MODULAR COMPRESSORS FOR ELECTRIC GEOTHERMAL PLANTS

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ABSTRACT

In order to reduce the construction time of Geothermal Power Stations, new turbo-generators and cycle machinery of modular type have been designed.

The paper describes the peculiar construction of the non-condensable gas exhauster which may be assembled in four different configurations and achieved by appropriate matching of impellers and casings.

The four configurations cover a range of flows which extends from 2000 kg/h to 13500 kg/h of non-condensable gases, with pressure ratios variable between 14 and 18.5.

INTRODUCTION

The extraction of non-condensable endogenous gases from the condensers of geothermal plants is accomplished by means of machines of various type as: ejectors, displacement compressors, centrifugal dynamic compressor.

The proper choice among said machines depends mainly on the flow of the gas to be exhausted.

This paper will illustrate a constant speed centrifugal compressor of recent design, which is assumed to be driven either directly by a geothermal turbine or by a constant speed electric motor, and which can be adapted to the flow of the fluid to be extracted; such flow may vary gradually during the operation as a consequence of variations of:

a) the geothermal area characteristics,
b) operation of the set in a different geothermal area,
c) insufficient knowledge of the geothermal steam characteristics.

CENTRIFUGAL COMPRESSORS FOR GAS EXTRACTION

The characteristic curve of a centrifugal compressor operating at constant speed which draws non-condensable gases from a mixing condenser has the qualitative shape shown in fig. 1.

SYMBOLS

$\rho = \frac{P2}{P1}$ = pressure ratio
P1 = absolute pressure at suction
P2 = absolute pressure at discharge
G = flow of endogenous dry gases
$P_\circ$ = design point
$G_\circ$ = flow at design point
$\rho_\circ$ = pressure ratio at design point
$t_\circ$ = inlet gas temperature at design point

Normally, the centrifugal gas exhausters are made of two casings in a tandem configuration operating at different speeds.

When the pressure ratio is. low the exhauster can be made of one casing only.

During the compression phase the gas is cooled in one or two intermediate coolers.

CENTRIFUGAL COMPRESSOR M-1R MODULAR TYPE

The M-1R compressor of new design illustrated in this paper is composed of prefabricated pieces, which can be assembled in a short time in several configurations

covering a wide flows range.

This feature is one of the objectives indicated by ENEL - U.N.G. (Unità Nazionale Geotermica) for the design of machinery for future electric geothermal plants.

For these plants, either the machinery or the civil works will be designed with modular standards, in order to reduce the construction time of the plants.

As far as the machinery is concerned, its components can be supplied even before complete analysis of the chemical and physical characteristics of the endogenous fluids to be used in the plant is carried out.

The. modular compressor consists of two casings: one operating at low pressure (L.P.), the other at high pressure (H.P.).

The relevant rotors are driven by means of a double-pinion speed increasing gear, this latter coupled to the turbine shaft (see fig. 2).

The L.P. casing has two compression stages: the first with a double flow, the second with a single flow.

The H.P. casing has a double series of single flow impellers, running in parallel, each series presents two stages.

The heat accumulated during compression is removed in an intermediate cooler, jet type with water injection.

On both L.P. and H.P. rotors, impellers of different capacity can be assembled so that four different configurations can be obtained, each suitable for a definite range of capacities (see Table 1).

From the base configuration No. 1, the configuration No. 2 is obtained by assembling the reduced flow impellers "a", "c" on L.P. rotor, and the 2 reduced flow impellers "b" on H.P. rotor.
The configuration No. 3 is obtained by assembling single flow impellers instead of double flow impellers on both the L.P. and H.P. rotors, and the reduced flow impeller "d" on the L.P. rotor.
The configuration No. 4 is obtained by assembling the reduced flow impellers "a", "e" on the L.P. rotor, and the 2 impellers "b" on the H.P. rotor. The impellers "a", "b" are like the corresponding impellers of the configuration No. 2.

The performances of each configuration are shown on the diagram of fig. 3.

The range of capacities covered by the four configurations varies from 2000 kg/h to 13500 kg/h, with pressure ratio variable from 18.5 to 14.

