No.5) reactions are summarized together, the overall reaction can be expressed as follows,

$$C + 2H_2O + CaO \rightarrow CaCO_3 + 2H_2 \quad (7)$$

Then we can obtain both solid $CaCo_3$ and H_2 gas as for the products.

The produced H_2 mostly comes originally from the accompanying H_2O in quantitative view, then the formula (No.7) can be considered coming from a thermo-chemical decomposing reaction. On other hand, the produced $CaCO_3$ becomes decomposed by the calcinations to form CaO and CO_2, then the CaO could become reused and the CO_2 be recovered in higher concentration. The heat used in the calcinations is released as shown in the formula (No.5) during the carbon oxide absorbing reaction, and then contributes to the improvement of the overall chemical reaction speed.

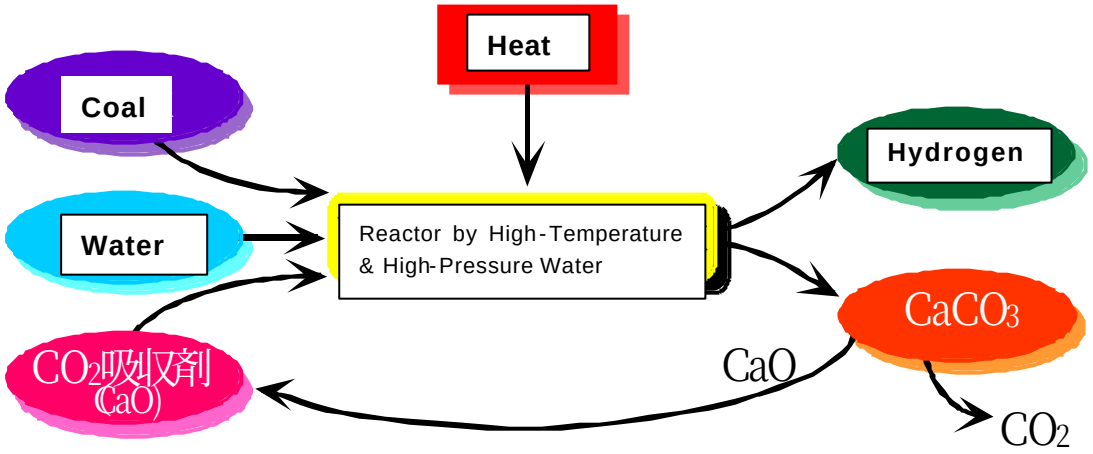


Fig. 1 Concept of the HyPr-Ring Process

The figure 2 shows a test result of the HyPr-RING experiment, run under a temperature of 650^0C and a pressure of 60MP_a, in which in the case of only coal is treated, one gram of coal produced about 0.79 liter (25^0C) of a gas of which composition was found as CO_2 31%, CH_4 13% and H_2 55%. However, when Ca $(OH)_2$ was put together to the reaction as a CO_2 absorbing reagent, the product gas volume increased to 1.3 liter, about double in amount, to reduce the by-producing CO_2 amount to almost zero, with contrastive increase of CH_4 by 24% and a drastic increase of H_2 by 76%.

Furthermore, when NaOH (as a catalyst) was put together, the produced gas volume and the hydrogen ratio were both highly raised. During the experiment, reaction rate of the carbon contained in the coal was found more or less 80%. The produced gas composition was also analyzed by Gas Chromatography, and it was found that the coexisting sulfur oxide SO_x and hydrogen sulfide H_2S were less than their detectable limit (1 ppm).

