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COMBINED CYCLE COAL UTILIZATION FOR POWER AND CHEMICALS

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Combined Cycle Coal Utilization for Power and Chemicals

Executive Summary

The aim of the project is to join efforts of the scientists from Israel and Kazakhstan in developing and testing some subsystems of a novel cycle of coal utilization, mostly for energy applications.

Detailed goals of the research in the first year are: a) fabrication and preparation of experimental facilities for generation of gas and liquid fuel from raw coal (prepyrolysis), b) preparation of an experimental facility including a gas turbine, a coal combustor and ash separators, c) equipping the facilities with measuring and controlling instrumentation, and d) conducting first experiments on the facilities.

During the reported period all the goals were achieved, however some changes in location of the activity were made. Namely, it was decided to erect a more complicated facility for prepyrolysis in Kazakhstan, which will include additional rigs for oil condensation and separation of solid fractions of the coal. It was also decided to perform first experiments on a model of the pyrolyzer that was erected in Israel, with the participation of Dr. M. Buchman from Kazkhstan.

The first series of experiments were performed on the pyrolyzer model to determine its flow characteristics. The results confirmed the feasibility of the suggested scheme, and indicated a number of changes which were found to be necessary in the apparatus, especially in the coarse coal powder recirculation system. All the changes as well as detailed drafts of the gasificator and ash separator were transferred to the Kazakh Institute of Energetics. The prepyrolysis conceptual scheme developed by the Technion team was transferred to the Kazakh team by Dr. Goldman, when he visited Russia and met with Dr. Buchman.

The experimental coal pyrolysis technological project was developed in Kazakhstan and the majority of the equipment, materials and supplies was purchased.

Section I

A. Research Objectives

Future energy needs of both our countries require development of more ecologically acceptable and more efficient forms of coal technology then is presently being used in conventional coal-fired power plants. The overall aim of the research program is to study and develop an integrated system comprising essentially four elements: prepyrolysis of coal; special pulverized char combustion; ash filtering and special gas turbine surface treatment and cooling. All these elements are already in some stage of development at various laboratories of the Technion.

The goals of the research are: a) determination of the effect of prepyrolysis conditions on the quantity and quality of the liquid and gaseous fuel yields, b) study of pulverized char burning process, c) development and study of ash separation systems for interface between the combustor and gas turbine, including self-regulated deposition and scrubbing processes at the turbine blades.

The cycle differs fundamentally from known coal utilization cycles by including:

a) A coal prepyrolysis low pressure scheme, representing a source of char for a turbine combustor (as well as gas and liquid-raw material to chemical industry), and a sink for hot residual coal and ash leaving the combustor.

b) A partial combustion of most reactive and available components of coal (about 70%) in the high pressure aerodynamically stabilized combustor.

c) High temperature char combustion followed by the addition of air to the hot combustion products to control the temperature below sticking ash at the separation stage, and following that gaseous fuel addition at the gas turbine inlet to raise the temperature up to a modern turbine operational level.

d) Formation of an active protective layer on the gas turbine blades, allowing use of more concentrated (above 10 PPM ash) and higher temperature aerosols.

B. Research Accomplishments

Study of coal mild gasification process (prepyrolysis) was performed in the Technion on an experimental facility, which is shown in Fig. 1. Dr. M Buchman from Kazakh Inst. of Energetics took an active part in preparation of the facility and in performing the first cold tests on it.

The experimental system includes a 800 mm diameter pyrolyzer of 1500 mm height. It is designed for about 100 kg/h raw coal pyrolyzation and provided with a combustor for hot tests (planned for the next year). Supplying systems include two air fans and a coal feeder. Pyrolyzed coal capturing and an exhaust gas cleaning system is based on a bag filtering method. Pressure, velocity, coal recirculation rate, air and gas consumption gages are included in the measurement system. A separate experimental rig was used for determination of the gas flow resistance values within a compact bed of coarse coal sand. These data are important for future design of the double chamber coal gasification apparatus particularly for its sand seal systems.

