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THE PRELIMINARY DESIGN OF THE EXPERIMENTAL MULTIPURPOSE HIGH TEMPERATURE GAS COOLED REACTOR

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I. INTRODUCTION

Research is being conducted throughout the world on the utilization of the heat generated by a high temperature gas cooled reactor in process heat, and the Japan Atomic Energy Research Institute is conducting research and development on an experimental reactor for this purpose. This experimental reactor has a thermal output of 50 MW and a remarkable reactor outlet coolant gas temperature of 1,000°C, the highest in the world. Developement of high temperature gas reactors in the United States, England, and West Germany has advanced from the experimental stage to the prototype construction stage. But these reactors are all designed for power generation use and use the steam produced by a steam generator to drive a steam turbine and the temperature of the helium gas used as the reactor coolant is about 750~850°C. This is sufficient to heat a steam generator which can generate the steam as well as the newest thermal power plant. Further, this high temperature gas can also be utilized in the process heat of various fields and its high temperature is especially notable. However, the realization of a gas temperature of 1,000~1,200°C would permit its utilization as the heat source in the main process of the iron and chemical industries.

The high temperature gas cooled reactor has excellent features for the generation of high temperature from the standpoint of fuel and reactor construction, and a temperature of about 800°C has already been realized for power generation purposes and multipurpose reactors having a temperature of 1,000°C are planned. Fuji Electric and the FAPIG Group have cooperated in the research and development on the experimental multipurpose high temperature gas cooled reactor of the Japan Atomic Energy Research Institute by performing preliminary design of the experimental reactor in 1970. An outline of the results of the second preliminary design performed in 1971 and based on the results of the first preliminary design is given here.

II. OUTLINE OF PLANT

The reactor comprises a core consisting of graphite blocks piled inside a steel pressure vessel. Thermal output is 50 MW, the core outlet helium gas temperature is 1,000°C, and the inlet helium gas temperature is 400°C. Two loops are connected centered around

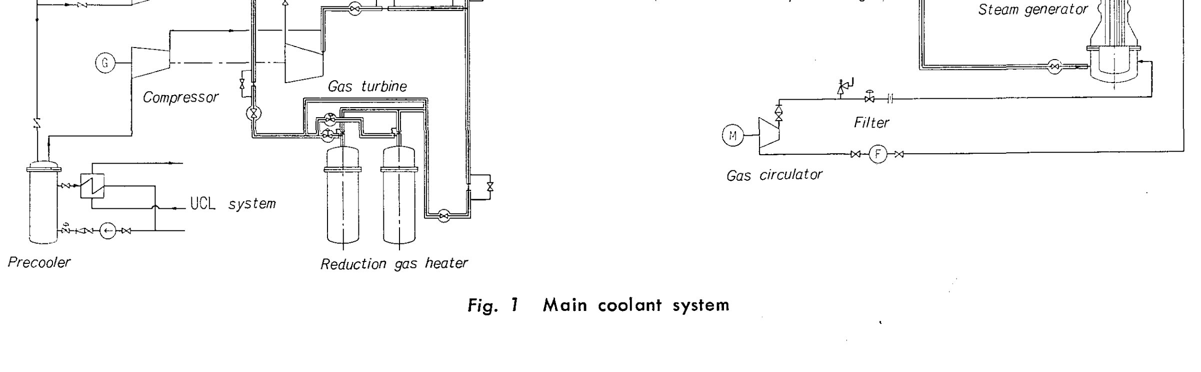


Fig. 1 Main coolant system

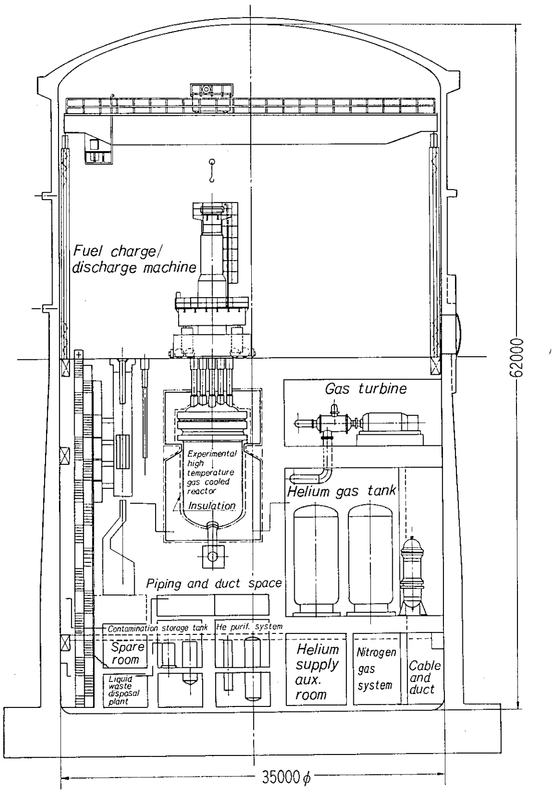


Fig. 2 **Reactor plant arrangement (elevation)**

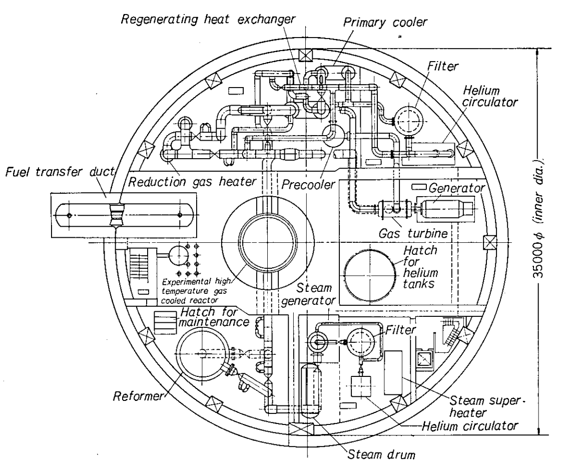


Fig. 3 **Reactor plant arrangement (plan)**

this one reactor. One loop is a reduction gas production loop which produces the reduction gas for iron making, etc. and the other loop comprises a test loop for operation test of the high temperature heat exchanger, gas turbine, etc.