CONSTRUCTIONAL FEATURES

The set is notably limited in size, being the two casings placed side by side, together with the speed increasing gear in a single baseplate of fabricated steel.

With the purpose of making disassembly of the unit for periodical maintenance easier and speedier, the inlet and discharge nozzles, except the final discharge nozzle, are cast in a single piece integral with the lower half of each casing.

Each rotor is supported by two journal bearings and maintained in axial position by a thrust bearing.

The impellers are "open" type, with high-efficiency threedimensional backward vanes.

The diffusers of the L.P. casing are free vortex type with kinetic energy high recovery scroll.

The diffusers of the H.P. casing are vaned type.

Each rotor is connected to the respective pinion of the speed increasing gear by means of a toothed gear coupling.

MATERIALS FOR MAIN COMPONENTS

- L.P. and H.P. casings: Meehanite cast iron.
- Impellers and vaned diffusers: martensitic high strength stainless steel.
- Sealing and pipes in contact with dry gases: stainless steel AISI 316 L.
- Pipes in contact with wet gases: carbon steel lined with lead; water distributors and rings: AISI 316.
- Internal supports and gratings: AISI 316 L.

DELIVERY TIME OF THE COMPRESSOR SET

It is possible to assemble each of the four configurations shown in Table 1 with the following components:

- 1 L.P. casing
- 1 H.P. casing
- 1 L.P. shaft
- 1 H.P. shaft
- 7 impellers for L.P. shaft (four of which at reduced flow)
- 6 impellers for H.P. shaft (two of which at reduced flow)
- 1 speed increasing gear
- 1 intermediate cooler
- 3 toothed couplings
- 1 baseplate
- accessories.

The delivery time ex-Works of a modular compressor, when patterns for casting and forgings for impellers are available, is 9 months approx.

The time required for compressor modules assembly at job site, erection and start-up is 3 months approx.