Cold tests of the pyrolyzer were started in March and completed in October 2, 1996. The influence of the bottom pressure on the penetrating air flow rate is presented in Fig. 2. It was studied in the flow range, where no fluidization exists within the recirculating bed of the coarse coal. The pressure rise at the bottom of the apparatus resulted in a relatively fast air flow rate increase for pressure up to ~ 160 mm.w.g. and in a slowing of the flow increase for the higher bottom pressure in the recirculating bed.

The same pressure rise resulted in transferring the regime within the inner chamber from a compact bed to a fluidizing bed. The fluidization starts at about a pressure of 160 mm.w.g., which corresponds to the superficial air velocity of 10 cm/sec. Intensive fluidization begins at

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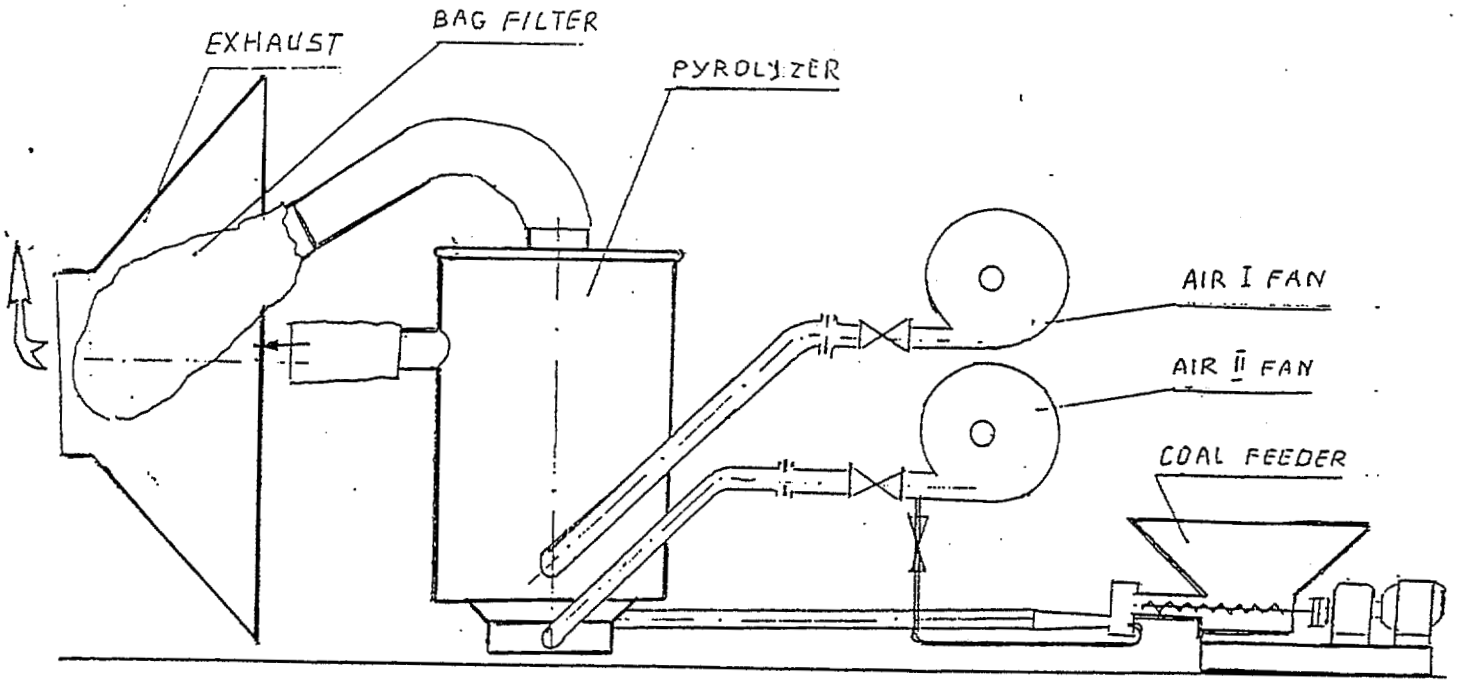

Fig. 1. Experimental facility for prepyrolysis - Technion.