The flow sheet of the primary circuit is shown in *Fig. 1*. The reduction gas production loop utilizes the helium gas heated to 1,000°C by the core to produce the reduction gas by means of a reformer, and is the helium circulation loop which reduces the temperature of the helium to 400°C and returns it to the core. This loop is equipped with a 400°C operating temperature helium circulator.

The test loop uses the 1,000°C helium from the core in conjunction with the reactor bypass flow and tests the operation of the reduction gas heater and gas turbine by changing the gas temperature to the 1,000∼750°C range, and is the circulation route which returns the helium gas to the reactor after its temperature is reduced to 400°C by the regenerating heat exchanger, and is equipped with a low operating temperature (175°C or less) helium circulator for gas circulation when the gas turbine system is not operating.

The reduction gas heater of this test loop is an insulated wall type heat exchanger which performs 1,000°C gas heat exchange and is one of the most difficult multipurpose high temperature equipment to design. All the piping for the high temperature gas from the reactor employs a double pipe construction. The pressure part at the outside, through which the low temperature gas returned to the reactor flows, is made a low temperature.

The reactor and equipments around the reactor, reduction gas production loop, test loop, helium purification system, auxiliary system, emergency core cooling system, and heating and ventilating systems are provided inside the containment (containment building). The layout of the reactor facility centered around the reactor, and each loop and fuel handling system is shown in *Fig. 2* and *Fig. 3*.

As for the fuel handling system, the layout of equipments is centered around the reactor room and the reduction gas production loop and test loop are arranged at both sides. The helium supply and dump tank room is located opposite the fuel charge/discharge room against the reactor room. The floor of the fuel charge/discharge room is at ground level and consideration has been given to shielding and ventilation to the part of its containment building above the fuel handling floor so personnel can enter even during operation. Moreover, the reactor room and primary loop room have been designed to have an inert gas atmosphere from the standpoint of safety. Plant particulars are given in *Table 1*.

III. REACTOR EQUIPMENT

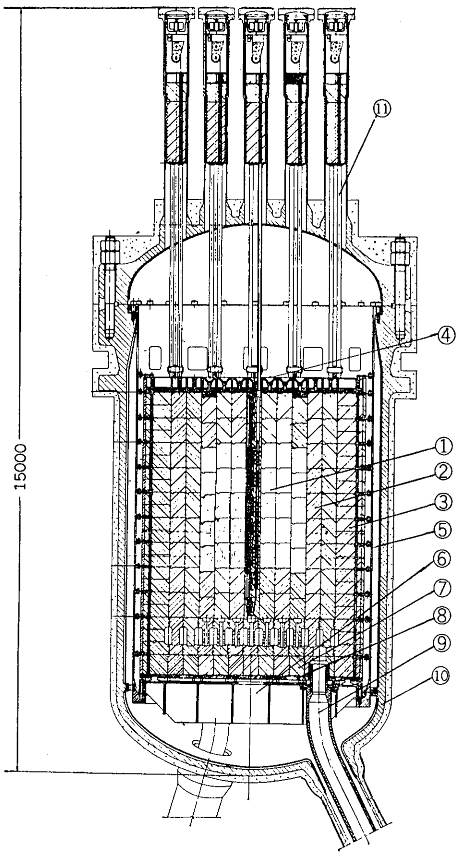
1. Reactor Construction

As shown in *Fig. 4*, the core comprises fuel elements, reflector, core barrel, diagrid, outlet tubes, pressure vessel, etc. The fuel element consists of a 500 mm long block of graphite having a normal hexagonal cross section and surface distance of 299 mm into which holes have been drilled and fuel pins inserted into the holes. Coated particle fuel with UO_2 are dispersed in the fuel compact in the fuel pins. There are total of 275 of these fuel element blocks stacked in 5 layers.