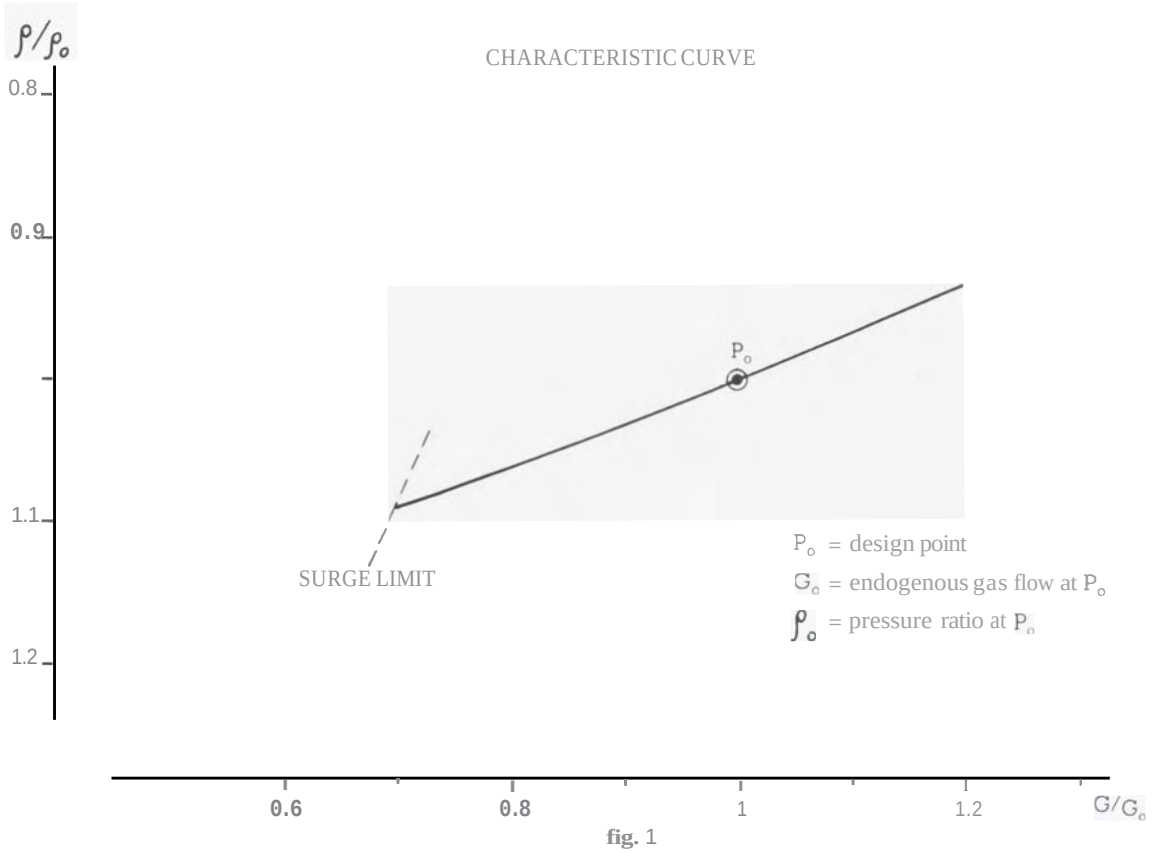

fig. 1

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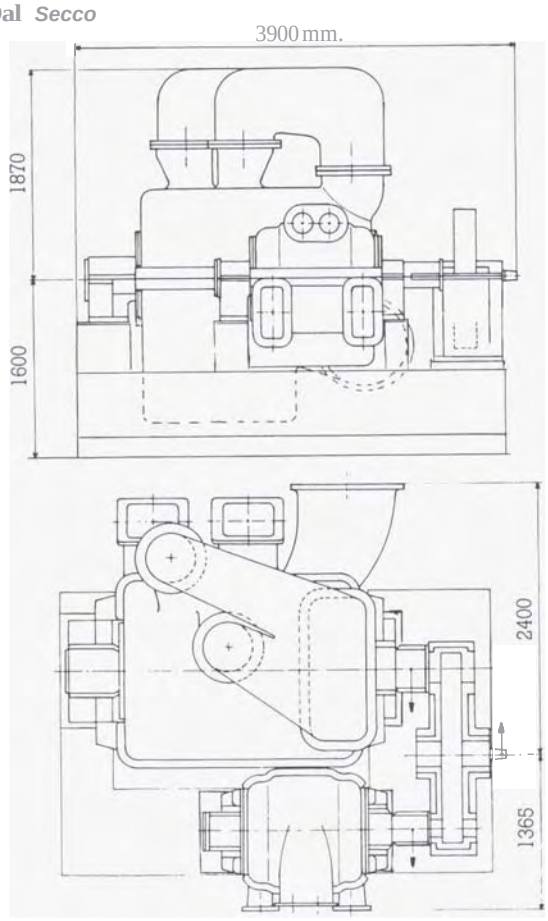