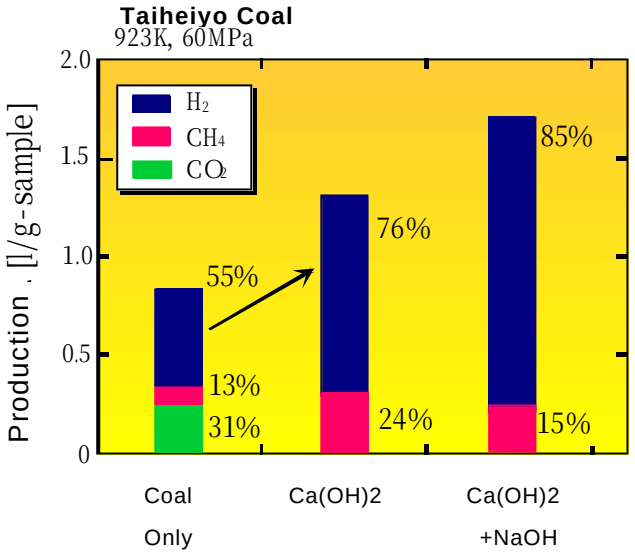


Fig. 2 Effect of Catalyst and CO_2 Absorbing Reagent

4. HyPr-RING Process

A flowchart of HyPr-RING process is shown in the Figure3. Coal, quick lime and water are mixed together to make slurry, which is supplied to a high-temperature, high-pressure reaction vessel to produce hydrogen in the reactor. Then, the hydrogen is separated from the products. Furthermore, the remaining products are separated into solid and liquid materials respectively. The solid materials are sent to the CaO recovering vessel and heated there to make CaO, at the same time, the generated CO_2 is recovered. Thus, the recovered CaO can be used as the CO_2 absorbing reagent repeatedly, while the liquid materials is led to a separation refining equipment. Then, the recovered water becomes usable for recycling.

The heating energy source to be supplied for both the reactivation of $CaCO_3$ and feeding for the reactor could be obtained possibly from the following sources, (1) Combustion of some partial feeding coal, (2) Burning some part of the produced gas, (3) Utilizing waste heats coming from a gas turbine or a high temperature fuel cell, after the produced gas has been primarily used.

Figure 4 shows an example of a power generation system combined with the HyPr-RING process and a hydrogen-firing turbine. In this case, we can expect improvement of their total thermal efficiency by using waste heats of the turbine exhaust gas. Even in the case of such a high temperature type fuel cell as a Solid Oxide type fuel cell being used, similar combination use of the system can be available.

