MHD In The Netherlands

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MHD IN THE NETHERLANDS*)

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The MHD activities in the Netherlands are coordinated in the Netherlands MHD Association (NMA) in which a number of research institutes and industries are involved.

The major MHD activities of the NMA are at present in progress at the Eindhoven University of Technology. For the research work two MHD facilities are available.

1. Shock tube facility (see figure 1)
   - working medium: argon and helium seeded with cesium
   - channel: linear and disk (see figure 2)
   - stagnation pressure: 7-8 bar
   - stagnation temperature: 1600-3500 K
   - test time: 5 ms
   - supersonic flow
   - magnetic field: 4T
   - input power: ~ 5 MWt
   - electrical power generated: 1.4 MWe max. at 3500 K.

2. Blow down facility (see figure 3)
   - working medium: argon seeded with cesium
   - channel: linear
   - stagnation pressure: 7-9 bar
   - stagnation temperature: 1800-2000 K
   - test time: 10 s
   - supersonic flow
   - magnetic field: 5T
   - input power: ~ 5 MWt
   - electrical power generated: 0.735 MWe max. at 1910 K.

The shock tube facility has been in operation since 1969. With this facility high enthalpy extractions, up to 24%, and high electrical power densities, up to 140 MWe/m^3, were demonstrated for noble gas MHD energy conversion. During later phases a proper insight in the conversion process under different generator conditions has been obtained. As one of the major results the existence of streamers and filaments in linear MHD channels has been established. The streamers carry the current and pass through the channel with a velocity roughly equal to the gas velocity. An effective transfer of momentum between streamer and background gas is present. The seed in the current path is almost fully ionized. Impurity levels for CO_2, H_2O (max. 100 ppm) and N_2 (max. 1000 ppm) can be accepted.

The blow down facility has been in full operation in the years 1981 through 1987. During this period it was the largest closed cycle MHD facility in the world. The work has clearly demonstrated that one can start from fossil fuels (propane), can operate a high temperature regenerative heat exchanger to generate hot argon gas of 2000 K with the required low level of impurities, and can generate substantial electrical power (735 kWe). After a number of serious technical problems during the start up phase, the work, which was partly carried out in close cooperation with General Electric and under contract with the US Department of Energy, has led to a proper understanding of the MHD conversion process in linear closed cycle MHD generators. Compare figures 4 and 5. Notwithstanding the high level of electrical power generated (735 kWe in a 12 l channel, max. enthalpy extraction 12.9%), the extrapolation of the obtained results to larger units (200 MWth) yields that the isentropic efficiency will be too low for efficient electrical power generation. In order to improve the conversion efficiency, the concentrated discharge structure has to be affected, e.g. by increasing the local conductivity by a factor 2. Another approach is the Japanese proposal to operate in a homogeneous medium, which according to the Japanese program can be achieved under fully ionized seed conditions.

The work on closed cycle MHD electrical power generation planned and carried out at the EUT has always emphasized that experimental conditions should be at least comparable with conditions for large scale electrical power generation. This holds for the stagnation temperature and pressure, impurity levels, electrical power density, etc. Further boundary layers should not dominate the process. One of the consequences is a magnetic field with a minimum magnetic induction of about 4 T.

The recent MHD activities in the Netherlands were and are now concentrated on the following topics:

1. Contribution to the MHD Faraday Working Group. This group, set up by the European Communities (EC), has prepared a document on the possible role of MHD for coal fired electrical power generation in the EC.

*) Communication prepared with contribution from W.J.M. Balemans, P. Massee, W.F.H. Merck and A. Veefkind.

The NMA has contributed to the work of this group. As a follow up of this study the EC initiated two contracts for further study. One will be carried by ESTS, Hoogovens Group, the largest steel manufacturer in the Netherlands (member of the NMA).
The workplan for this study contract is schematically formulated as follows:
"Cost, performance and lifetime of the mainly ceramic components of an MHD power plant: the direct air preheater and the MHD generator."

The proposed study will include the following aspects:
- "refractory materials with a high chance for successful implementation will be defined from a broad range. A literature study will compare reported results with test results, thermodynamic information and high temperature experience available at Hoogovens IJmuiden."
- "based on the desired capacity a predesign of a high temperature ceramic regenerative heat exchanger will be prepared. The starting points for this design will be the well proven Hoogovens hot blast stoves."
- "a project definition document about a long duration test of a coal-fired state-of-the-art MHD generator in an existing facility will be prepared in order to remove uncertainties concerning lifetime and availability of such a generator design."

The second contract "off-gas clean-up, fly-ash and seed treatment in coal-fired MHD combined cycle power generation" has been granted to Steinmueller, GmbH, FRG.

2. A comparative study is carried out at EUT for different MHD systems, all fueled by coal.
   The objective is to compare:
   - an open cycle linear MHD/steam power plant,
   - an open cycle disk MHD/steam power plant,
   - a closed cycle linear MHD/steam power plant, and
   - a closed cycle disk MHD/steam power plant.

   The final conclusion should include comparison based on efficiency, cost of electricity and environmental effects.

