COMPLEX ENERGETIC UTILIZATION OF HIGH-CO_2 NATURAL GASES

By

G. VERES

Institute of Heat and Systems Engineering,
Technical University, Budapest

Received July 2, 1980
Presented by Prof. Dr. I. SZABÓ

General concept:

Enforced by the increasing energy demand, the question of the utilization of also natural gases considered earlier uneconomical because of their high inert content has recently emerged. A research team of the Technical University Budapest, in co-operation with industrial organizations, recommends now a system for the complex utilization of low-grade natural gas in gas turbine as a result of research work carried out for years in this field. The application of this system results in optimum utilization of the potentials of natural gas resources.

The fundamental concept was laid down by Professor HELLER.

There are two essential points in the system recommended, one concerning the method of enrichment of the combustible component of natural gas, while the other the special layout of the gas turbine system.

The enrichment plant governed by the principle of thermodynamics cuts the inlet raw gas flow into two streams. In the first stream, the gas becomes so rich in combustible component that it can be effectively burnt in the combustion chamber of the gas turbine. In the second stream, the gas becomes rich in inert component. The thermodynamical process takes place without the addition of energy from extraneous source. The differential pressure required for the process comes from the difference between source pressure and the pressure of the combustion chamber of the gas turbine.

The gas stream rich in combustible component enters the combustion chamber of the gas turbine to be burnt there with the stoichiometrically necessary air. The other pressurized gas stream which is poor in combustible component enters the system after the combustion chamber in order to cool the hot gas flowing towards the turbine blades, to the temperature tolerated by the blade material (filling). In the recommended system, the compressor power demand reduces (as only combustion air has to be compressed) so that the net output increases considerably. Thus, the chemical and physical potentials of natural gas resources offer a maximum contribution to energy production.

Flow Diagram of the gas turbine

Figure 1 illustrates the Flow Diagram of the GT schematically. High-CO_2 gas arrives from the gas-field through conduit (1) and enters scrubber/separator unit CS which is considered a "Black box" for the time being. Here, the inlet gas flow (1) is cut into two streams, one (2) becoming rich in combustible component, while the other (3) in inert content. During separation, the gas pressure drops from the inlet pressure of about 70 Bars to about 20 Bars which