The reflector consists of a stack of graphite blocks having the same shape as the fuel elements and has a thickness of 1 m in both the side and vertical

Table 1 Main characteristics of the plant

1. Type of reactor	Low enriched Uranium (6~8%), graphite moderated, Helium cooled multi-purpose reactor
2. Thermal output	50 MW×1
3. Fuel form, dimensions	Cylinder, effective rod. 233.6 cm effective height 250 cm
4. Fuel element	
Standard element	240
Control rod area element	35
Total fuel element	275
Fuel element/column	5
5. Fuel element arrangement	Delta arrangement
6. Power density	
Average	4.7 W/cm^3
Maximum	18.4 W/cm^3
7. Initial loaded fuel at the rated output	
U^{235}	61 kg
U^{238}	773 kg
8. Type of fuel element	Hexagonal graphite block 500 mm height and 299 mm across flat with 36×37 mmφ holes into which fuel pins are inserted. Coolant is passed through annulus of 1.5 mm in width around pins
9. Temperature of core inlet/outlet	400/1,000°C
10. Pressure of core inlet/outlet	40/39.5 kg/cm^2
11. Control rod	
Type	Dual cylinder, vent type
Number	38
Absorber	
Material	Sintered material of B_4C and graphite powder
Inner dia., outer dia.	30 mm, 50 mm
Effective length	375 mm
Outer tube material	Hastelloy-X
12. Pressure vessel	
Unit	1
Type	Vertical cylindrical
Main dimension	
Inner dia.	5,120 mm
Total length	ca. 15 m
Vessel height	ca. 11 m
Thickness	140 mm
Material	2¼ Cr–1 Mo steel
13. Fuel charge/discharge machine	
Unit	1
Type	Travelling and traverse type, off-load charge/discharge
14. Reduction gas loop	
Cooling capacity	25 MW
Coolant flow rate	28.5 t/h
Reformer	
Unit	1
Thermal load	10 MW
Inlet/outlet temp.	1,000/760°C
Steam generator	
Unit	1
Type	Forced circulation
Heat density	16.2 MW
Inlet/outlet temp.	760/370°C (Mode I) 1,000/370°C (Mode II)
Steam condition	250/41°C/ata
Feed water temp.	133°C
Tube material	Hastelloy-X
Gas circulator	
Unit	1
Operating temp.	400°C
Flow rate	28.5 t/h
15. Test loop	
Cooling capacity	25 MW
Coolant flow rate	28.5 t/h
Reduction gas heater	
Unit	2
Type	Shell and tube straight pipe without tube plate
Heat density	6.16 MW
Pressure	40/3 atg
Helium temp. inlet/outlet	1,000/923°C
Reduction gas temp. inlet/outlet	40/850°C
Tube material	Incoloy 800
Gas Turbine	
Unit	1
Heat density	17.9 MW
Temp. of inlet/outlet	750/497°C
Pressure of inlet/outlet	40/17 ata
Compressor	
Unit	1
Heat density	11.3 MW
Temp. of inlet/outlet	40/196°C
Pressure of inlet/outlet	15.4/40.9 ata
Pressure heat exchanger	1
Inlet temp.	1,000°C
Tube material	Hastelloy-X
P'ry cooler	1
Precooler	1
Gas circulator	1
16. Helium high temp. side piping	
Type	Double pipe
Material	Hastelloy-X lining 2¼ Cr–1 Mo steel
17. Containment	
Structure	Prestressed concrete Steel plate lining
Dimensions	Cylinder inner dia. 35 mm inner height 62 m
Design pressure	1 kg/cm^2g
Penetration	Equipment lock 1 Personnel lock 1



① Fuel element
② Movable reflector
③ Fixed reflector
④ Orifice
⑤ Core barrel
⑥ Diagrid
⑦ Carbon block
⑧ Support plate
⑨ Outlet tube
⑩ Reactor pressure vessel
⑪ Control rod

Fig. 4 **Vertical cross section of the reactor**

directions.

The core cooling gas flows downward, and the control rod device and other metallic devices are installed at the low temperature part at the top of the core and the core is located at a position comparatively lower in the reactor containment building. In addition to being convenient from the standpoint of aseismic design, it also has a number of other advantages such as utilization of the self-weight in emergency insertion of the control rods and prevention of blow-up of the fuel elements. Its disadvantage is that a certain amount of ingenuity is required in the heat resistant design of the core support structure at the high temperature part at the bottom of the core. But this problem can be solved by forming of hot plenum by means of graphite blocks, weight resistance and heat resistance by means of carbon blocks, and gas passage schemes.

The diagrid, support plate, core barrel, and pressure vessel employ a reentrant system which only contacts the 400°C inlet gas. The piping material is 2¼ Cr–1 Mo steel which is reliable at temperatures of around 450°C.

2. Control Rods

The reactor is controlled by 38 control and safety rods which are inserted and withdrawn by independent drive mechanisms. The control rods are made of boron carbide uniformly dispersed in graphite powder and placed in a Hastelloy-X tube. Since the control rods are exposed to high temperature, when a construction in which an absorber is sealed in is employed in the design of the guide tube for a low allowable stress at high temperature, the wall thickness required to withstand the gas generated by the absorber will become extremely thick and the weight will also become large. This is one of the problems encountered in this design.

The so-called vent type construction in which the pressure difference between the inside and outside of the guide tube is eliminated by a vent hole in the guide tube was studied and since the stress caused by the pressure inside and outside the guide tube can be disregarded with this system, not only is the wall thinner and design of the drive mechanism easier, and a gas plenum inside the guide tube is unnecessary and the effective length of the absorber is larger. However, a construction scheme is required so that the absorber and absorber impurities do not enter the reactor coolant as induced radioactive material. Therefore, a filter made of porous material was used at the vent section to prevent the entry of the absorber into the coolant. Moreover, the impurity component must be controlled by means of quality assurance from the standpoint of manufacture. This vent type guide tube is currently in the investigation stage and is, of course, not the final design.