3. Experimental work using the shock tube facility is now carried out with disk MHD channels using helium seeded with cesium as working gas. Diagonally conducting channels are tested in close cooperation with the university in Bologna, Italy. Future work is aimed with combustion gases.

4. Theoretical work on effects of concentrated current layers on the efficiency of MHD generators (open and closed MHD) is in progress. Work is carried out in cooperation with the Institute of High Temperatures (IVTAN) in Moscow, USSR.
   In modelling the observed filament structure, joint work is carried out with the Institute of Electronics of the Bulgarian Academy of Sciences in Sofia.

5. A proposal to convert power of a nuclear fusion reactor of the Tokomak type into electricity was carried out under contract with the EC. In order to determine the feasibility of this concept quasi-one-dimensional calculations of MHD generators working with a Hg-Cs medium have been performed. It has also been studied whether the electron cyclotron radiation emitted by the fusion plasma can be absorbed by the medium in the MHD generator in order to be able to work with enhanced non-equilibrium ionization. It is concluded in the paper that the latter aspect can not be realized in practice. In order to obtain reasonably compact MHD generators the stagnation pressure at the inlet of the generator should be rather low (< 1.8 bar). Under these circumstances, however, the absorption length which is needed to absorb the cyclotron radiation by the generator medium is excessively large. It is also concluded in this paper that the non-equilibrium ionization induced by Joule heating is sufficient to convert 35% of the fusion power into electricity by means of the IN-SITU MHD concept within the space limitations defined by the fusion reactor geometry (see figure 6).

6. A test facility has been built and put into operation to test ceramic materials under dynamic stresses (80 MN/m^2) at high temperatures (1700 K). The program includes mathematical modelling of ceramic components and confront the results of the numerical calculation with the performed tests.

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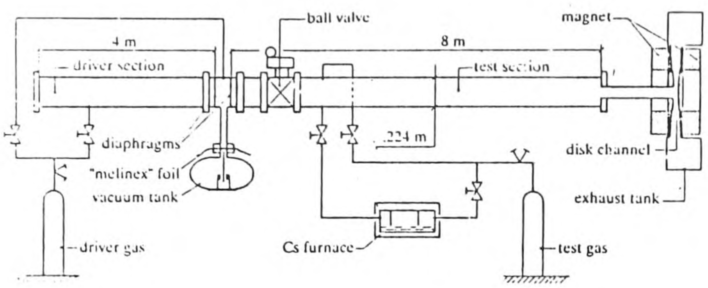

Fig.1. Schematic of the shock tube facility with disk generator.

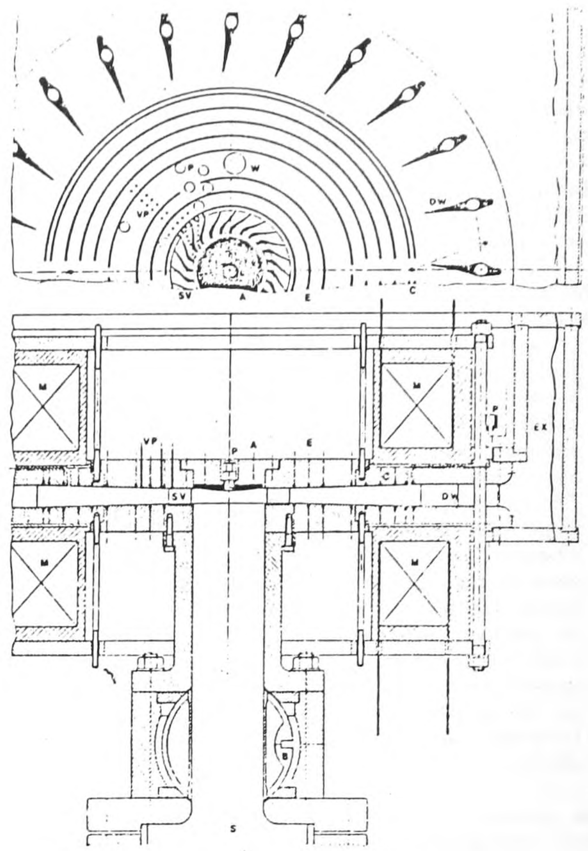

Fig.2. Lay-out of the disk generator with inlet swirl.

A	Anode	E	Electrode	SV	Swirl vane
B	Ball valve	EX	Expansion chamber	VP	Voltage probe
C	Cathode	M	Magnet coil	W	Window
DW	Diffuser wedge	P	Pressure transducer	S	Shock tube

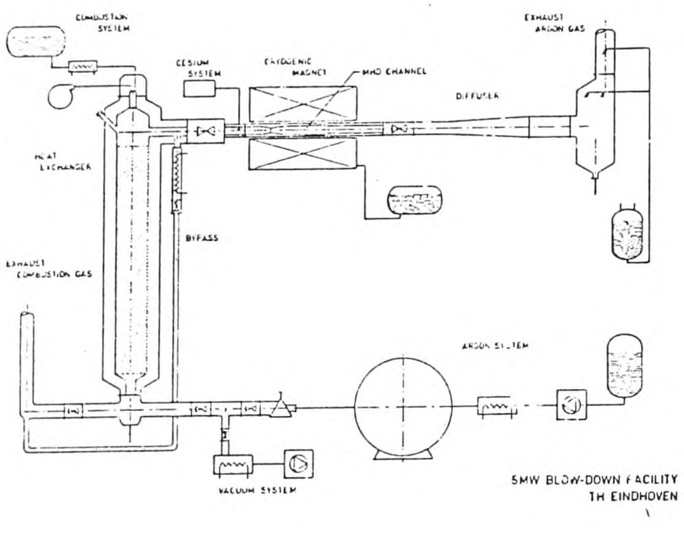

Fig.3. Line diagram of the MHD Blow-down facility.