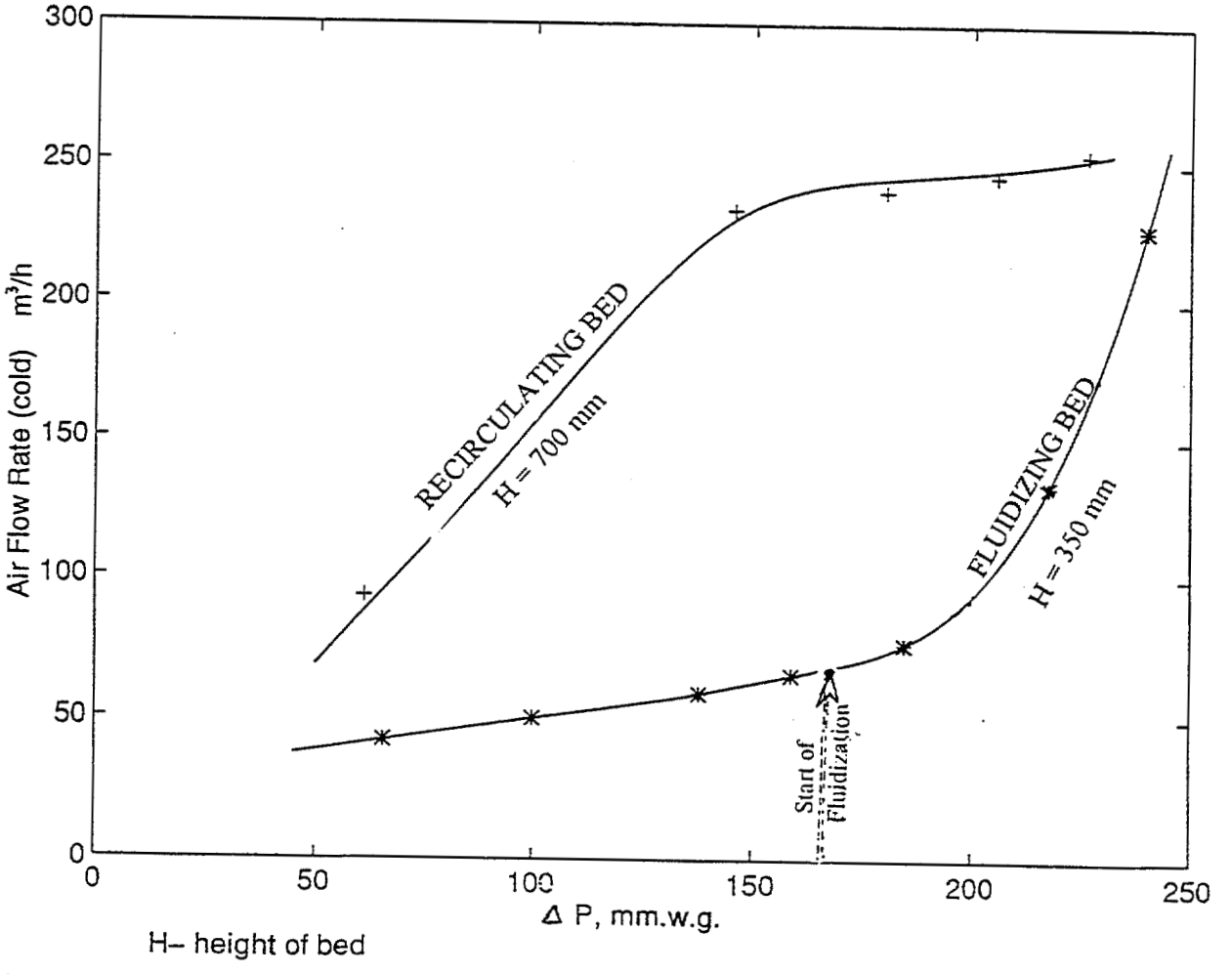

Fig. 2. Influence of bottom pressure on flow rate.

higher superficial velocities and it is characterized by the appearance of two zones in the fluidized bed. A lower zone of about 300 mm height above a flow distributing grate with a dense fluidizing matter, and a "splash" zone of about 500 mm height with matter spouting up.

It was found, that the intensity of the process in the splash zone strongly influences a mass transfer from the inner to the outer chamber of the pyrolyzer. The mass transfer process represents a link in successive processes of the coarse coal circulation. It includes an upper sand seal penetration, a downward movement of the bed in the outer chamber and a bottom sand seal transport back to the inner chamber. A parametric study on the influence of the separate and the overall effects was accomplished this year.