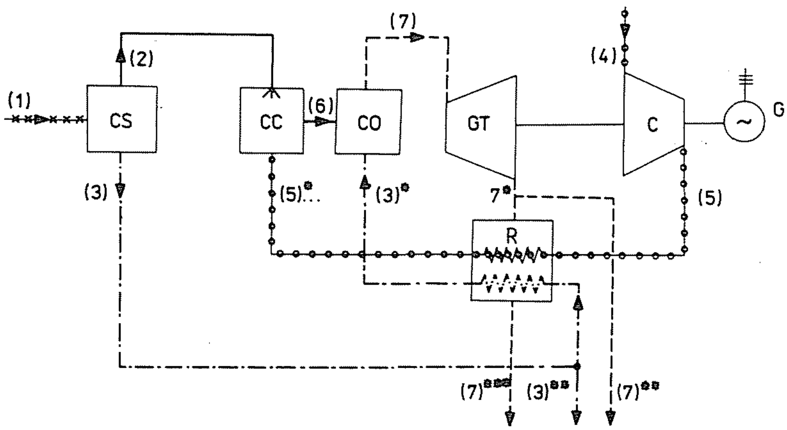

Fig. 1

corresponds to the pressure of the combustion pressure of GT. The gas (2) rich in combustible component is burnt in combustion chamber (CC) with air supplied by compressor C. The compressor supplies only the amount of air required for combustion stoichiometrically. The temperature of hot gas produced in combustion chamber (CC) is higher than that tolerated by the turbine blades. It is customary to feed filling air to cool the hot gas. In the system in question, the outlet gas of separator CS, rich in inert component (3), is used to adjust the required temperature. This gas is available at the same pressure as that of the combustion chamber, because the separator (CS) is so controlled that its outlet pressure will correspond to the combustion chamber pressure of GT. The outlet gas (7) leaving section CO of the combustion chamber expands in gas turbine GT. The outlet gas (7*) of the turbine preheats the combustion air (5) supplied by compressor C in recuperator R (7***), utilizing the heat of the outlet gas of GT. Also the filling inert gas (3*) can be preheated. Inert gas (3**) if in excess leaves through the stack. Compared with the conventional systems, the scheme illustrated seems to be advantageous in saving the compression power demand of filling air. This means that, assuming identical fuel input for both, the net turbine output of the recommended system increases compared with the conventional system.

Block Diagram of the Separator

Block Diagram of the separator is schematically illustrated in Fig. 2.

Raw gas (1) arriving from the gas-field passes through methanol-filled scrubber (M) where the vapour is extracted from the raw gas to eliminate the risk of freezing. Dry raw gas (2) flows into the tubes of parallel-connected heat exchangers H–1 and H–2. Here the coolant is the cold gas passing along the shell-side. The precooled gas is led into gasoline separator (G) where the gasoline and the condensed impurities (4) are separated, then the gas is cooled again to about −20 °C in heat exchanger H–3. At this temperature, the binary mixture is in a mixed phase condition, i.e. the liquid phase appears (5). The mixed phase mixture is led to cyclone separator S–1 where the gaseous phase (6), rich in CH_4, separates from the liquid phase (7) of high CO_2 content. From separator S–1, the liquid-phase material (7), after being throttled, gets into separator S–2. During throttling the pressure drops from the initial value of 70 to 80 atm. to about 20 atm. Also the temperature reduces considerably. Vapour phase reappears in the liquid phase. In separator S–2, the two phases can again be separated. Now again, the vapour phase is rich in CH_4, while CO_2 predominates in the liquid phase. The required amount of the liquid (9) leaving S–2 flows along the shell-side of heat exchanger H–3 evaporates and cools. The evaporated medium flows then along the shell-side of heat exchanger H–2 to precool part of the entering raw gas. Another part of the raw gas is precooled in

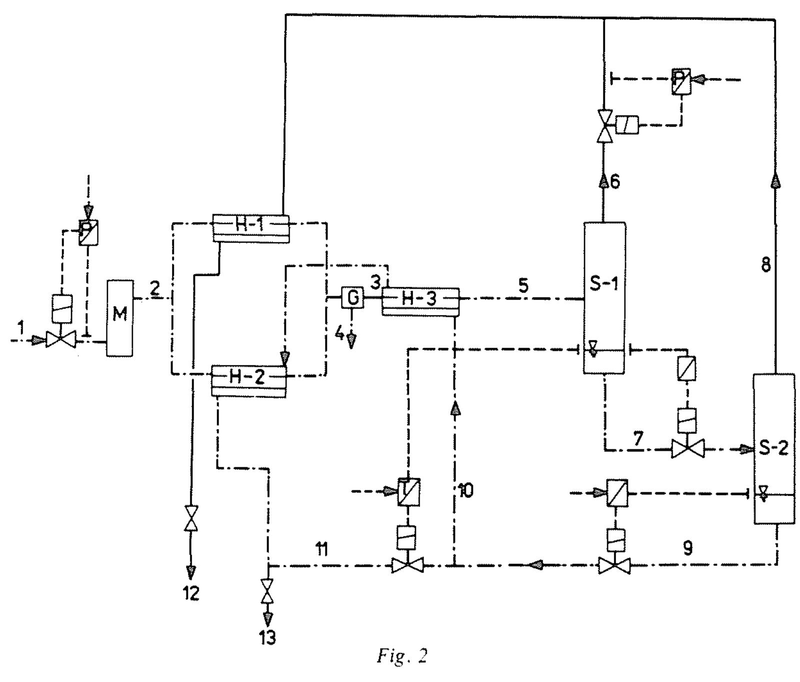

Fig. 2

heat exchanger H–1 where the gaseous phase medium leaving separators S–1 and S–2 is used as coolant. The pressure and temperature of the two media are different and an equalization is therefore necessary. The method of equalization resulting in possibly least loss may be decided on the basis of an analysis of the t – Q diagram of the recuperation process.