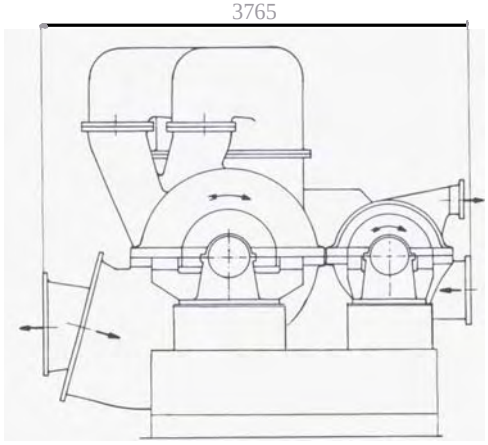

MODULAR COMPRESSOR
Type M - 1R

fig. 2

OPERATING CHARACTERISTICS

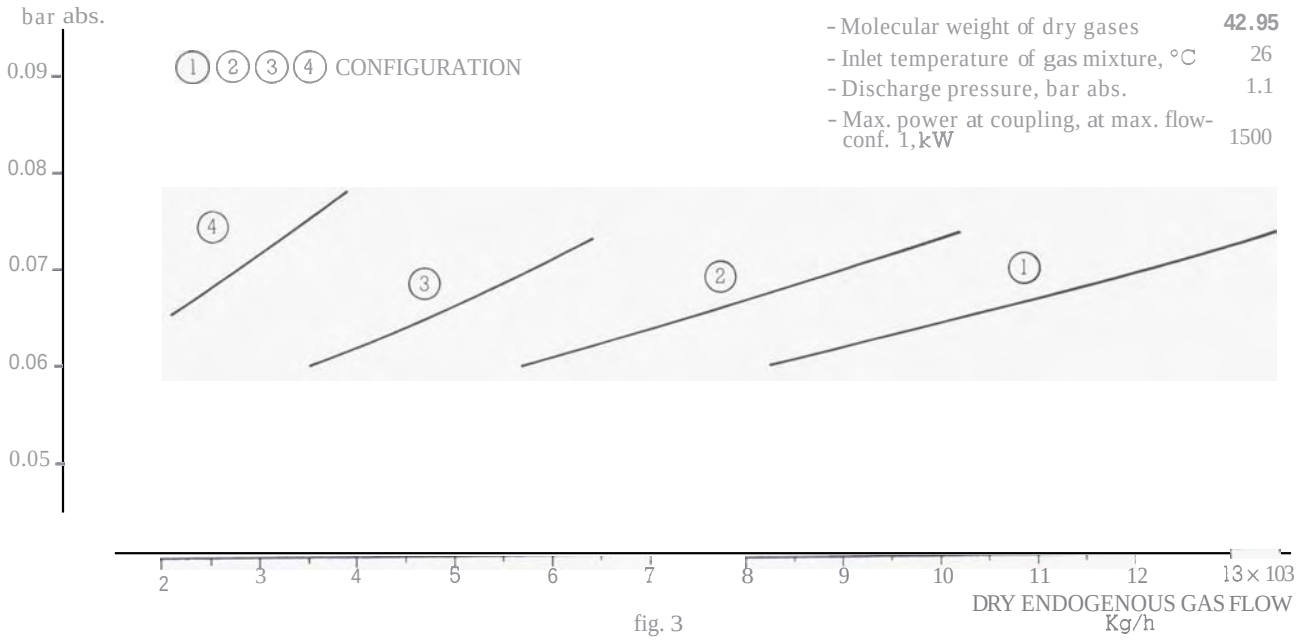

fig. 3

MODULAR COMPRESSOR
Type M - 1R

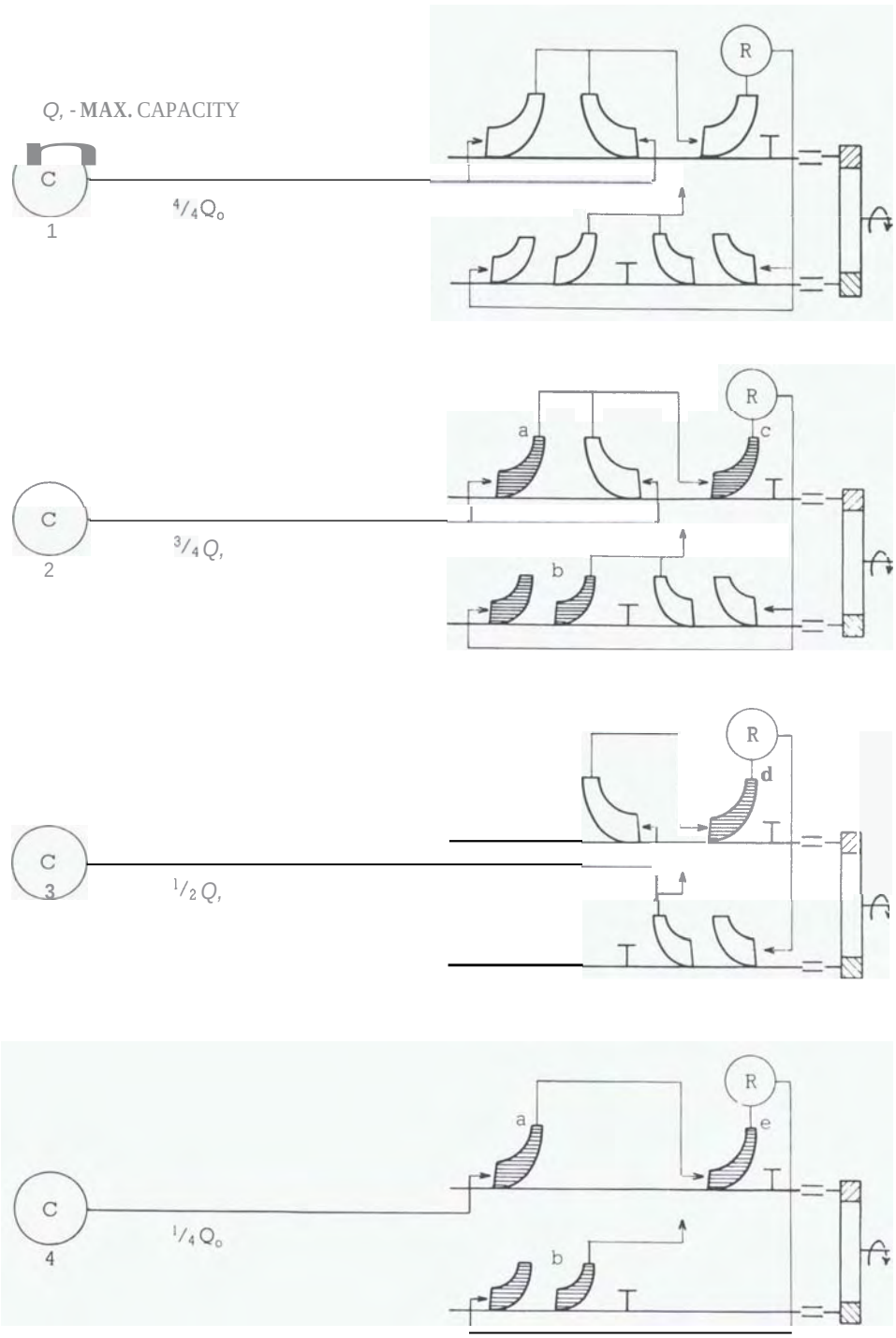

table 1

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LIST OF FRANCO TOSI CENTRIFUGAL GAS COMPRESSORS FOR GEOTHERMAL POWER PLANTS

Customer / Plants	ENEL LARDERELLO 3	ENEL SEREAZZANO LAGO	ENEL LARDERELLO 2	ENEL CASTELNUOVO	ENEL GABBRO S.D. SERRAZZANO RADICONDOLI
- Number of units	6	4	2	1	4
- Type	centrifugal	centrifugal	centrifugal	centrifugal	centrifugal
- Number of casings	2	2	2	2	2
- Number of intercoolers	3	3	3	3	3
- Gas handled	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam
- Capacity at suction conditions m^3/h	93,000	114,000	210,000	310,000	330,000
- Suction pressure ATA	0.10	0.072	0.077	0.0905	0.06
- Discharge press. ATA	atm.	atm.	atm.	1.02	1.08
- Speed rpm	4500	4100	4200	3000	3000
- Power at coupling kW	930	880	1850	2270	1625
