Pilot Plant For MHD Power Generation - Research Programme Of Bharat Heavy Electricals Limited (India)

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PILOT PLANT FOR MHD POWER GENERATION -- RESEARCH PROGRAMME OF BHARAT HEAVY ELECTRICALS LIMITED (INDIA)

(S.SRIDHARAN)

Background of Research Programme in Bharat Heavy Electricals Limited:

For quite sometime, studies on magneto hydro dynamics were being pursued by two organisations - Bharat Heavy Electricals Limited (BHEL) and Bhabha Atomic Research Centre (BARC) in India. The studies so far made by various other countries revealed that it would be possible to achieve an overall energy conversion efficiency of 50% with MHD. The present average level of thermal energy conversion efficiency through steam cycle in India is around 29% on a heat input to electrical output basis. The MHD programme promises a significant energy economy which prompted the Government of India to sponsor a research programme in this regard. The Department of Science and Technology of Government of India, therefore launched a research programme for MHD, to be carried out jointly by Bharat Heavy Electricals Limited and Bhabha Atomic Research Centre to study various aspects of MHD with plasma obtained from coal as fuel. In the initial phase, a clean gas obtained from coke would be burned to produce the plasma.

System description of the Pilot Plant:

The pilot plant system adopted is of open cycle type. The calculations indicate that in order to obtain a reasonably high temperature plasma, it is necessary to have a fuel gas with a calorific value of at least 2000 KCal/Nm^3. The pilot plant being set up at Trichy, India, is therefore equipped with a water gas plant generating fuel gas from coke. The Blue Water Gas Plant consists of 3 gas generators of 7'-4" dia. and 13'-5" height. The gas generators are not water jacketed and hence steam for the shift reaction is obtained from a separate oil fired boiler. The gas generators are provided with rotating water-cooled ash grates for slag evacuation. Each gas generator can deliver 7,50,000 cft. of gas in a day of 18 working hours. The gas generators are provided with washer-scrubber units downstream primarily for removal of dust. The washed gas is taken to a compensating gas holder from which it is taken to a main gas holder of 1,50,000 cft. capacity. This gas holder acts as a buffer for the variation in the gas drawal rates during the experiments. The gas from the gas holder is drawn by 2 reciprocating gas compressors of 1400 Nm^3 per hour capacity. The gas compressors deliver the gas at a delivery pressure of 7 atg. The fuel gas would be having a calorific value of around 3000 Kcal/Nm^3.

The oxidiser for burning the fuel gas is enriched with oxygen obtained from an oxygen plant. The oxygen plant consists of 3 units, each of 140 sm^3 per hour of pure oxygen. The oxygen plant is supported by an oxygen gas holder which can hold oxygen at a pressure of 30 atm for delivering to the oxidiser stream at various pressures and flow conditions.

The plasma temperature obtained from the combustor is enhanced by preheating the oxidiser. The air preheaters are of pebble bed regenerative type capable of preheating the oxidiser to a temperature of 1600 ^oC. The Air Preheaters are of vertical cylinder regenerative type as shown in Figure 3. The Air Preheaters are lined with successive layers of insulating felt, insulating bricks and refractory bricks. The refractory bricks are chosen for withstanding a maximum inside temperature of 2000 ^oC. The entire APH vessel is double-jacketed and is cooled by circulating water. The initial calculations reveal that the cooling water for APH would not be necessary. However, cooling water provision is being made to prevent damage to the vessel due to unforeseen hot spots developing during operation. Three heaters are connected in parallel and work cyclically heating the pebble through fuel gas combustion and cooling the pebble with the oxidiser admitted in the reverse direction.

For cyclic operation of the air heaters, the outlet from the air heaters is provided with special type of shut-off valves. The shut-off valves which will have to intermittently open and close are shown in Fig.2. The shut-off valve is entirely water-cooled. Separate cooling circuits are provided for the valve body, bonnet and the disc. The main disc is further lined with refractory for withstanding temperatures upto 1800 ^oC. In order to restrict the heat losses due to cooling to the minimum, the flow passages are suitably designed to keep the metal temperatures at the optimum level.

The fuel gas and hot oxidiser are brought together in a cylindrical water cooled high velocity combustor. The main combustor is of a disc in duct design. This affords a high degree of flame stability for a very wide turn down ratio. In order to make the combustor compact and at the same time restrict the choice of materials to economical ones, the combustor is allowed to be water-cooled. Since the combustor will be suffering a Hall potential, the combustor will be cooled with low conductivity water similar to the main channel.

