1984

Turbo Boosted Reciprocating Compressors

J. P. Clegg

J. E. Grimmer

TURBO BOOSTED RECIPROCATING COMPRESSORS

John P. Clegg, Staff Engineer
GrimmerSchmidt Corporation, Franklin, Indiana

John E. Grimmer, President
GrimmerSchmidt Corporation, Franklin, Indiana

ABSTRACT

An ongoing program to reduce the package size and lower the cost of portable compressors resulted in the development of a compound compressor using turbochargers for the first stage and our standard reciprocating compressor for the second.

Turbocharging was selected because it was easily applied, with little modification to the engine and compressor, but offered substantial performance improvement which could be sustained at high altitude. Details of initial development units and later production models are described in this paper. The program resulted in the introduction of new machines into production that outperformed their predecessors by considerable margins, but did not increase in package size.

Several of these machines are now in service, they are performing well and the compact, high speed single axle package has been well received.

INTRODUCTION

A mono-block compressor, having both power and compressor components housed in a common cylinder block, is shown in Figure 1. They have been used

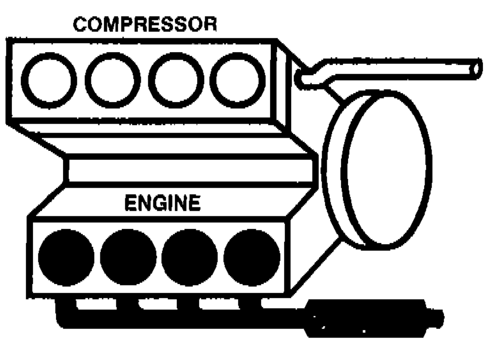


FIGURE 1 · CYLINDER ARRANGEMENT OF A V-8 MONOBLOCK RECIPROCATING COMPRESSOR.

successfully for many years in Europe and North America, primarily in the smaller sizes - below 200 CFM. Popularity has been due to the simple, compact, durable and low cost nature of these machines.

In larger sizes, the mono-block is not as prevalent - mainly due to the higher cost of the larger diesel engines over the conventionally engine driven compressor. When high volume, low cost engines are not available, the mono-block becomes less attractive.

IMPROVING THE PERFORMANCE OF THE MONO-BLOCK COMPRESSOR

The use of precharging with a high capacity, low pressure blower such as a Roots is well established; but while being effective, requires mechanical drives, is expensive and is relatively bulky. A better machine to use for a high volume flow first stage would be the centrifugal dynamic compressor which has extremely high flow for a given housing size and, with modern designs, a good pressure capacity.

This type of compressor could be applied to a mono-block, or any other positive displacement compressor using a diesel engine, by applying a turbocharger. A turbocharger is a device having a dynamic compressor driven by an exhaust driven turbine.

All the elements to apply a turbocharger for boosting the air compressor inlet are present on a diesel powered compressor. The diesel exhaust is available to drive the turbine, with little modification, and only tubing connections are required to make exhaust and compressed air hookups.

CONSTRUCTION AND TESTING OF TURBOCHARGED COMPRESSORS

The turbocharging program was started by converting an existing 903 cu.in. diesel mono-block compressor, previously rated at 450 CFM. Since our goal was to increase performance to 600 CFM, this meant a turbocharger delivery of 1000 CFM was needed for the combined engine and compressor; three times the air flow requirements of the turbochargers normally applied to 450 cu.in. (approximately one-half of the 903 engine) engines. This turbocharger configuration is unavailable as a current production product and would have some basic problems to overcome. This is why the two-turbo configuration shown in Figure 2 was chosen. By

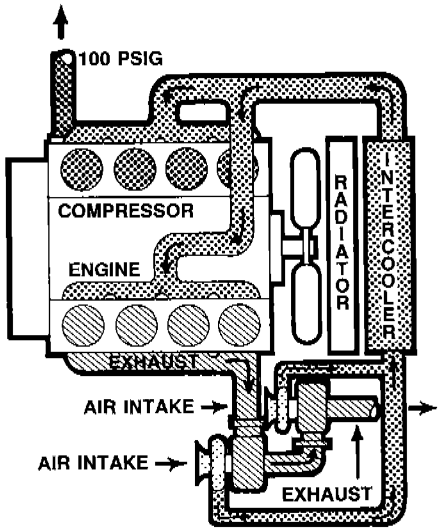


FIGURE 2 · TWO STAGE COMPRESSOR WITH TURBOCHARGER FIRST STAGE AND RECIPROCATING SECOND STAGE

using two turbochargers, the necessary turbine and compressor characteristics could be obtained from high volume production units.