- Driven by	5, el. motor 1, steam tur	2, el. motor 2, steamtur	steam turbine	main turbogen.	main turbogen.
- Operating since	1950	1957 1968	1962	1967	1969 1975 1979

Customer / Plants	ENEL LARDERELLO 3	ENEL LAGONI ROSSI MOLINETTO LA LECCIA	GIE/TEK KIZILDERE (Turkey)	ENEL S. MARTINO	ENEL NEW PLANTS
- Number of units	3	3	1	1	3
- Type	centrifugal	centrifugal	centrifugal	centrifugal (modular)	centrifugal (modular)
- Number of casings	2	2	2	2	2
- Number of intercoolers	1	1	2	1	1
- Gas handled	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam	CO_2, H_2S steam
- Capacity at suction conditions m^3/h	237,000	79,300	293,500	60,000	213,000 max
- Suction pressure ATA	0.09	0.085	0.09	0.0725	0.07
- Discharge press. ATA	1.08	1.08	1.08	1.07	1.12
- Speed rpm	3000	5800	3000	3000	3000
- Power at coupling kW	1850	790	2380	515	1500 max
- Driven by	main turbogen.	main turbogen.	main turbogen.	main turbogen.	main turbogen.
- Operating since	1976 1978	1981 1982	erection on site	in manufacture	in manufacture

In total 28 gas compressors of 7 different sizes, for a total of 2,500,000 hours of operation.