The control rod reaches its highest temperature near the channel outlet and is subject to the most severe condition from the standpoint of material strength even through the excellent high temperature characteristics of the Hastelloy-X can be expected. The vent system studied to reduce the stress applied to the above guide tube must also be cooled by

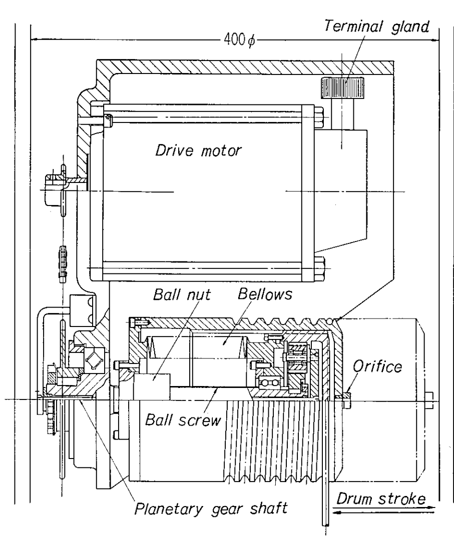


Fig. 5 **Control rod drive mechanism**

passing a suitable amount of helium gas through the control rod channel in order to suppress the temperature rise of the guide tube.

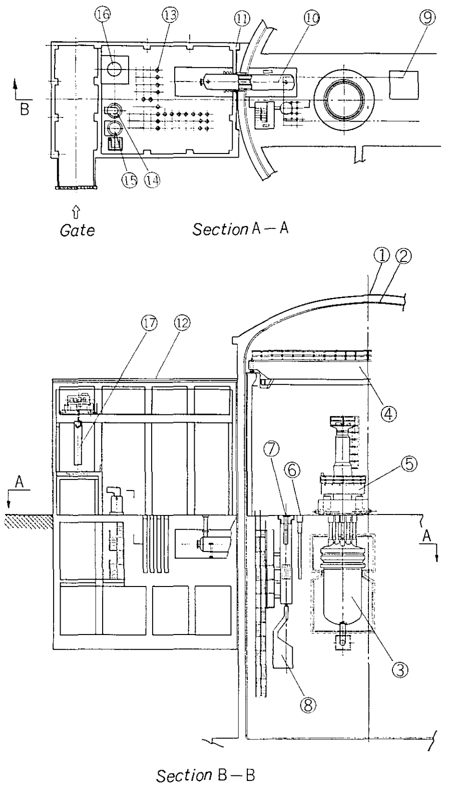
3. Control Rod Drive

The control rod drive can be reliably designed by means of various systems in the case of the hanging system of a gas cooled reactor such as this reactor. Emergency scram insertion can also employ the gravity drop system.

Since the shock at the lowest point is considerable and there is the danger of breaking of the control rod when freely dropped when the scram employs the gravity drive system, a brake mechanism is normally installed at the bottom end of the control rod. This construction must be both simple and reliable. For example, the installation of a device such as a spring and dush pot at the bottom end of the control rod is sufficient. However, one problem with this reactor is that since the bottom end of the control rod is in the high temperature region around 1,000°C, the installation of a simple, positive metallic buffer mechanism which can withstand a temperature of 1,000°C was considered impossible.

In order to suppress the drop impact of the control rod when one of the hanger wires breaks, for example, a Hastelloy-X bellows is installed to the bottom of the control rod and the impact energy is absorbed by the plastic deformation of this bellows. However, this cannot be used over and over a number of times and a control mechanism for scram drop is installed in the drive mechanism.

The construction of the control rod drive mechanism is illustrated in *Fig. 5*, and consists of a drive motor and pneumatic braking device. Braking at scram is 2-stage with a preumatic brake installed as back-up, in addition to normal control of the drop speed itself by regenerative braking by a permanent magnet inside the motor rotor.



① Containment
② Containment liner
③ Reactor vessel
④ Ceiling crane (60 t)
⑤ Fuel charge/discharge machine
⑥ Control rod drive storage hole
⑦ Rehearsal shaft
⑧ Mortuary hole
⑨ Maintenance pit
⑩ Fuel transfer facility
⑪ Bellows
⑫ Fuel storage building
⑬ Fuel and control rod storage hole
⑭ Aux. transfer cask
⑮ Isolation valve
⑯ Spent fuel handling room
⑰ Spent fuel transfer cask

Fig. 6 Fuel handling system

4. Fuel Handling System

This facility takes in and stores the fuel, movable reflector, orifice, etc., charges into the reactor, and performs cooling, storage, and take out after discharge and consists of fuel charge/discharge machine which charges and discharges into and from the reactor, fuel transfer equipment which connects the inside and outside of the containent and transports the fuel, etc., control rod drive mechanism holes, mortuary holes, rehearsal equipment, etc. An outline of the system is given in *Fig. 6*.

Fuel exchange is performed after the reactor is shut down and the temperature and pressure drop. The construction of the fuel charge/discharge machine is illustrated in *Fig. 7*.

Transfer of the fuel charge/discharge machine is performed by a travelling girder and traverse truck. The body of the charge/discharge machine consists of a grab housed inside the body container, grab elevating drive chain mechanism, grab swing and rotation mechanism, cable which transmits the electrical signals from the grab and hose reel which transfers the grab operating use helium pressure, new and spent fuel storage box, new and spent control rod and drive mechanism containment rack, charging chute rack container, charge nozzle, and shield plug.

IV. COOLING SYSTEM

1. System and Operating Modes

The cooling system comprises a reduction gas production loop and test loop. The system layout is shown in *Fig. 8* and *Fig. 9*.

