GAS GENERATOR FOR THE STEAM GASIFICATION OF COAL WITH NUCLEAR GENERATED HEAT *

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Summary

The use of heat from a High Temperature Reactor (HTR) for the steam gasification of coal saves coal, which otherwise is burnt to generate the necessary reaction heat. The gas generator for this process, a horizontal pressure vessel, contains a fluidized bed of coal and steam. An "immersion-heater" type of heat exchanger introduces the nuclear generated heat to the process. Some special design problems of this gasifier are presented. Reference is made to the present state of development of the steam gasification process with heat from high temperature reactors.

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1 Introduction

Basis for the process under discussion is the well-known steam-gasification for the production of water gas. In this process coal reacts with steam at high temperatures, normally above 700°C. The gas produced mainly consists of hydrogen, carbonmonoxide and, additionally of noticeable quantities of methane and carbondioxide. Depending on process conditions the proportion of the various gases may vary widely.

After purification of the raw gas there is a wide range of applications. It may be directly used as fuel or as reduction gas. In the first case the combined gas- and steam-turbine process for the generation of electric power should be referred to.

When CO is partly or totally converted to CH_4 synthetic gas is obtained, which may be processed to ammonia, methanol, gasoline or other chemical raw materials. Catalytic methanization of CO and H2 produces a high Btu gas if the reaction is only partially performed or substitute natural gas (SNG) if the methanization is complete.

For the production of SNG a combination of steam gasification and hydrogasification is particularly advantageous. The gasification of coal with steam is endothermic. In all traditional processes of steam gasification coal serves a dual purpose. On the one hand it is the base material for the gas to be generated, on the other hand it has to supply the energy required for reaction heat and cover the heat demand in other areas of the plant.

The special feature of the process to be discussed is the allothermic supply of the reaction heat. This heat is to be generated by a high temperature nuclear reactor. (1), (2), (3), (4).

The coal otherwise used for heat generation can thus be conserved.

The gasifier for this process shall be described briefly and its functions shall be explained in the following sections.

2 Description and Function of the Gasifier

In principle the gasifier is a horizontal pressure vessel (fig. 1).

This arrangement allows for an unidirectional extended fluidized bed. The coal is fed to one end of the bed and is flowing slowly along the longitudinal axis of the vessel while fluidized by the process steam. At the other end the residual ash is drawn off.

This design of the fluidized bed together with the shape and arrangement of the heat exchanging elements allows for a uniform "plug-type" flow of the coal. Backmixing is restricted and kept at a minimum. This, of course, is of great importance as far as the full utilization of the feedstock is concerned.

2.1 Pressure Shell

The reaction room with its service conditions - pressure 40 bar and temperature up to 900°C - is enclosed by the outer pressure shell. For economic reasons and to make fabrication possible within the available production facilities the shell is lined with a thermic insulation.

Thus the operating temperature of the pressure shell is kept low (fig. 1 and 2)

The pressure vessel consists of single, identical units. This way an economic transportation of the vessel is guaranteed and by varying the number of modules the size of the gasifier may be changed. Therefore it can be adapted to different requirements of capacity or process needs which may for instance originate from different qualities of feedstock. Further, this arrangement allows for an easy maintenance or repair of the plant. Spare modules can be kept in stock and be exchanged rather quickly. Thus the down-time of the plant for maintenance operations can be kept at a low rate.

2.2 Steam Distributor

The process steam, which is utilized for the fluidizing of the coal as well is fed to the vessel through a nozzle at the bottom of each module. The steam pressure system inside the vessel is designed as a pipe coil. Each of these distributor pipes bears the steam orifices in a well defined grid.

2.3 Heat Exchanging Unit

The reaction heat is introduced to the fluidized bed allothermically. To achieve this in reality the heating elements are hanging from the top into the fluidized bed like an immersion-heater.

The heating system consists of a tube coil. Through the heating tubes flows the heat bearing fluid. In our case we use helium which has been heated to a temperature of 900°C by heat from a high temperature nuclear reactor.

As the reaction temperature is not far below the temperature of the helium the mean temperature difference is rather low. Here the high heat transfer rates of fluidized beds are of great advantage.