Elaborate flow modelling trials were made to determine the length of ducting required downstream of the main burner to ensure uniform mixture of seed material with the product of combustion. It is estimated that with the present design, a downstream length of approximately 1 metre would be quite sufficient to ensure thorough mixing of seed material with the products of combustion. Fig.1 shows the general arrangement of the main combustor.

The combustor is equipped with atomisers through which concentrated solution of potassium carbonate is sprayed as the ioniser or the seed. The products of combustion along with the evaporated seed spray comes out of the combustion chamber at a temperature of 2600 ^{o}C approximately. This high temperature gas is then sent through a specially formed nozzle for increasing the plasma velocity.

The high temperature high velocity plasma then goes through the MHD duct or channel. A specially designed magnet will deliver a maximum magnetic induction of 3 Tesla. The Faraday potential will be collected by water-cooled copper electrodes. The hot gases coming out of the MHD duct will be taken through a seed recovery system which recovers the potassium carbonate for reuse.

The seed recovery system consists of cyclone separators and venturi scrubbers along with a foaming device. The venturi scrubbers collect the seed material in the form of a weak seed solution into the seed system.

In the experiment presently, there will not be a bottoming steam unit and hence the outgoing flue gases will be quenched with spray water before being sent to the seed recovery system. It is expected that the quenching process itself will take out bulk of the seed material in the form of weak seed solution. The quenching is done by specially designed flat spray nozzles which would spray the cooling water as a curtain across the flow of the gases for effective quenching. The calculations indicate that effective cooling of the gases downstream of the channel from 2200 ^{o}C to 300 ^{o}C can be achieved in a flow distance of 3 metres. The cooling system is designed to quench the gases from the maximum possible temperature of 2600 ^{o}C. The hot gases will be sent out through the chimney after cooling it sufficiently.

The first stage experiment would be with a heat input of 5 MW. During the second stage, the high calorific value fuel gas would be generated from a high pressure coal gasifier with a heat input of 15 MW or more to the MHD channel.

Development of Components:

In the system, Bharat Heavy Electricals Limited is entrusted with the responsibility of developing and installing fuel gas generators, oxygen plant, water treatment plant, high temperature regenerative air heaters and valves, the main combustor, the nozzle as well as the seed injection and seed recovery systems.

Bhabha Atomic Research Centre will develop the special magnet, the MHD duct and power tap-off system. The research groups would be closely interacting with the scientists of the High Temperature Science Institute of Moscow, USSR, as per the cooperation agreement reached between the two countries.

Current Status of the Project:

The component designs of the special components (Air Preheaters, High Temperature Valves, high velocity nozzles etc.) have all been completed. The common industrial facilities, like Oxygen Plant, Gas Generator, Air and Gas Compressors, Water Treatment Plant etc. have all been installed and their trial runs completed. Major special components, like Air Preheaters, high velocity combustor etc. have been fabricated and installed at the project site. The special ceramic lining for Air Preheaters, Combustors etc. have been arranged. Trials on the development of high density alumina pebbles have been completed and the Air Preheaters will be charged with the pebbles very shortly. The system safety interlocks have been worked out and being arranged for. In the first stage, the channel will be designed to tap around 90 KW of electricity in the Faraday mode.

Experiment Studies:

A large number of experimental studies have to be undertaken before the adoption of the MHD process for coal-based power generation. The design of the air preheaters, combustors, nozzle and seed system are to be studied extensively before they are declared commercially viable. These equipments are therefore extensively instrumented for study of various parameters during the experimental runs of the pilot plant. As a part of the experimentation programme, the following data will be studied:

Air Preheater

(1) Establishment of satisfactory start up and shut down procedures.

(2) Effect of heating and cooling cycle timings

(3) Range of operation with different heating and cooling rates

(4) Evaluation of high temperature valve performance with different flow rates and refractory lining

(5) Operation of APH under part loads and performance correlation

(6) Evaluation of thermal insulation and pebble material

(7) Study of alternative pebble materials and shapes

Combustors and Nozzles

(1) Testing of various burner configuration and optimization of the design

(2) Testing of various combustors with different lining materials

(3) Seed injection nozzles, spray characterisation, optimisation of the location of injection and type of nozzles.

(4) Velocity profile mapping using LDV system.