System design and component design of these loops were performed. The complexity of the operating modes is a problem in system design and the 1,000°C region is a problem in component design. The reactor systems placed in practical service up until now have been monopurpose reactors, and new problems related to each operating mode and component are encountered in the case of a multipurpose reactor such as this design. The present stage does not extend to sufficient system design, but sufficient

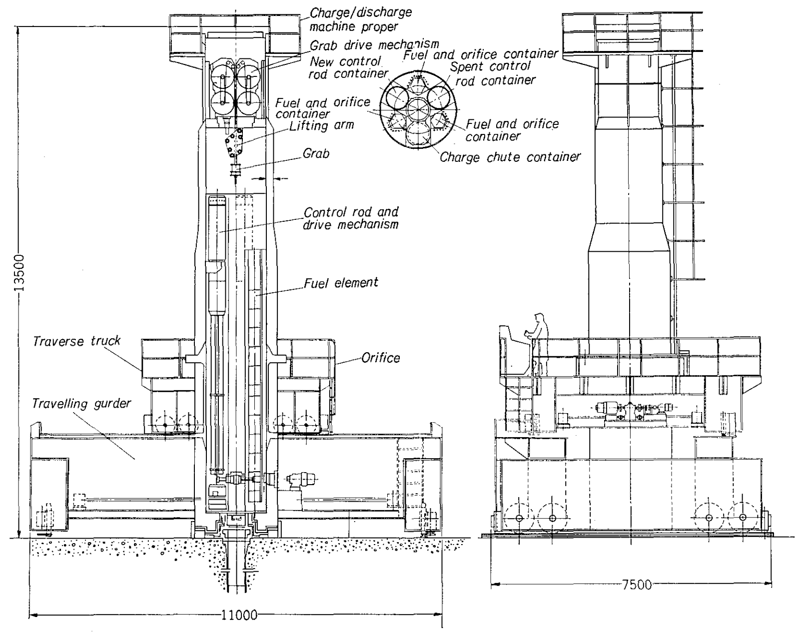


Fig. 7 **Fuel charge/discharge machine**

operating modes and problems of the 1,000°C region are known.

As a rule, the reduction gas production loop and test loop are normally operated and not operating in an independent loop is made the principle. This is done to provide redundancy in the reactor cooling functions from the standpoint of safety. Each loop is divided into a number of operating modes corresponding to each purpose. For example, the test loop is designed to have the following modes.

Operating mode I Exclusive cooling operation which bypasses the test section (reduction gas heater and gas turbine system)
Operating mode II Gas turbine operation

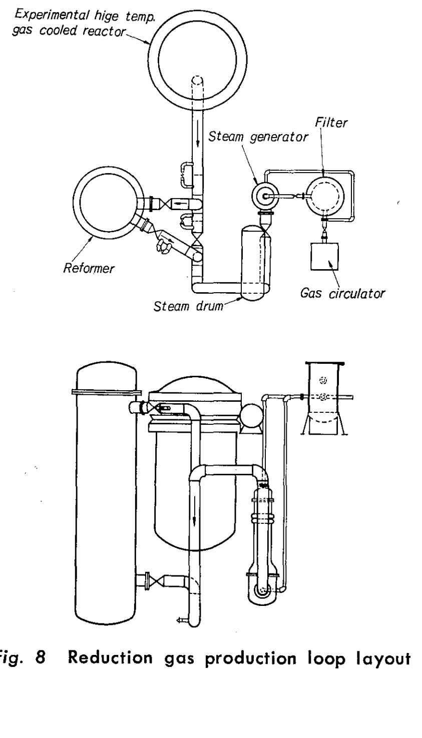


Fig. 8 **Reduction gas production loop layout**

Operating mode III Reduction gas heater operation
Operating mode IV Test section bypass (helium temperature 750°C)

Moreover, in the reduction gas production loop, there are times when the reformer is operated and times when it is bypassed. Of these operating modes, component design must be performed under the most severe conditions.

Component design is based on techniques which permit design and manufacture at the highest technological level currently available. For example, in the 1,000°C region, all structures are constructed so that pressure is not applied and, as a rule, pressure resistant structures are designed so that they can be used at a comparatively low temperature of 460°C or less. This low temperature design has been realized through the use of insulation and outer surface cooling methods. However, insulation and high temperature valves which directly contact the 1,000°C high temperature gas must be developed and typical parts were selected in this design. However, a comparative study with other types remains as a future development objective.

As for the type of construction of the main component in the loop, the regenerating heat exchanger and primary cooler are an exterior cooling system U-shell type with a fixed tube plate, the reduction gas heater is a straight tube system shell and tube type with a header without a fixed tube plate, the secondary cooler is a shell and tube type, the steam generator is a forced circulation straight tube type with a fixed tube plate, and the gas circulator is a helium gas bearing system centrifugal 3-stage horizontal type. As for the valves, the high temperature valve (1,000°C) permits a certain amount of internal leakage as a helium flow switch, and the low temperature