The medium (12) leaving heat exchanger H–1 is rich in methane and thus it can be burnt in the combustion chamber of the gas turbine (or, possibly, delivered to other consumers). The gas leaving heat exchanger H–2 with high CO_2 content (13) can be utilized as the filling medium of the gas turbine. System control includes pressure, temperature and liquid level control of separators S–1 and S–2.

Matching of Gas Turbine and Separator System

With the enrichment process described, the methane content of high-CO_2 natural gas can be increased from the initial volume of 25 to 32% to over 50 per cent by volume. Such a high methane content results in a calorific value acceptable by the gas turbine manufacturers.

Figure 3 shows a possible setup of the gas turbine, and the separator supplying the turbine with fuel.

The parameters of a Soviet gas turbine of a rated output of 30MW have been taken as a basis for investigation. Required amount of natural gas is

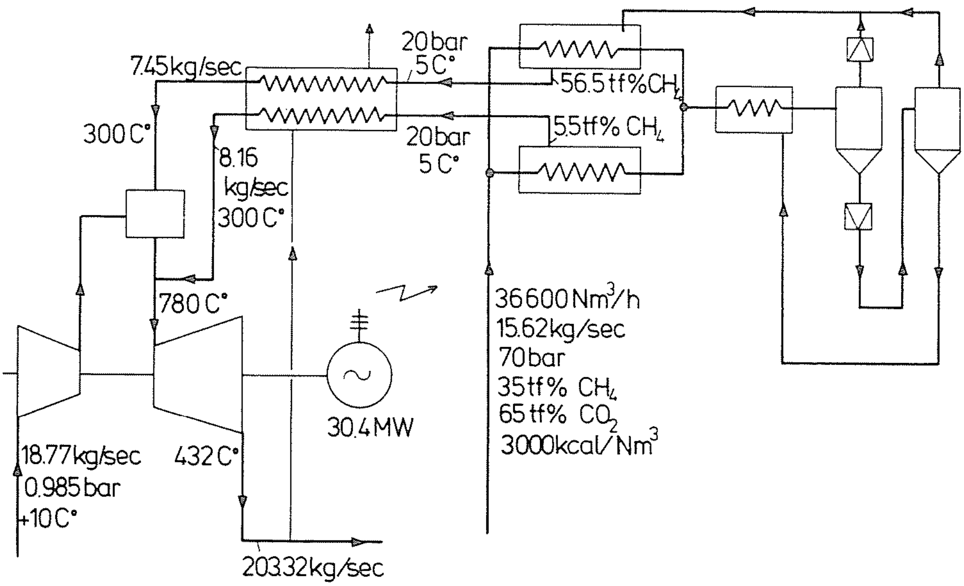

Fig. 3

36,600 Nm^3/h, assuming a methane content of 35 per cent by volume and a CO_2 content of 65 per cent by volume. The data of the Figure give information on the conditions prevailing in the system and on the attainable results.

Gas stream 13 of high methane content, with a calorific value of 4800 $kcal/Nm^3$, leaves the separator to enter combustion chamber 3 while gas stream 13 of a CO_2 content of 94.5 per cent by volume is utilized as a substitute for cooling air (filling air). Before entering the GT system, both gas streams can be preheated in heat exchanger 6 with part of the exhaust gases leaving the turbine.

Net gas turbine output is given by the difference of turbine and compressor power. For the system investigated, the efficiency of the GT unit increases by about 20% as a result of the economy in compressor power due to the utilization of inert gas.

