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ABSTRACT

The intercooler volume and cooling rate can affect the compressor performance. Larger volume will reduce the amplitude of pressure fluctuation and intercooler temperature will affect the average intercooler pressure and the inlet density of second stage.
The theoretical model used is a four equal-chamber positive displacement rotary compressor ,figure 1, in which three chambers are used for the first stage Adiabatic compression and on-off nozzle type valves were used in the model

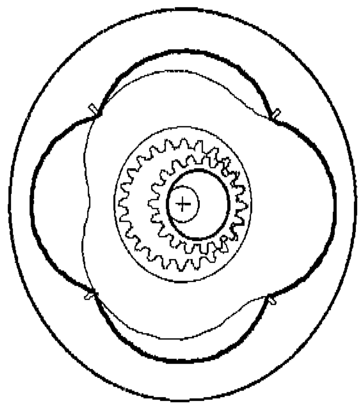

Fig 1

SYMBOLS AND DEFINITIONS

Eff — efficiency
I.C. — intercooler
K — ratio of specific heats=1.4
Temp — temperature
Pres. — pressure
Clearance volume=
dead volume/swept volume
Intercooler efficiency=
(I.C set temp.-inlet temp.) /
(I.C temp. at ideal I.C. press. - inlet temp.)
Ideal I C pres.=
(inlet pres * exhaust pres.)$^{1/2}$
I.C. temp at ideal I.C. press.=
inlet temp. * (ideal I.C. pres./ inlet pres)$^{(k-1)/k}$
Swept volume=
first stage swept volume

INTRODUCTION

The intercooler has a complex effect on the performance of a two-stage compressor. Some indirect effects such as heating the inlet gas or the effect of the efficiency of compression and re-expansion are difficult to account for This paper tries to focus on the direct effects of an intercooler by assuming an adiabatic compression process, constant temperature intercooler and on-off type compressor valves. An on-off compressor valve is either open with a maximum port area or closed

THEORETICAL MODEL

The theoretical model introduced here considers a four equal-chamber positive displacement rotary trochoidal air compressor (1) in which one of the chambers is used for the second stage. A clearance volume of 8% is assumed for all chambers

An on-off nozzle-type valve with a fixed coefficient of discharge of .7 is used. The valve port area is calculated to maintain an average mach of .2 at the inlet condition

The exhaust pressure is varied from 120 psia to 200 psia in four steps. For each exhaust condition, the intercooler temperature was varied in four steps between inlet temperature and isentropic temperature at ideal intercooler pressure. This temperature variation is generalized by defining a non-dimensional intercooler efficiency as the ratio of (I.C. set temp.- inlet temp.) to (I.C. temp. at ideal I.C pressure- inlet temp.). For each exhaust pressure and intercooler efficiency, the intercooler volume is varied from 1/3 of swept volume to 3 times the swept volume.

Figures 2-5 show the effect of intercooler efficiency and volume on the volumetric efficiency for different exhaust conditions.

CALCULATION PROCEDURE

An explicit method is used to calculate the mass, pressure and the temperature of each chamber and the intercooler. Starting with ideal pressures and temperatures at zero shaft angle, the shaft angle is then increased one degree per step and the variables are calculated.

After one revolution, the starting data are updated and the new set of variables is calculated. This calculation cycle is repeated until the maximum relative variation in mass flows through the first and second chamber at the end of calculation cycle is less than .005.

At each calculation step, an open control volume is assigned to each chamber and intercooler. Mass flows in and out of the first and second chamber are calculated using nozzle-type formulation (2). Pressure for each chamber is then calculated using perfect gas law Energy equation is used to calculate the chamber's temperature Balance of mass flow out of first chambers and into the second chamber is used to calculate the mass of intercooler. The intercooler temperature is set to corresponding efficiency settings. For the set volume of the intercooler, the pressure is then calculated using perfect gas law.

This calculation procedure converges to set tolerance in about 9 iterations.

CONCLUSION

Figures (2-5) show direct improvement in volumetric efficiency by reducing intercooler temperature. For intercooler volume less than swept volume, a stronger dependence on intercooler volume is observed. This is due to a higher intercooler pressure fluctuation which reduces the exhaust valve opening time for the first chambers. This volume dependence is dampened by improving the intercooler efficiency. Higher volume ratios show a small improvement in the volumetric efficiency. In an actual intercooler, the intercooler volume and the cooling rate or temperature are tied together. This means that with an optimum cooling design for the intercooler, the volumetric efficiency of this type model would depend on the volume only. The data presented here can be used for design guidelines.