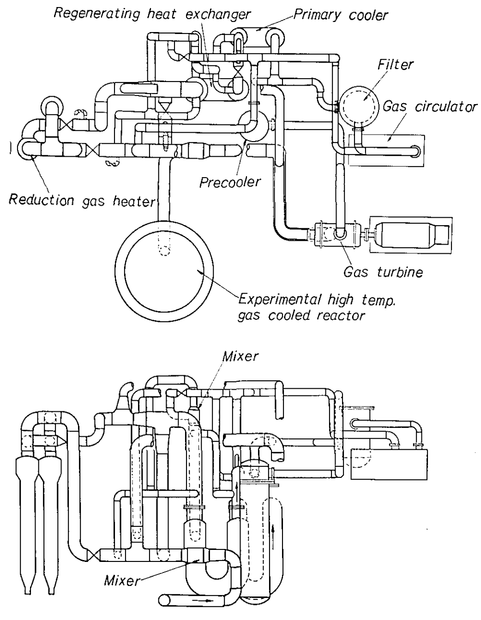


Fig. 9 Test loop layout

valve employs a system which does not permit leakage. The high temperature part of the piping from the reactor outlet employs a double construction.

2. High Temperature Heat Exchanger

Since in this design, the 1,000°C helium from the reactor is sent directly to the reformer by the reduction gas production loop, a 1,000°C, 40 kg/cm^2 large helium insulated wall type heat exchanger was not designed. But the reduction gas heater can be considered as the first stage of this type of technology.

In other words, this reduction gas heater, for example, heats the low temperature reduction gas produced by the reformer in the iron smelting process to at least 850°C or higher for iron ore reduction use. This can only be done with a high temperature insulated wall type gas/gas heat exchanger. The reduction gas heater in the test loop of this design is only for the purpose of confirming the characteristics and reliability of the high temperature heat exchanger as a single unit and has a small capacity and operation with the reformer of the reduction gas production loop was not considered. This type of high temperature insulated wall type gas/gas heat exchanger is indispensable in a multi-purpose high temperature gas cooled reactor system even when the reduction gas heater is not considered and its developement is toward technological difficulties which cannot be avoided.

That is, we designed this experimental reactor on the most up-to-date techniques and employed a double construction in which the high temperature resistant part and pressure resistant part are separated. The direction of developement in this case is toward heat resistant structural ingenuity using insulating material and is the same as the basic manner of thinking concerning high temperature design. However, the insulated wall heat exchanger is required from the standpoint of separation of the primary system of the reactor from the standpoint of safety, and there must be a boundary which transmits high temperature while withstanding pressure when transmitting heat. The use of a material other than metal as this boundary is impractical because of the problem of leakage.

The only heat exchanger between the primary and secondary system incorporated in the reactor system at the present time is the metal insulated wall heat exchanger. However, there is no heating transmission use or piping use metal which can withstand 1,000°C and a pressure of 40 kg/cm^2 over its life in the design range which does not deviate from the norm. Since the gas temperature of the unheated side is not 1,000°C but 850°C in this design, high temperature design was somewhat easy, and the high temperature, high pressure heat transmission tube was designed so that it can be replaced any number of times over the life of the plant.

3. General Problem Points from the Standpint of high Temperature Equipment Design

(1) Material

The design of high temperature equipment starts from selection of a material suitable for the usage conditions and determination of the design stress. However, various factors must be considered in this example, at the present time the effects of creep, relaxation, high temperature fatigue, thermal shock, oxidation, corrosion, and radiation have not necessarily been clarified. Therefore, in order to perform actual design, the characteristics of the materials required in accordance with the purpose, functions, and construction of the equipment must be confirmed by experiments beforehand.

(2) Thermal expansion

In order for high temperature equipment to absorb the large heat expansion caused by high temperature, metal contact and sliding parts are unavoidable at each part from the standpoint of design. However, the phenomena of metal contact in high temperature helium has not be clarified at the present time. For example, the self welding phenomena between metals in high temperature high purity helium has been reported, but its clarification and prevention measures must be established.

Moreover, there are also places where a flexible joint must be used in order to absorb heat expansion, but their record of use is small at the present time and ample confidence testing is required beforehand.

(3) Insulation

In order to design appropriate high temperature equipment by combining or extending present techniques, heat insulating construction and insulation material are conceived and there is a large dependence on these. A reliable insulation material is especially required. The characteristics required of insulation

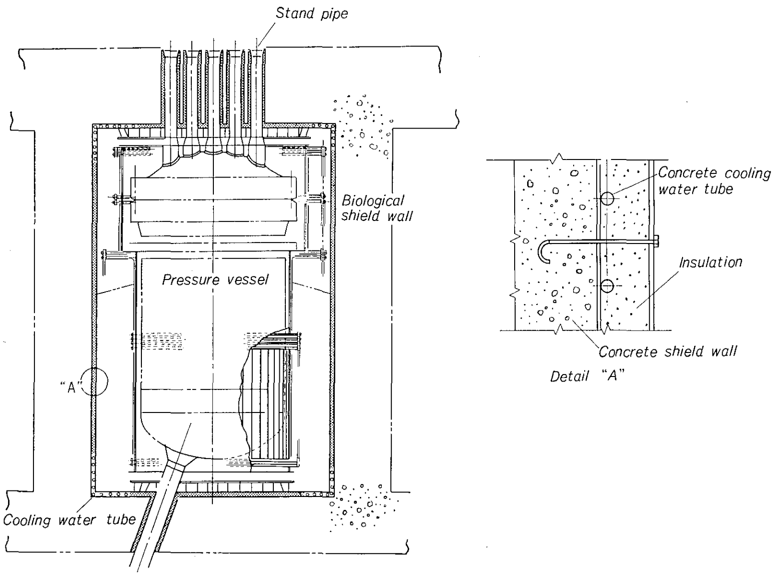


Fig. 10 Emergency core cooling system

material are high temperature characteristics, heat resistance characteristics, little aging, little irradiation damage, and no degradation of the helium purity. However, these various characteristics have not been clarified for various materials. Whether or not production in the required shape is possible, heat transmission in the helium from the standpoint of design, durability, whether or not impurities are generated, must be amply tested and confirmed beforehand.