On the other hand the great volume of heating gas requires a multiple subdivision of the exchanger tube bundle into several units with parallel flow. These units are required to achieve uniform pressure drop values between each unit as well as between each single tube to provide for an equal flow rate and a uniform heat supply for the chemical reaction.

Fig. 4 shows an example of the arrangement of the tube coils in a gasifier cross section. Even with two tube banks connected to each header - except for the outermost ones - quite a number of headers are required. In the example shown there are nine such collectors.

Supply and drain of the helium require large nozzle sizes in the pressure vessel shell. These nozzles have to be of "Thermal-Sleeve" type due to the temperature difference between helium and vessel shell. (fig. 5). So it is not possible to provide individual connecting lines from each header to a system outside the gasifier. It was therefore necessary to provide a helium-distributor system within the pressure vessel (fig. 6 and 7).
Here, the He-distributors are in the shape of spherical collectors. The connecting lines flow into the center of each of the header tubes.

This means a diminishing of the helium speed in the headers. The wall thickness of the helium distributors could be kept low using a spherical shape. As we have learned in our discussions with several manufacturers, it is absolutely possible to manufacture the single parts of these spheres. Thus, the number of helium nozzles could

could be reduced in each module to one inlet- and one outlet nozzle. The header system could be arranged symmetrically to the transverse axis of the vessel. This is of particular importance when considering thermal expansion.

As to the dimensions and temperatures in question the thermal expansion is within the range of some centimeters, with the present solution up to approx. 75 mm. This expansion by far exceeds the elastic limit of the components. Furthermore .in the upper part of the gasifier the largest possible space is left for the disengagement of the raw gas. Finally, this solution offers the best space conditions for the erection and assembly of shell and piping system.

2.4 Suspension of Heat Exchanging Units

The single heating pipe coils are being welded each with one end directly to the inlet- resp. outlet header. In order to take the weight of the coils without any additional stresses the pipes are guided vertically to the headers.

In view of the fact that the headers carry the total weight of the pipe units, the reliability of the supporting of these hangers is of the utmost importance. Out of the various possibilities of suspension resp. supporting the obviously most stable and most simple one was chosen. The headers were placed on two transversely positioned and continuous girders. These girders are designed as box-type beams with internal cooling and an outside thermal insulation. They are arranged in such a way that the bending moments in the headers are minimized.

A system has been developed in which the cooling medium (hot water) is fed to the girder by one suspension tube and discharged by the other one. This results in an efficient circulation-system (fig. 8). By baffles resp. displacement bodies in the box type girders a sufficiently high water velocity will be achieved to assure safe outlet of the heat which is penetrating the insulation. Thus the girder walls are kept cool.

2.5 Support of the Hangers at the Generator Shell

It is an essential function of the supporting system to take up the total weight of the heat exchanger including headers and feeder lines which move up and down approx. 60 mm due to thermal expansion.

For the transmission of forces between hanger and shell a system had to be developed allowing for a movement of 60 mm in the direction of the forces under full load without creating additional forces. In addition, the supply of the cooling medium to the hanger has to be maintained. Fig. 9 shows a possible design of such a system. The gas-tight connection between the hanger and the generator shell is achieved by inserting an expansion joint. The load is carried by a hinged link to a vertical operating hydraulic cylinder.

During operation of the gasifier the hydraulic cylinder has to be kept under constant internal pressure corresponding to the weight, and the suspension is capable of following the thermal motions without any additional force being introduced.

3 Present State of Development

In the preceding paragraph the gasifier for a large-scale plant was described and some design problems were demonstrated. Finally, it shall be mentioned that Bergbau-forschung GmbH following laboratory research and low-scale testing in 1976 put a semi-technical plant for steam-gasification of coal into operation.

The reaction room of the gas generator of this plant is identical to a section of the full scale gasifier described above (fig. 10).

In a number of trial runs the technical feasibility of this process could be proved.