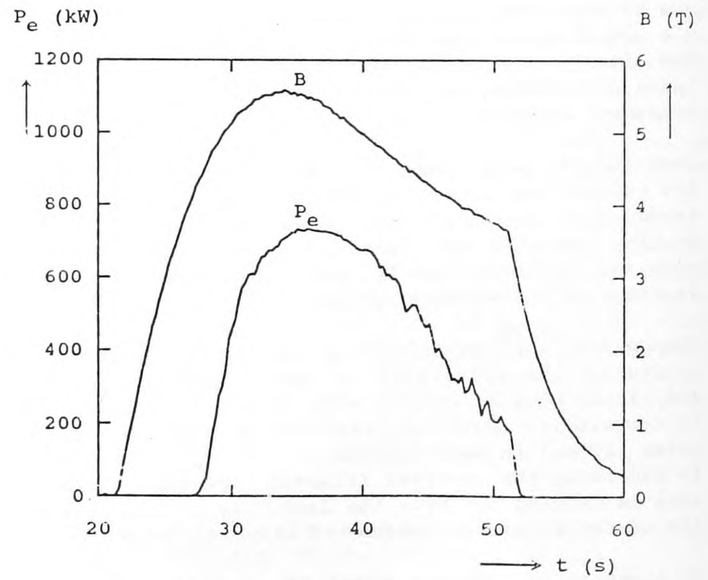

Fig.4. Electrical output (Pe) and magnetic induction (B) during run 808.

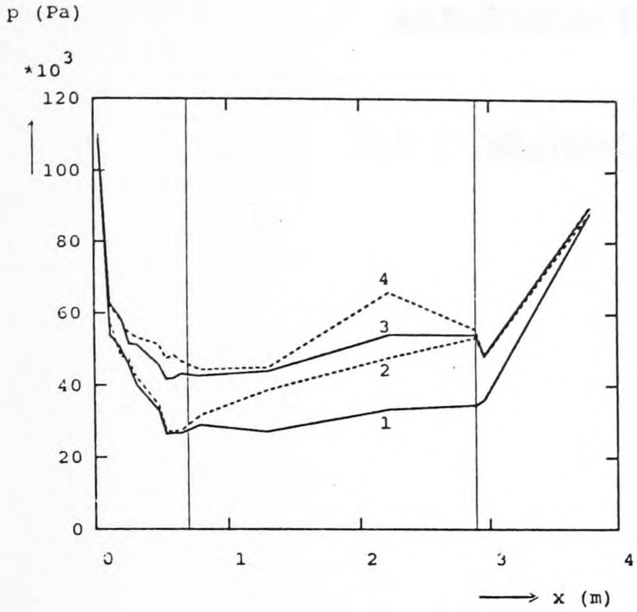

Fig.5. Static pressure (p) as a function of distance in the hot flow train (generator and diffuser).
1: run 802, ηent= 8.4% (B=4.8T, RL=5.4 ohm),
2: run 810, ηent= 9.2% (B=5.4T, RL=7.3 ohm),
3: run 803, ηent=12.9% (B=5.2T, RL=3.6 ohm),
4: run 805, ηent=12.1% (B=5.0T, RL=2.7 ohm).

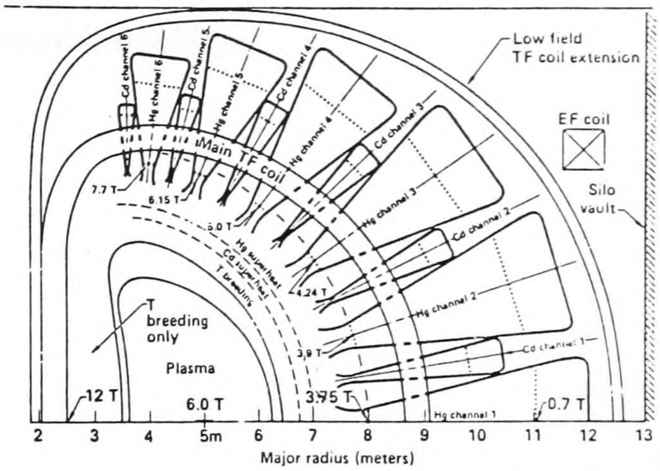

Fig.6. Schematic of the IN-SITU MHD concept; cross section through the plasma torus with MHD generators.