(5) Temperature and species concentration mapping (CARS)

(6) Development of pressure pulsation measuring techniques

(7) Vibration characterisation of Combustor-nozzle system

(8) Hall potential distribution measurement

(9) Electric field effects on combustor flames

(10) Correlation of pulsation in combustor to fluctuations in feed line

(11) Operation and testing of combustors over the range of possible parameters.

Heat Recovery System:

(1) Development and optimisation of spray nozzles and spray cooling system

(2) Studies relating to certain aspects of two phase flows

(3) Effect of seed deposit on heat transfer surfaces

Seed Recovery System:

(1) Evaluation of recovery efficiency

(2) Optimization of operating parameters

(3) Long range operation and effect of seed deposit on the plates

Operation of component as part of the complete system:

(1) Operation with optimised conditions of APH

(2) Operations with optimised conditions of combustors

(3) Operation with optimised conditions of Channel

(4) Evaluation of optimised operation for the whole system

Operation of MHD Pilot Plant System covering range of parameters:

(1) Operation with different combustion product mass flow rate

(2) Operation with various air to fuel ratios

(3) Operations with different preheat temperatures

(4) Operations with different oxygen enrichments

The optimised operating sequence of the air heaters and the seed system will also be worked out from the results of the experiments from the pilot plant.

A group of scientists and engineers from Bhabha Atomic Research Centre will be making diagnostic studies of the magnet and the MHD channel.

One of the very important studies required for MHD process concerns high temperature material. High temperature ceramics dealing with pure alumina, magalsia, zirconia and chromates of rare earth material are being pursued as a part of the MHD Research Project.

Experiments are envisaged for the development and synthesis of oxide ceramic materials, such as aluminium oxide, magnesium oxide, stabilised zirconium oxide etc., to suit MHD application. The development of pebbles for air preheater, suitable refractories and insulator ceramics for air preheater, combustor, hot air duct and channel are of prime importance for the successful operation of MHD generator facility. Simulation of behaviour of ceramics under the influence of potassium seeded plasma will be arranged as a part of the material development laboratory. Separate facilities are being arranged for study of semi-hot and hot electrodes. Suitable high temperature electrical conductivity measuring apparatus are being arranged to evaluate contemporary materials, like lanthanum, magnesium chromate, rare earth combinations in metal oxides etc.

The possible application of refractory metals, such as Tungston, Vanadium, Tantalum and Titanium will be investigated by powder metallurgical techniques. The studies will also include development of new alloys with emphasis on dispersion strengthening and fibre reinforced composites. Solid state reaction studies and x-ray analysis will be pursued in the development of new borides carbides, nitrides and silicides of metals.

Conclusion:

The hardwares are being installed in the pilot plant facility at the MHD Complex at Bharat Heavy Electricals Limited, Trichy. Apart from the major breakthrough in energy economy, the spin offs will bring additional benefits to the steel plants, fertilizer plants and other thermal energy-oriented industries.