V. ENGINEERING SAFEGUARDS

An emergency shutdown system, emergency core cooling system, steam water dumping system and feed water limiter, emergency gas injection system and containment facilities design were studied as engineering safeguards. However, reactor safety requires overall evaluation of surrounding phenomena, the characteristics of the reactor, the functions of the engineering safeguard facilities, etc. At the current stage of design of this experimental reactor, there are parts in which the required conditions have not been sufficiently obtained and there are a large number of evaluated places which are based on assumed conditions.

1. Secondary Backup System

As a secondary backup system, a large number of balls containing a neutron absorber are always maintained in the stand pipe at the top of the core and the absorber is dropped into the core even when insertion of the control and safety rods into the core is impossible due to deviation of the position of the fuel elements inside the core caused by an earthquake or other reason. This type of system has a record of achievement in gas cooled reactors.

When the cooling ability of the primary system is lost after reactor is shut down, the temperature inside the core rises, because the operating temperature of this experimental reactor is very high, so there are some problems remaining concerning the balls material containing the absorber must be studied in the future. However, there are no problems concerning the mechanism which stores the balls at the top of the core and releases them when an accident occurs.

2. Emergency Core Cooling System

Since this reactor system has two cooling loops and the 2 loops are operated simultaneously as a general rule, perfect and permanent loss of forced cooling is difficult to conceive. However, even in such a case, an emergency cooling system which maintains the cooling effect with respect to decay heat after the reactor shut down has been designed. This system intermittently cools the core from the outside of the vessel. As shown in *Fig. 10*, the outside of the reactor vessel is surrounded by a panel, the heat from the reactor vessel is primarily absorbed in the form of radiation heat transfer by passing cooling water through the cooling water through the cooling tubes installed to the outside of the panel, the temperature at the surface of the reactor vessel wall is lowered, and the relative core temperature is suppressed. According to the results of heat analysis, it is assumed that the maximum temperature of the core will not exceed the fuel melting temperature with this system. Moreover, the temperature of the core barrel is also suppressed and its functions are not lost during the period of an accident.

3. Water and Steam Dump System

This has been provided to limit the danger of a increase in the pressure of the primary system by damage of the fuel and graphite by water and steam which may enter the primary system due to damage to the steam generator tube contacting the graphite in the core. As shown in *Fig. 11*, this system consists of a circulating water shutoff valve connected to the

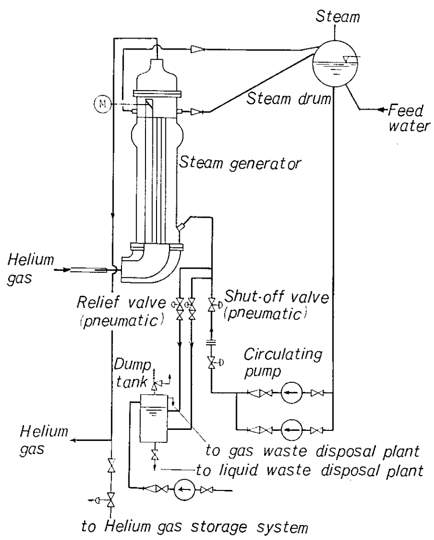


Fig. 11 Water vapor dumping system

circulating loop of the steam generator, piping from the circulating water system to the dump tank, circulating water relief valve, and steam check valve to the dump tank and drum. The steam check valve prevents the reverse flow of water and steam to the inside of the steam generator when the steam generator tube is ruptured. The circulating water shutoff valve prevents the flow of supplementary water inside the steam generator.

Since the mode of damage of the steam generator was not set in this design, analysis was performed by assumption. However, the effects of graphite-water steam reaction caused by rupturing of the steam generator tube is only slightly related to the mass defect of the graphite, and it was found that the problem could be almost completely disregarded from the standpoint of core construction. But a fairly large pressure rise resulted. However, the assumed amount of water and steam flowing into the core, the assumption that the full amount of water and steam which flowed into the core reacted with the graphite, and other assumptions ware made toward the safe side and it is estimated that there is no danger. In any event, future studies are required for accuracy. In the current studies, the effect of the isolating valve of the primary loop was totally unexpected, but if operation of this type of high temperature valve is expected, the amount of flow can be reduced considerably.

4. Emergency Gas Injection System

This is a facility which limits the entry of air into the core when the primary system is damaged. Air can coexist with graphite as far as possible as the cooling material at 200°C or lower, but the graphite is severely oxidized at 400°C or higher.

There are actual examples of emergency gas injection systems installed in a gas cooled reactor, but this is because an independent containment is not provided and the atmosphere outside the reactor vessel is air. On the other hand, since this experimental reactor has an independent full containment and the primary system ambient atmosphere during normal operation is designed to be an inert gas, the entry of a large volume of air when an accident occurs is impossible.