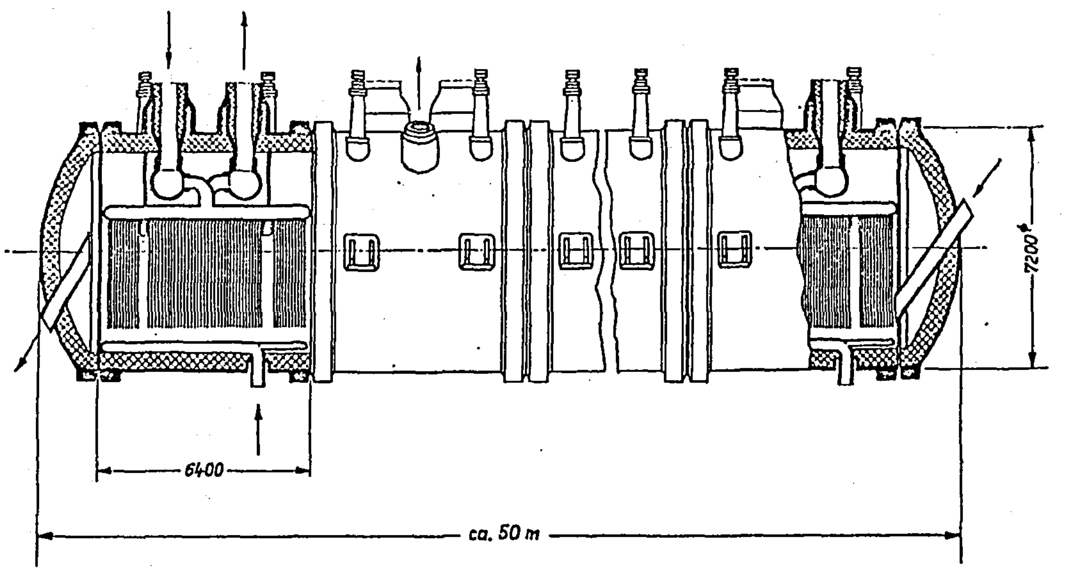
4 Literature:

(1) H. Juentgen, K. H. van Heek: Gasification of coal with steam using heat from htr's. Nucl. eng. design 34 (1975) 59.

(2) P. P. Feistel, R. Duerrfeld, K.H. van Heek, H. Juentgen: Layout of an internally heated gas generator of the steam gasification of coal. Nucl. eng. design 34 (1975) 147.

(3) H. Juentgen, K. H. van Heek: A technical scale gas generator for steam gasification of coal using nuclear heat. Nuclear technology 35 (1977) 581.

(4) P. G. Kalwa, A. Gala, K. H. van Heek, W. Wanzl: Alloys for the transfer of htr-heat into fluidized coal beds, Europ. Nucl. Conf. Paris 1975.