A packed coal bed resistance to a penetrating air flow is presented in Fig. 3. It indicates a linear type dependence between the pressure gradient, dp/dx, and superficial velocity. Sufficient difference exists between the resistance to upward and downward flow. The last is about 3.6 times higher for the same flow rate, compared to upward air movement. This phenomenon is explained by creation of local fluidization of a fine component of the coal, located between the coarse coal particles. In our case the coal comprised 18% of particles less than 0.5 mm diameter (80% between 0.5 and 1.5 mm). By removing the fine matter it was possible to obtain a narrow size particles bed with the same resistance to downward and upward flows, as in curve 1 of the graph. The results were used for improving the sand seals configuration, see Fig. 4, and choosing a preferable gas flow direction there.

Influence of the lower seal area and the superficial velocity on a rate of the coarse coal recirculation is shown in Figs. 5 and 6. The results show a relatively small area of fast recirculation. It is located at the seal to bed. ratio bigger than 4, and at the superficial velocity between 30 cm/sec and 50 cm/sec. A reason for this is formation of coal sand bridges at the seal and destroying them by an intensive fluidization of the coal at the inner chamber wall.

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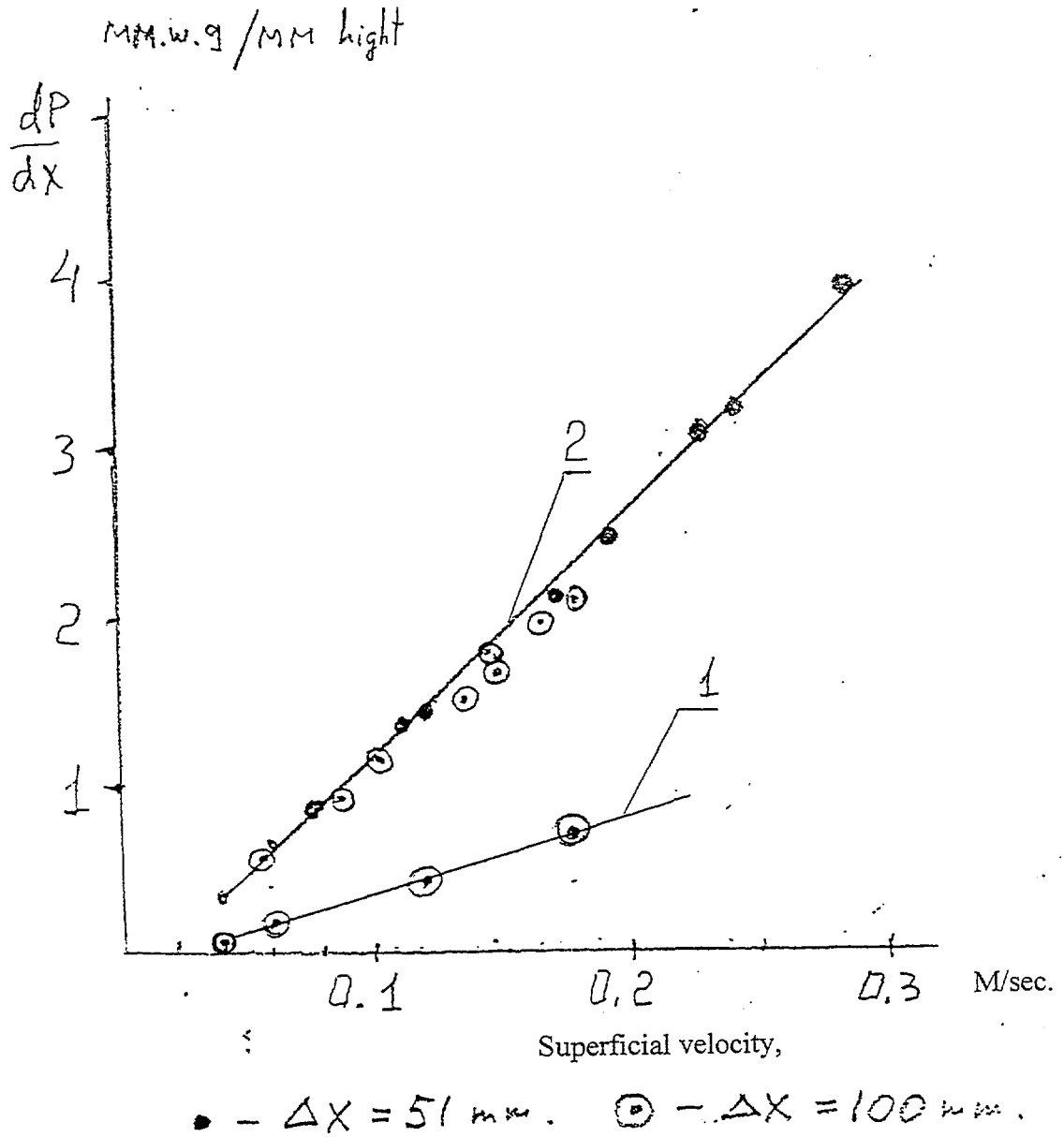
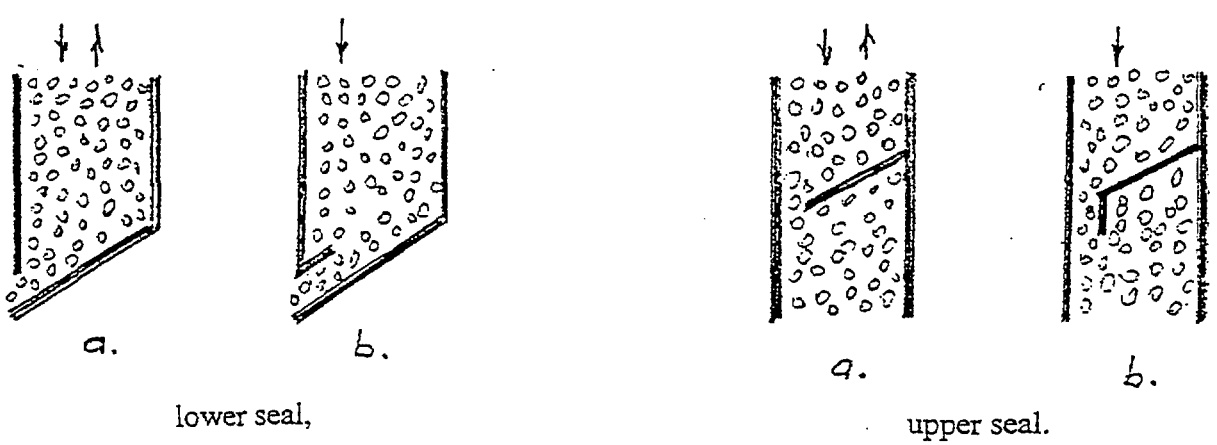