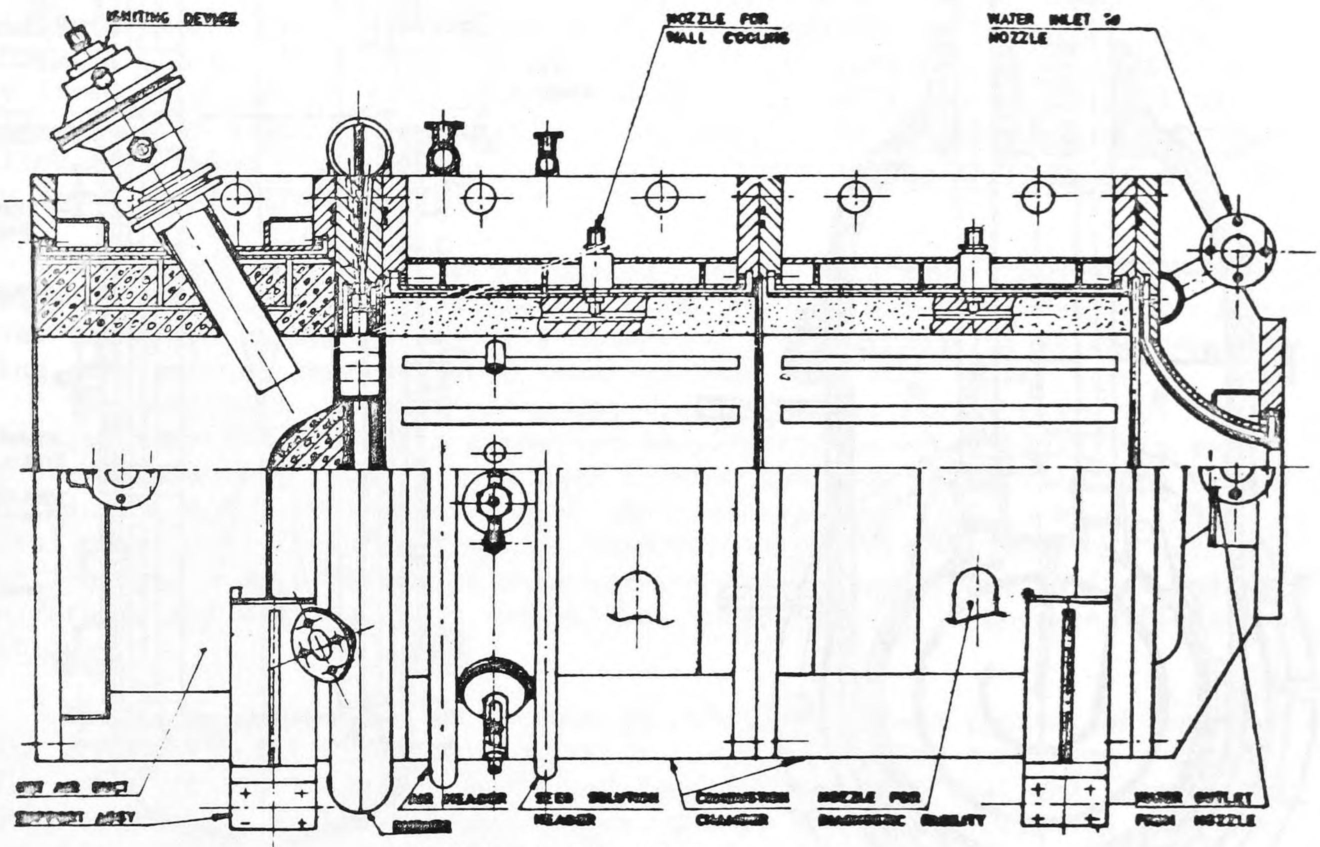
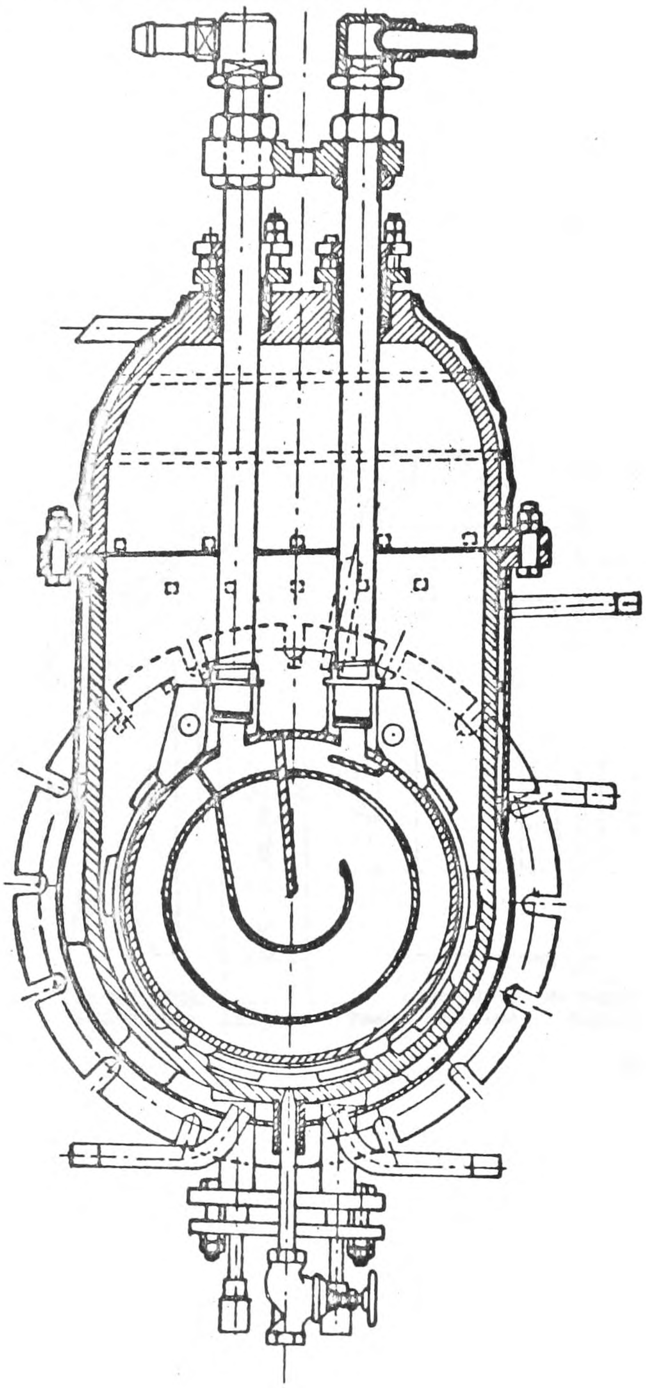