Gas Generator
for the Steam Gasification of Coal

Fig. 1

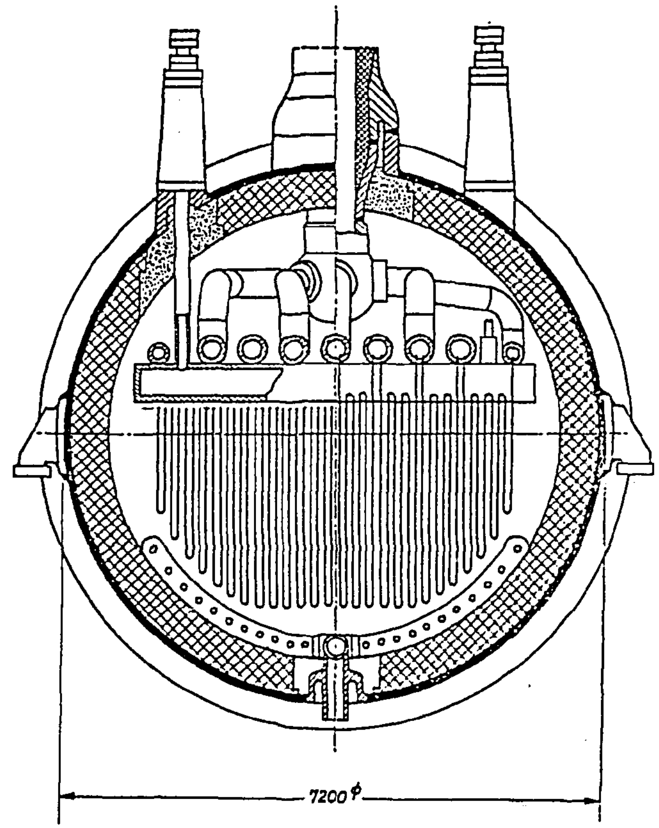


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Fig. 2

Anströmboden

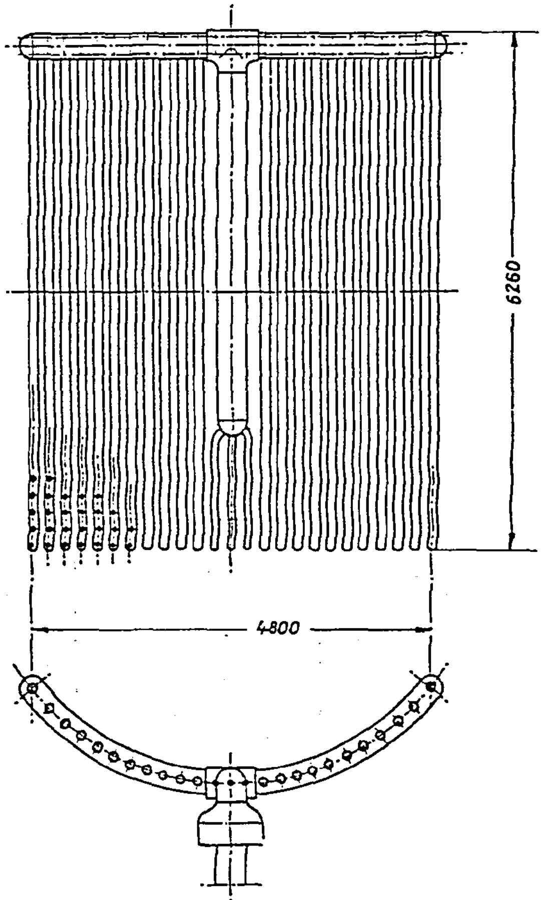

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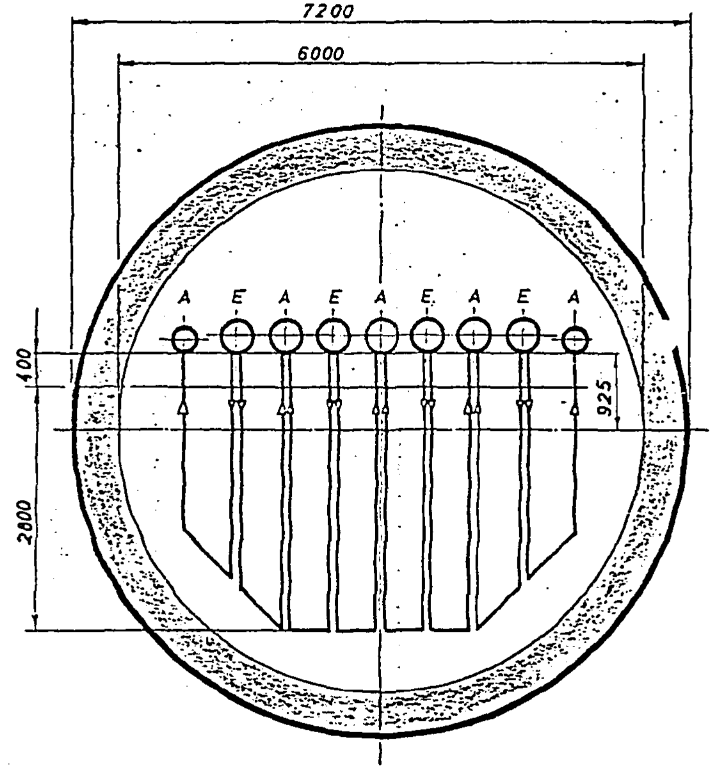
Fig. 3

Sammleranordnung



Heliumfließrichtung : E = He - Eintritt in das Bündel
A = He - Austritt aus dem Bündel