Fig. 3. Packed coal bed resistance.

1-upward flow. 2-downward flow.



lower seal, upper seal.

Fig. 4. Sand seals. a. first version, b. improved version

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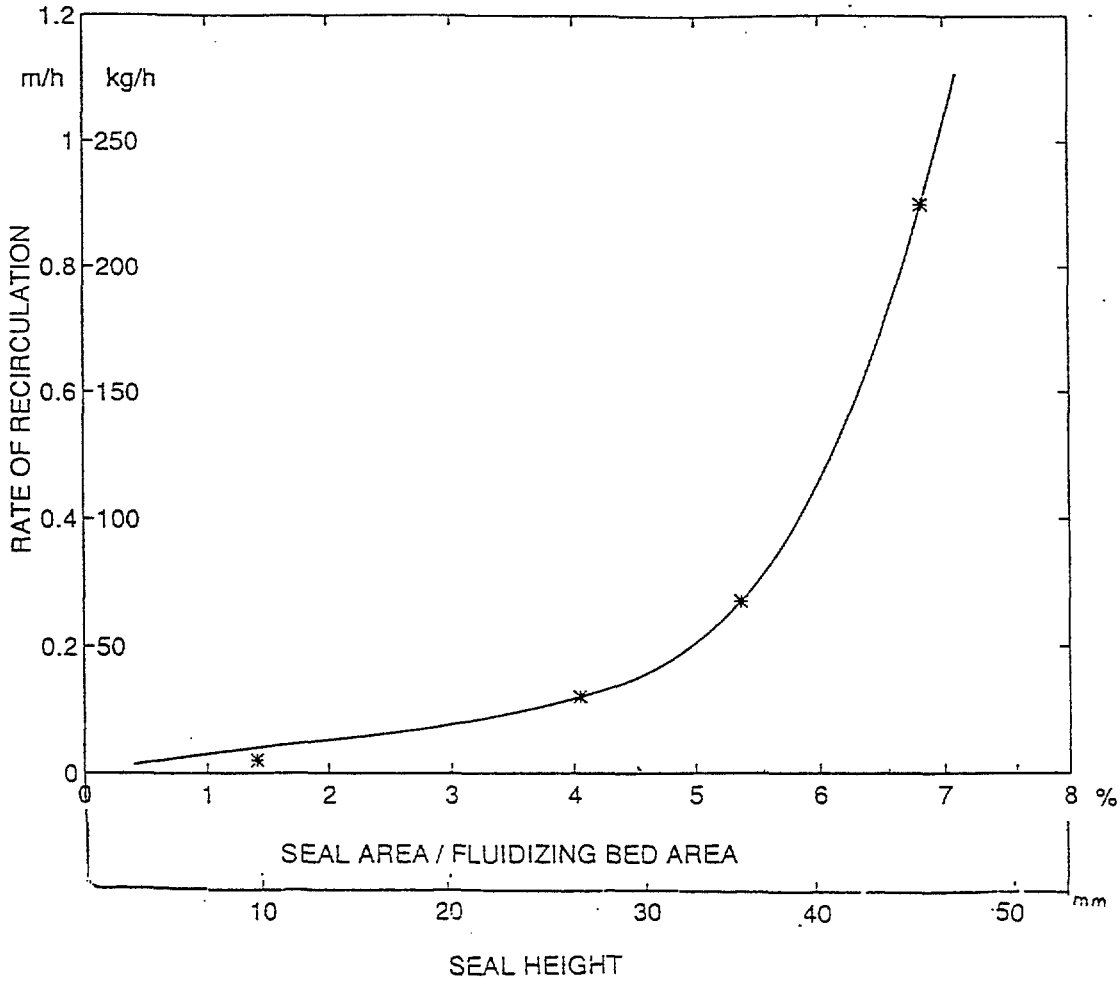

Fig. 5. Seal cross-section area influence.