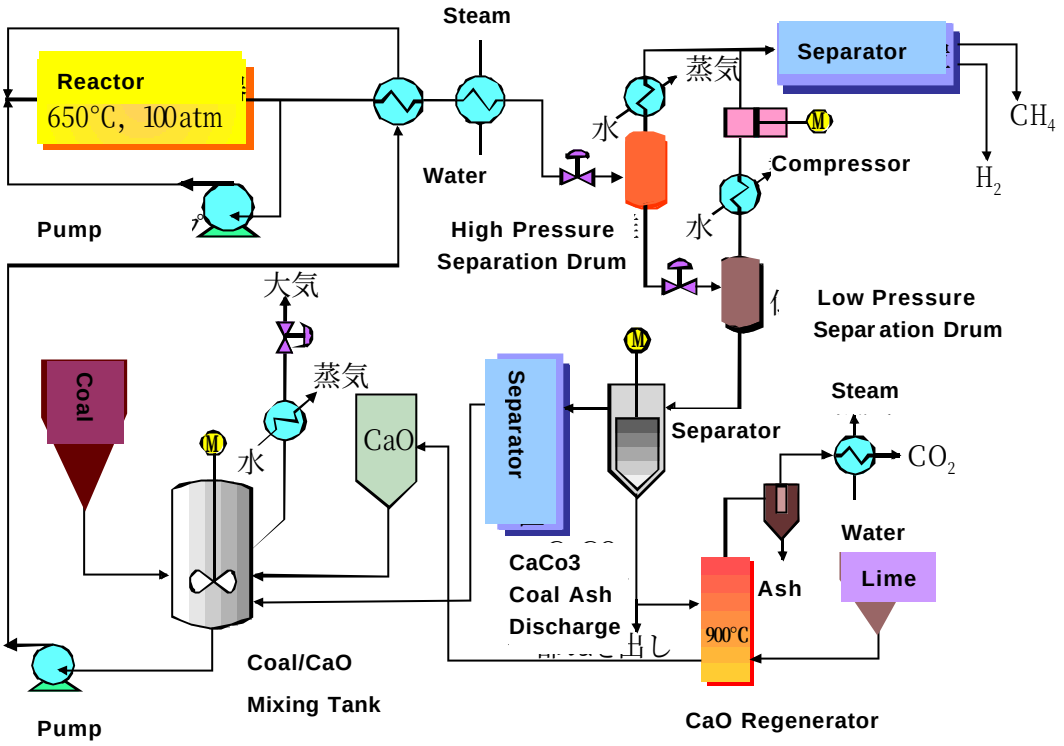


Fig. 3 Example of a HyPr-RING process flow chart

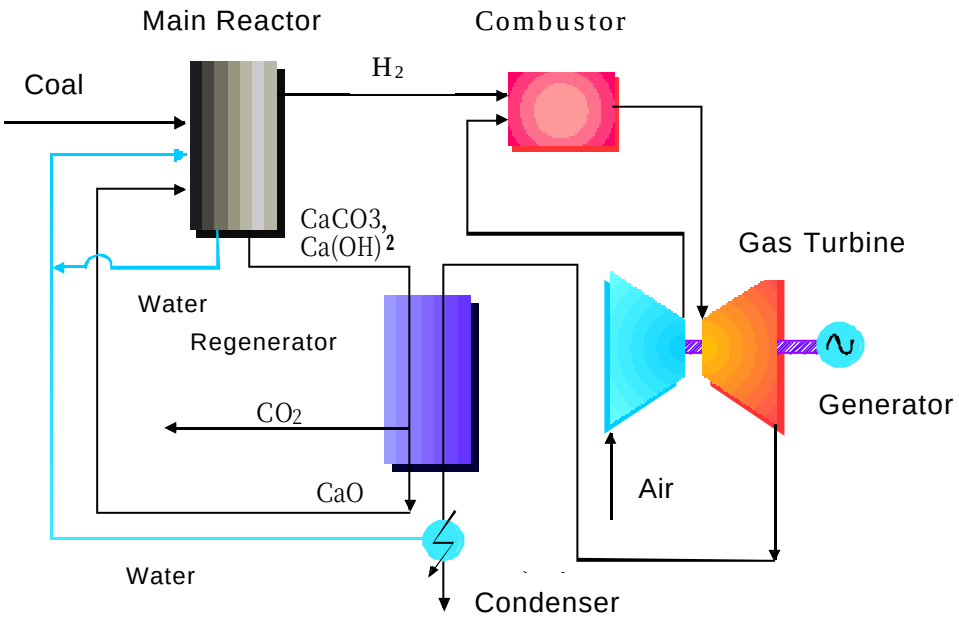


Fig. 4 Hydrogen Turbine Power Generation System by using HyPr-RING

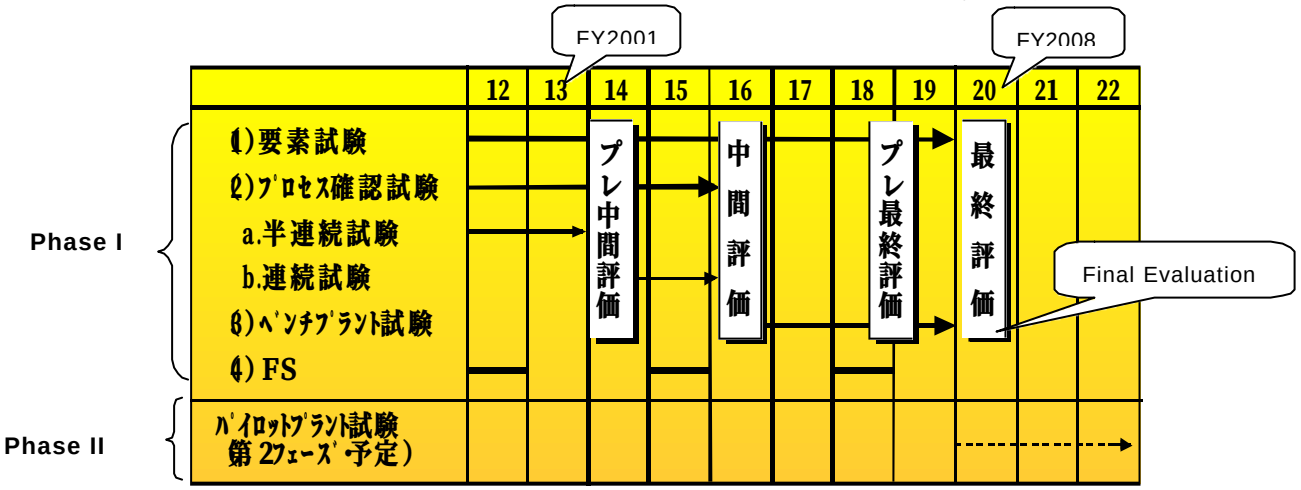
5. Development Schedule of the HyPr-RING Process