Pilot-scale Experiment

The raw gas coming from the gas-field can be considered a binary medium. In the knowledge of temperature — composition and enthalpy — composition diagrams describing the expectable thermodynamical behaviour of the system, the applicable separation process can be determined. Obviously, the process will take place in accordance with the requirements only within certain limits determined by the characteristics of the mixture. Restrictions are imposed on feasibility by the critical curve of the mixture and, on the other hand, by the curves representing the appearance of solid phase.

Namely, the supercritical mixture cannot be liquified so that, during separation, the starting condition of the mixture shall by all means comply with the pressure and temperature range dictated by the physical/chemical laws controlling the process. Throughout every phase of the separation process, conditions with the inherent risk of solids segregation shall reasonably be avoided as otherwise the equipment becomes blocked up.

It was found that the technically feasible technology could be kept within the natural limits mentioned under the following conditions:

— Pressure of as-received raw gas is increased to a value of about 70 atm,

— temperature is prevented from dropping below a value of -50 °C throughout the entire process.

To back up the laboratory experiments in order to acquire most reliable data, a pilot-scale experimentation programme was carried out. Within the framework of this programme, an equipment suited to process a natural gas flow of 1000 kg/h was designed. Figure 4 shows the simplified Block Diagram of the equipment, indicating the most important quantitative, qualitative and temperature figures.

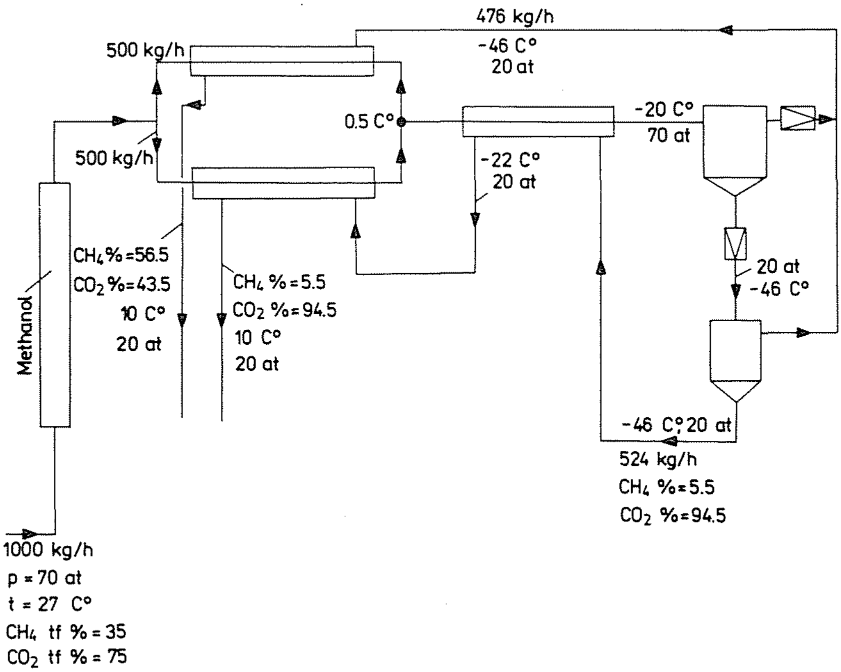

Fig. 4

Based on calculations, the equipment was designed in details and using these plans, the pilot plant was constructed. The pilot-scale experiments resulted in reliable data for the design of large-scale equipment to be constructed at a later date. In the spring and summer of 1978, the pilot plant was operated successfully. It confirmed that the equipment complied with the planned parameters, i.e. the principles of rating the construction was based on, were suited to design large-scale equipment, as well.

Summary

Abrupt increase of energy demands urges to utilize natural gases previously considered as uneconomical because high in inerts. Research done for years at the Technical University, Budapest and partner institutes resulted in a suggestion for complex utilization by means of a gas turbine making optimum use of potentialities of the natural gas wealth.

Dr. Gergely VERES, H-1521 Budapest