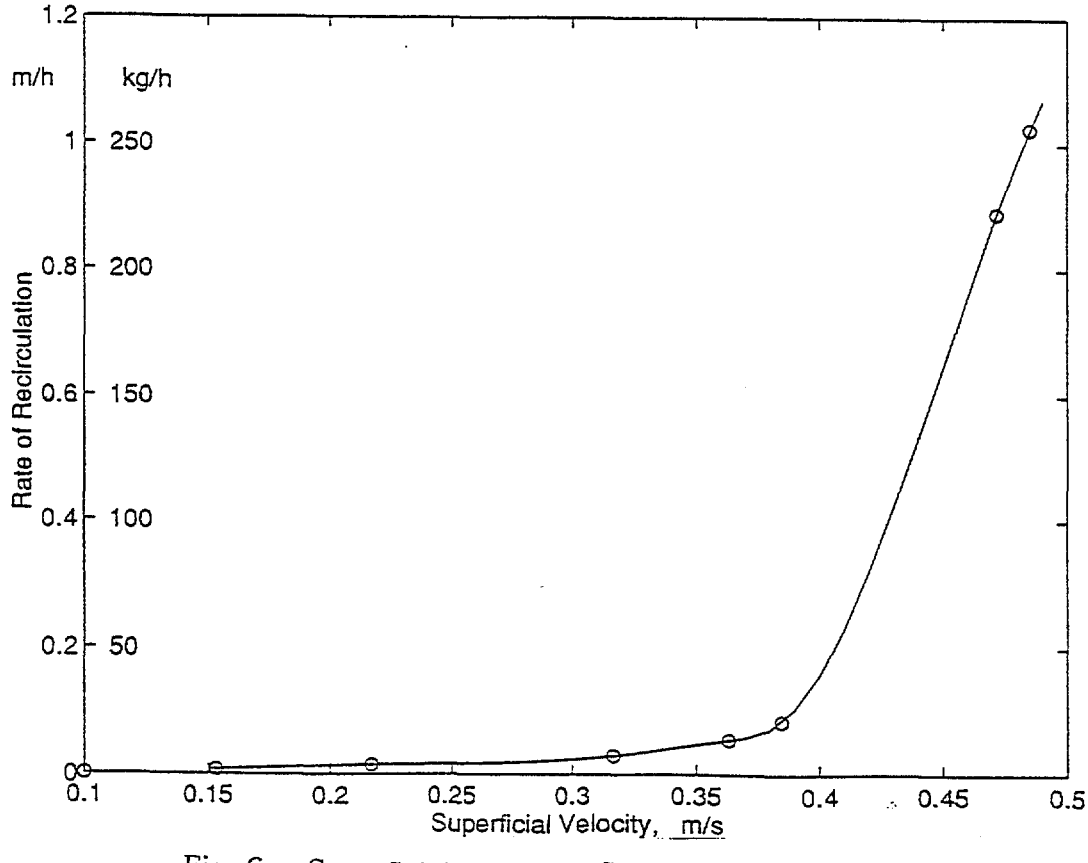

Fig. 6. Superficial velocity influence.

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The results confirmed the feasibility of the suggested scheme of mild gasification of coal, and indicated a number of changes in the apparatus which were found to be necessary in the facility under construction in Kazakhstan.

C. Scientific Impact of Collaboration

Regular contact between the Kazah and Israeli teams is maintained by phone, facsimile and mail. All the changes as well as detailed drafts of the mild gasificator and ash separator were transferred to the Kazakh Institute of Energetics. The prepyrolysis conceptual scheme was developed and transferred to the Kazakh team.

Dr. Buchman visited the Technion in the period from February 11, 1996 to March 10, 1996. He participated in final assembly of the experimental rig (Fig. 1) and in performing the first of the cold experiments on it. He discussed with the Israeli team main subjects of cooperation in the framework of the USAID grant.

A discussion on preparation of the experimental facilities, on results of cold tests of the pyrolyzer in the Technion (coal combustion in a gas turbine, ash separation) and on the developmental work in the Kazkh Institute of Energetics (mild gasification and condensation of liquid chemicals from coal) took place in Moscow (Russia) on 15-16 September, 1996. Dr. Y. Goldman attended the meeting with scientists of the former Soviet Union (supported by the Technion) and Dr. M. Buchman came to report on the Kazakh team's activity in the framework of the cooperative project. He delivered a final concept of the mild gasification scheme (see Fig. 7) and explained the detailed characteristics of the facility, under erection.

D. Description of Project Impact

Two Israeli companies: 1-EHUD-Energy and Engineering Co. Ltd.; 2-Israel Electric Co. Ltd., and a foreign company: ABB Carbon, AB c-01282 Pludbang, Sweden, have discussed the project's possible impact. The demonstration facility in Kazakhstan can promote the technologies industrial applications.