(1) Target of Development

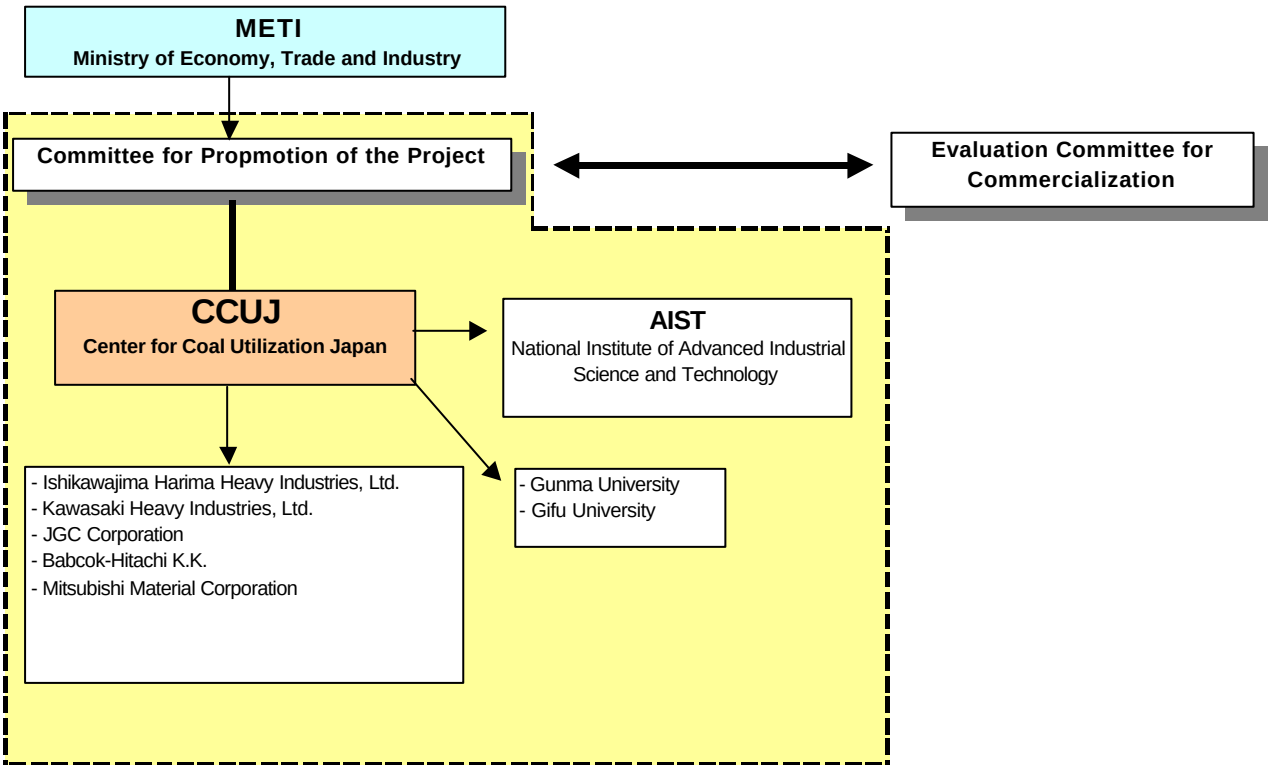
Item	Target
(1) Gasification Efficiency (2) Cleanness of Produced Gas (3) CO_2 Recovery	(1) 75% or more (2) Sulfur Contents: 1ppm or less (3) 40% or more of carbon contained in inputted coal (Less than CO_2 emission per calorie in case of natural gas)

(2) Schedule of Development

Please refer to the next article (6. Commercialization of the System).



(3) Framework of Development



6. Commercialization of the System

- This project expects to run such staging-up tests as Batch testing, semi-continuous and/or continuous equipment based testing, then both confirmation of the most optimum process and a feasibility study at that time should become implemented together with undertaking various necessary component tests. After those works, test operations using a bench scale plant will be done so as to implement more realistic feasibility study based on the results of the test operations. By these efforts, the best process of the HyPr-RING would be finalized towards its commercial uses. Thus, this project as Phase 1 is scheduled to complete around 2008. Then, its commercialization is currently expected after running necessary tests, etc. by using a pilot plant (phase 2) for 3 to 5 years and demonstration tests expectedly starting from 2011 until 2015 by using a commercial size facility (Final Phase).

- When the HyPr-RING technology becomes commercially used, a massive production of clean hydrogen energy will become feasible, which is now called an ideal future energy as a most epoch-making means of coal utilization. We expect very much of the coming contribution of the HyPr-RING for the solution of our Global Environment issues, particularly, in the sphere of coal utilization.

7. Related Technical Paper

The following technical paper is available on this R & D. If you like to know this technology more, please click the following title of the paper to link it.

→ **Hydrogen Production from Coal with Carbon Dioxide Fixation**