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Fig. 4

Heliumstutzen: Ein- und Austritt

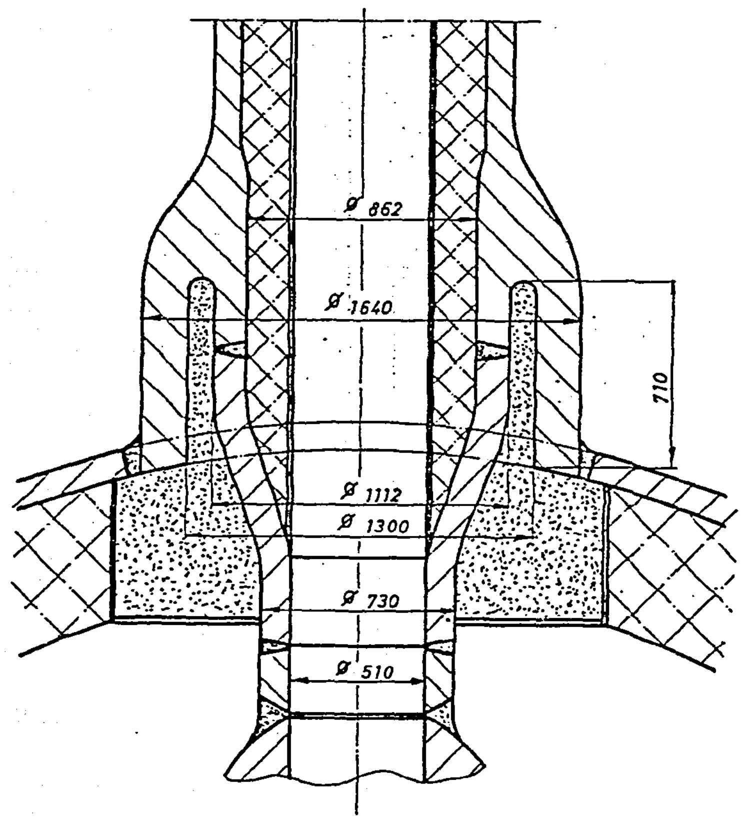

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Fig. 5

Heliumkreislauf

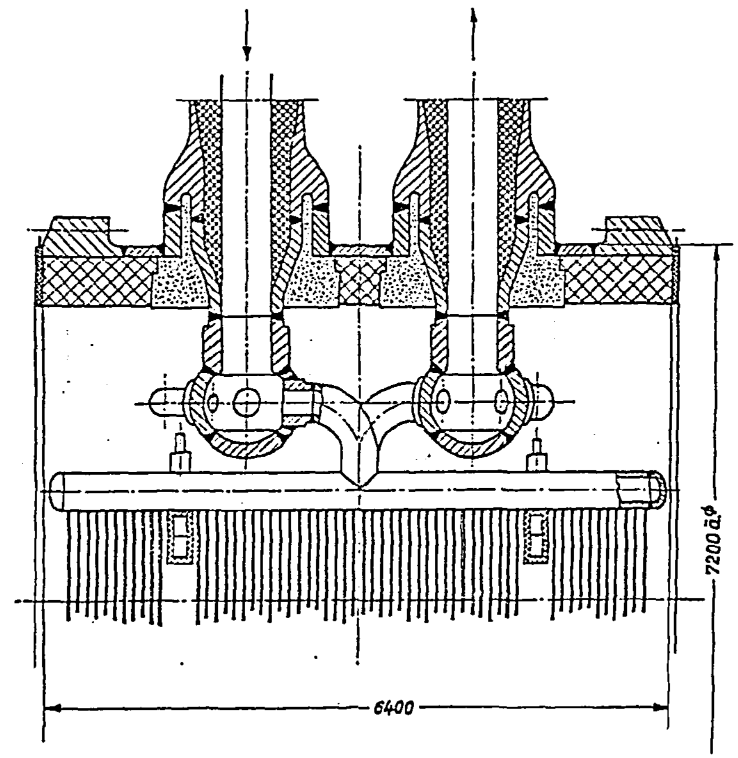