FIG.1 MAIN COMBUSTOR

FIG. 2

HIGH TEMPERATURE VALVE



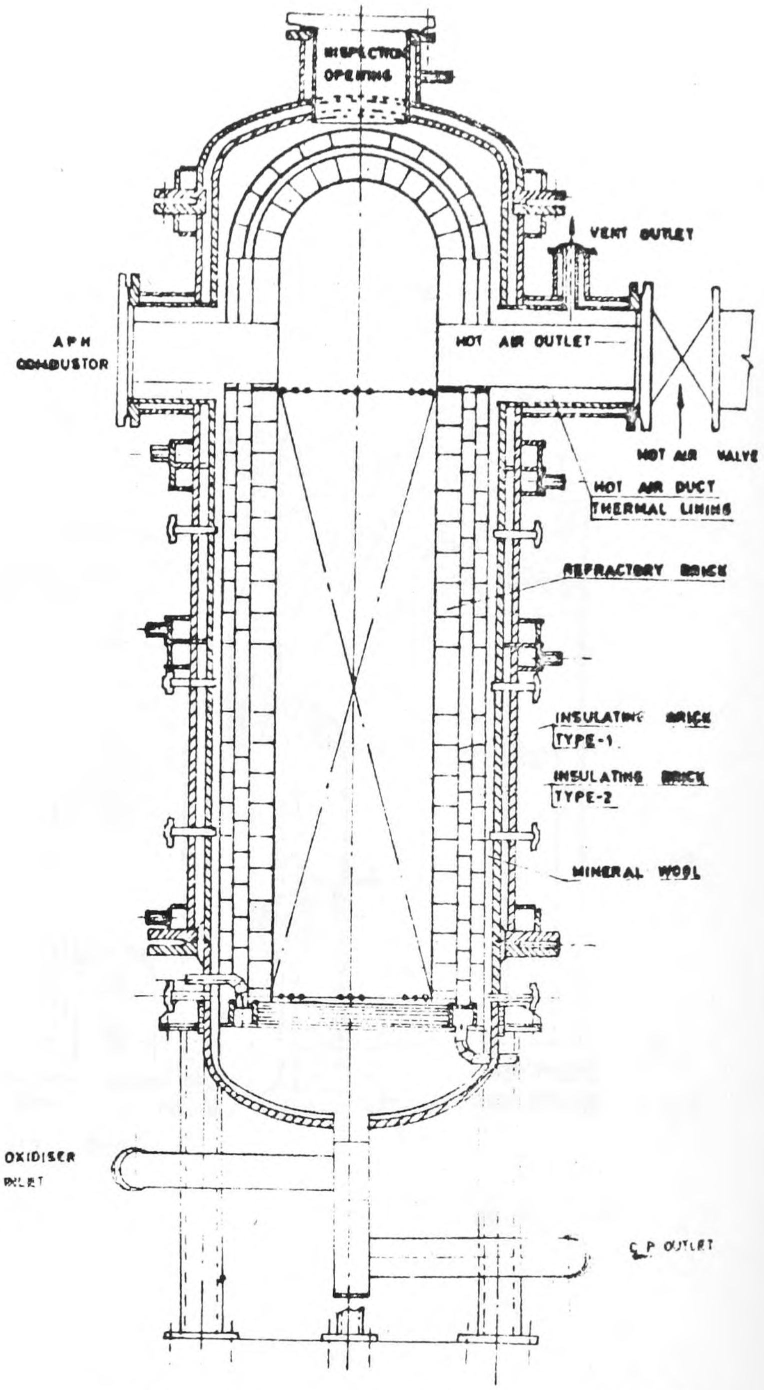


Fig. 3. PILOT PLANT AIRPREHEATER