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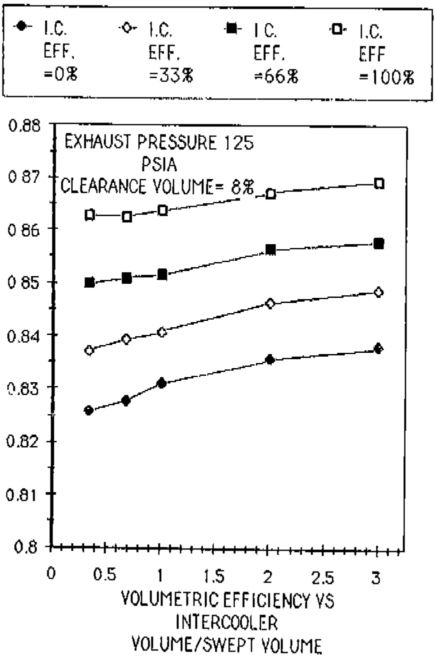

Fig. 2

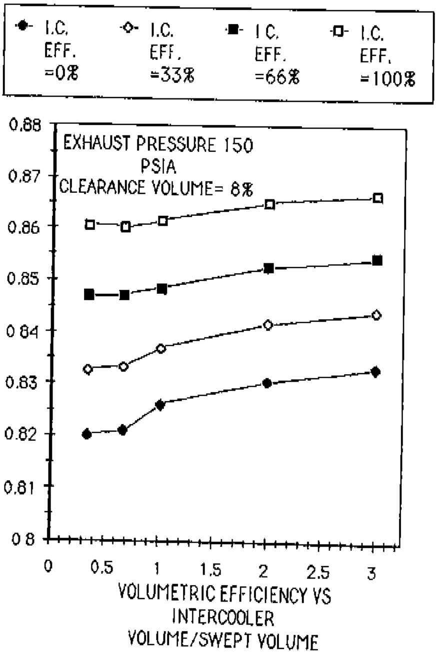

Fig. 3

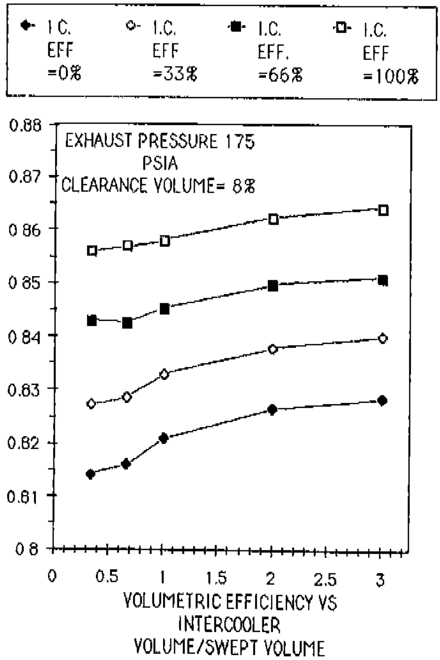

Fig. 4

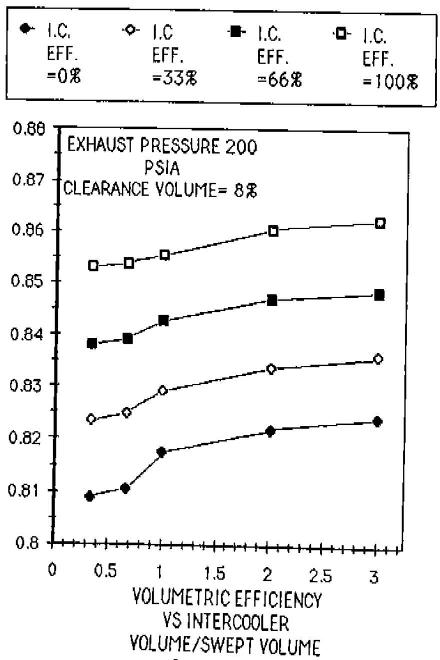

Fig. 5