Therefore, the effect was calculated by assuming that air corresponding to the full amount of helium contracted by a drop in temperature after an accident entered the core and it was found that there was no problem.

In other words, it was concluded that the installation of an emergency gas injection system was unnecessary, but system design was performed by assuming that its installation was required for some reason.

5. Reactor Containment Building

There are various types of containment buildings such as steel (double or semidouble), reinforced concrete with steel liner, prestressed concrete with steel liner, and a prestressed concrete construction with which this group has design experience and which is considered to have a bright future was adopted. However, this is not strictly adhered to.

As can be seen in *Fig. 2* and *Fig. 3*, the building is a cylinder having an overall height of approximately 66 m and a inside diameter of 35 m. The concrete wall is 0.6m thick at the thin point and 1.8 m thick at the thick point. The inside is lined with steel, but this is for air tightness and is not a reinforcing member. Tensioning method is steel bar for longitudinal and the Freyssinet method for others. One of the reasons the prestressed concrete construction is recommended for the containment building is safety with respect to damage and that compact design which can serve as both a shield and container is possible from the standpoint of layout. However, a comparison of building costs with other types of containments is to be conducted in the futuie.

VI. INSTRUMENTATION AND CONTROL

1. Instrumentation

One feature from the standpoint of instrumentation is a system which permits 1000°C temperature measurement possible. The outlet temperature of the channel is about 1,200°C. There are no measurement use thermocouples whose stability is guaranteed against neutron irradiation and this high temperature, but various types of thermocouples are planned. However, future studies are required on their ability to withstand years of use in a reactor environment. In any event, there should be a system which permits replacement of the thermocouple when long term temperature measurement is desired. In this case, the problem from the standpoint of design of this

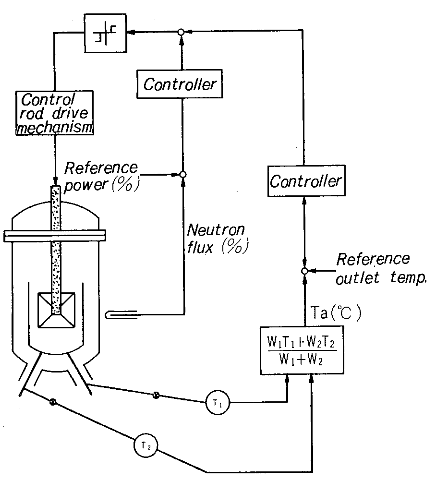


Fig. 12 Reactor outlet temperature control diagram

reactor system that the design of this reactor is down stream and, the mounting position of the measurement thermocouple is at a low part because the high temperature part is at the bottom of the reactor and design is extremely difficult, but not impossible. Both the inside and outside of the core are monitored by neutron instrumentation at the time of starting.

The in-core instrumentation instruments are inserted into the double tube inserted in the in-core relector area by a pulley and raised to the top after measurement. During measurement, the measuring instruments are cooled by circulating helium gas inside the double tube. Because the out-core detectors of the starting system must be extremely sensitive, a B_{10} proportional counter is used.

Other instruments are a burst fuel detection system employing the wire-precipitate method and helium radiation measuring system by detection of its filter part, helium moisture detection system, helium impurity measuring system, secondary system radiation measuring system, and an indoor explosive gas (H_2, CO, etc.) detector which is a feature of this plant.

2. Control

This plant features a reactor outlet gas temperature set at a high 1,000°C and connection of independent loops for several different systems connected to a single reactor. Therefore, the control system

(1) must not disturb the reactor so that large changes do not occur in the outlet gas temperature.

(2) mutual interference between the loops must be as small as possible.

Large changes in the outlet temperature above 1,000°C are especially troublesome. Input which can be considered to disturb the reactor are the external disturbance of flow volume in the reactor, reactor inlet temperature and reactivity. The flow volume which flows in the reactor is inemeasured at each loop inlet and the gas flow to the reactor is made constant by adjusting the flow adjustment valve. With respect to the reactor inlet temperature, the temperature is adjusted without changing the test section flow by adjusting the bypass regulating valve of the regenerating heat exchanger and the regenerating heat exchanger inlet regulating valve at the test loop side and the reactor inlet temperature is made constant by adjusting the bypass regulating valve of the steam generator in the reduction gas production loop.

With respect to the disturbance of reactivity, the temperature of the reactor outlet to each loop is measured, the average outlet temperature is found, and the reactor outlet temperature is made constant by operating the control rods. At this time, output control is incorporated as a stabilizer by means of neutron flux. Reactor outlet temperature control concepts are illustrated in *Fig. 12.*

In order to make control easy, the part to which the fllow regulating valve is to be installed sticks out at the high temperature part. But the high temperature valve is one of the main developement themes of this plant. In the case of this design, a flow regulating mechanism provided for operating mode switching use inside the steam generator is utilized as the bypass regulating valve of the steam generator. This system is also considered to be good even as one high temperature countermeasure.

VII. CONCLUSION

An outline of the features of the results of the preliminary design of the experimental high temperature gas reactor has been given above. Improvements, detailed design, and additional studies based on the preliminary design conducted in 1970 were performed in this preliminary design, which completed the preliminary design stage. Changes may be made in the final design in the future, but the problem points and their countermeasures are now known. At the present time, design studies have been started as the first step toward future developments and a considerable amount of research and development is required in the future.

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