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Fig. 6

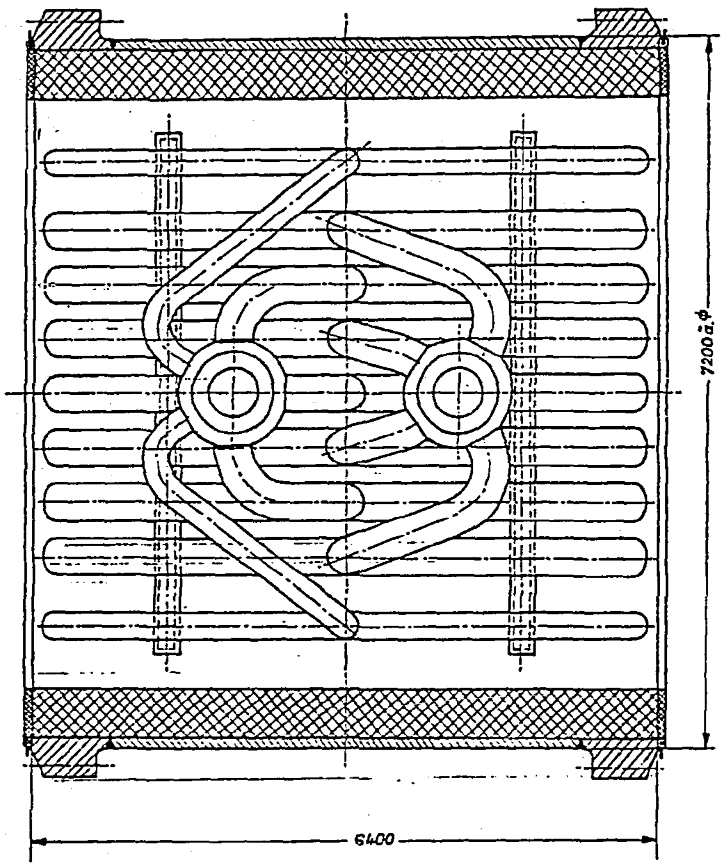

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Fig. 7

Unterstützung des Sammlersystems

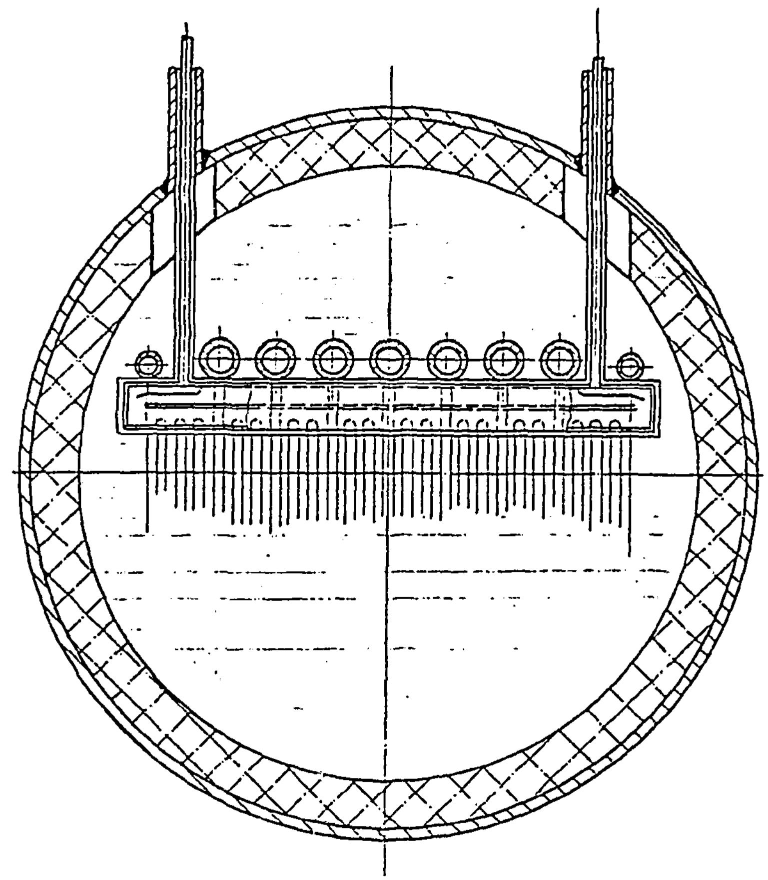