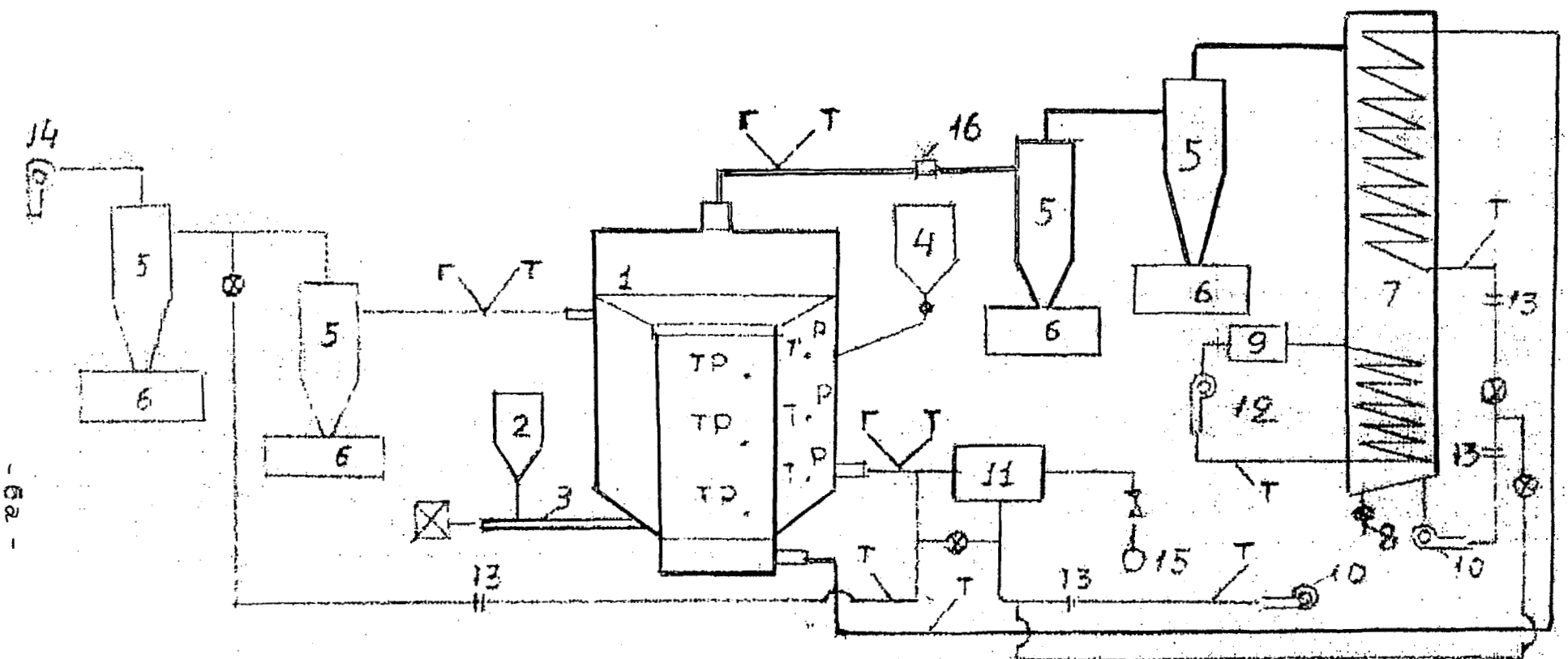

Fig. 7. Experimental facility schematic-Kazakhstan.

1-Pyrolyzer, 2-funnel of pulverized coal, 3-screw feeder, 4-funnel of coarse coal, 5-cyclone, 6-char accumulator, 7-condenser of tar, 8-tar outlet, 9-cooler, 10-blower, 11-combustion chamber, 12-water pump, 13-flow meter, 14-exhauster, 15-gas supply, 16-explosion safety device.

E. Strengthening of Development Country Institutions

The majority of the financial support for Kazakhstan is directed to purchasing new equipment for the experimental facility and for participation of the Kazakh scientists in experimental work at the Technion Combustion Laboratory.

The facility, which will be erected in the Kazakh Institute of Energetics is developed on the basis of available resources and subsystems. The facility's structural components and arrangement were coordinated with the Israel team data. The unit includes a gasificator, a fine coal storage, a feeder, a char separator, an oil condenser, hot and cold fans, a combustion chamber and a measurement and control system.

Measurements of the gas volatiles and the liquid oil concentration and yield as well as temperature and pressure are planned. Two pressure release valves for safety reasons are included in the scheme.

F. Future Work: The project is on schedule.

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Section II

A. Managerial Issues

The project in Israel is proceeding as scheduled. No changes in the management of the work in the Technion were raised.

In the project management in Kazakhstan some changes were made. As a result of difficulties in controlling the funds, it was decided to ask the USAID authority to transfer the equipment and material expenses directly to the equipment source. Namely, the Experimental Mechanical Workshop of Kazakh Inst. of Energetics. For the same reason the travel expenses of the Kazakh team are paid directly at the Technion.

B. Budget: No major changes needed.

C. Special Concerns: No additional protocols.

D. Collaboration, Travel, Training and Publications

The results of the first years activity of the joint team are being prepared for submission to the Heat and Mass Transfer in Spray Systems, 1997 ASME International Congress, Dallas, Nov. 16-21.