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Fig. 8

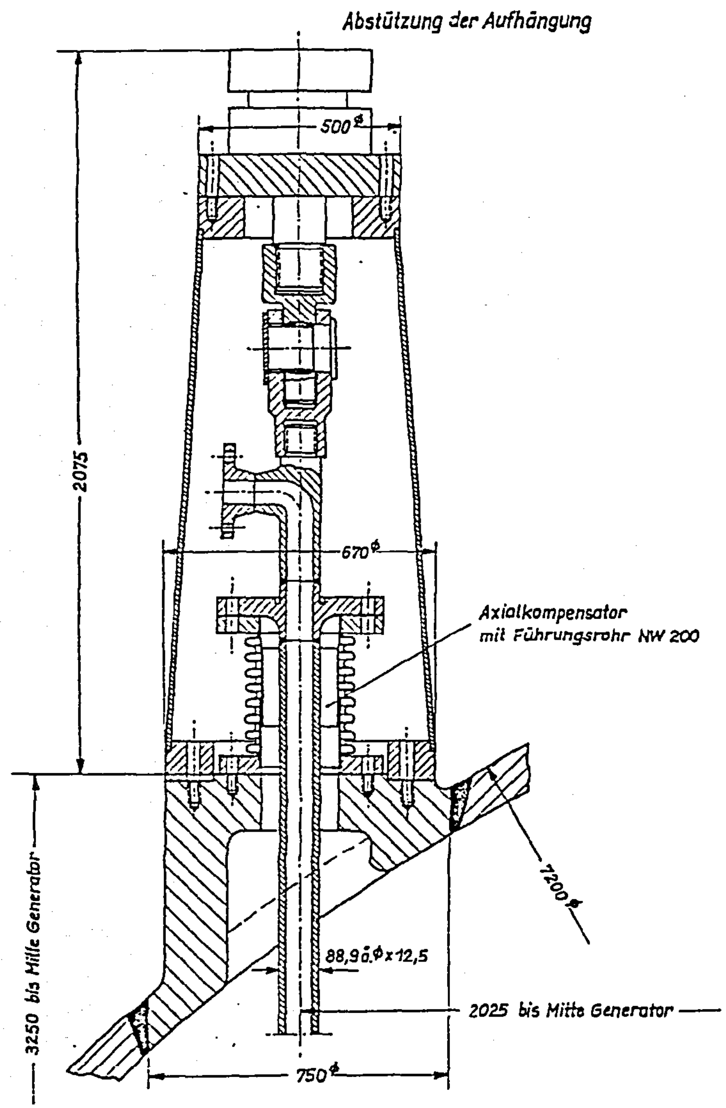

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Fig. 9

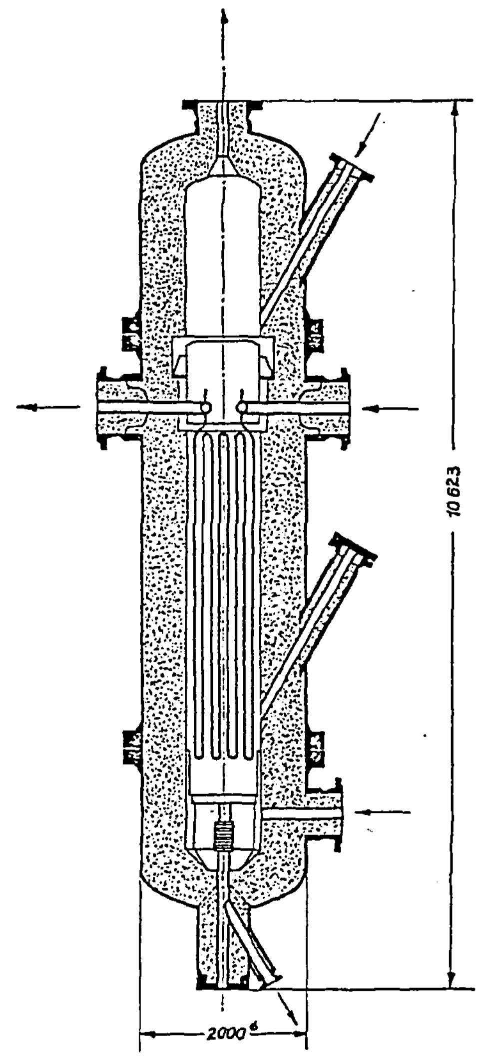

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Fig. 10