The selection of components for the turbocharged machine has not included any newly developed parts. The open skid assembled unit, Figure 3, shows the

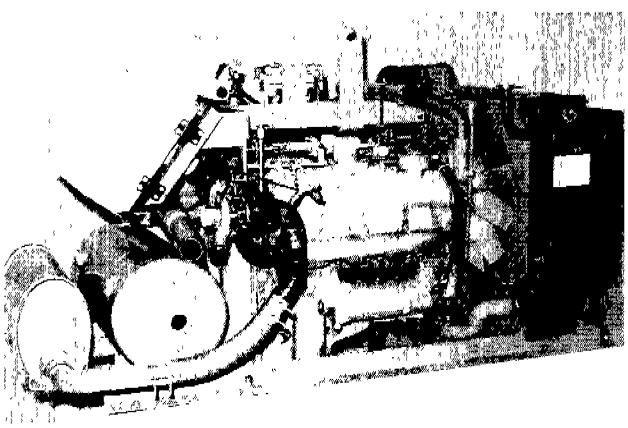


FIGURE 3 · OPEN SKID UNIT.

mono-block compressor built out of a current diesel engine with turbochargers mounted at the rear. A large radiator is used with automatic continuous

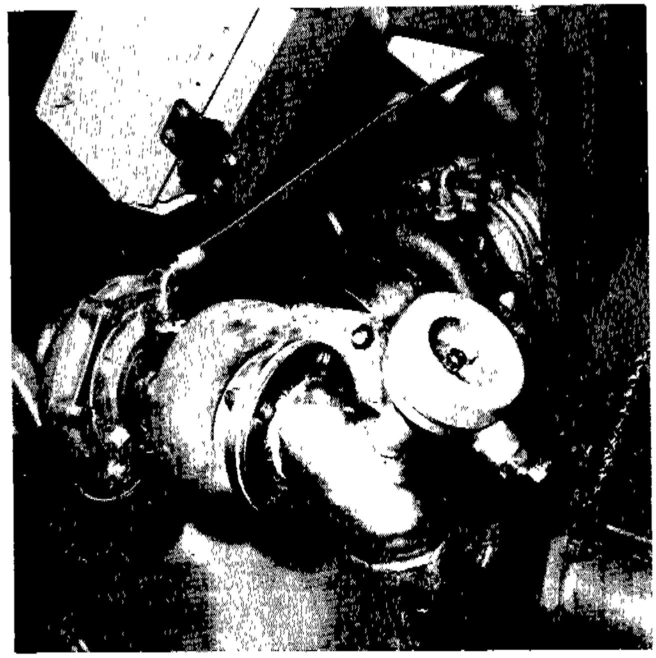
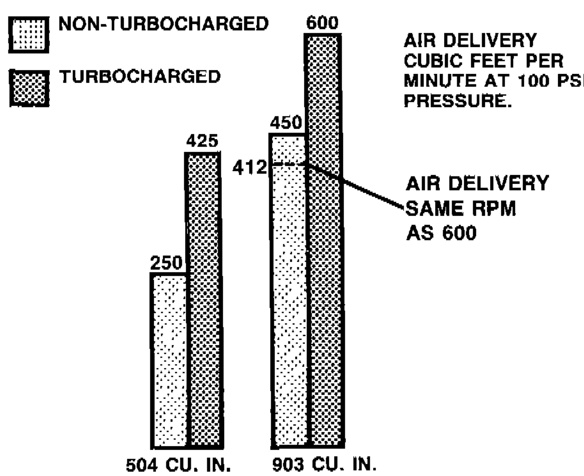


FIGURE 4 · TURBOCHARGERS MOUNTED WITH COMPRESSORS IN PARALLEL.

deaeration. Air-to-air intercooler and aftercoolers are mounted directly in front of the radiator. Cooling air is provided by a 12 bladed aerofoil fan and intake air is filtered by an oversize unit with dust extractor. Figure 4 shows the exhaust and mounting system of the twin turbochargers in parallel.

So far our results have been the production release in 1982 of a 600 CFM (100 psi) machine and a 425 CFM machine in 1983. Without any increase in package size the twin turbo concept has increased our 450 at 2400 rpm to 600 CFM at 2200 rpm and our 250 to 425 CFM at similar speeds. The performance improvements are shown in the bar chart, Figure 5.

FIGURE 5 · PERFORMANCE IMPROVEMENTS IN TWO SIZES OF COMPRESSORS DUE TO TURBOCHARGING.



To protect the operator against shutdown due to malfunction, these units use a single exhaust temperature sensor which reacts to turbocharger failure, injector malfunction, intercooler or duct leakage, exhaust manifold leakage or any situation that would raise exhaust temperatures above a safe limit. This sensor reduces power to a safe level without shutting down the machine.

At an advanced stage of development is a three stage unit having turbocharged first stage similar to the previously mentioned units, but with the positive displacement (pistons) portion divided into second and third stages. This configuration is shown in Figure 6. The results from the three

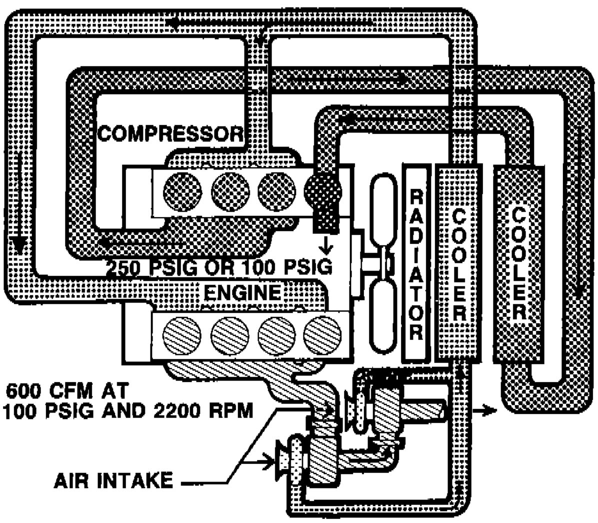
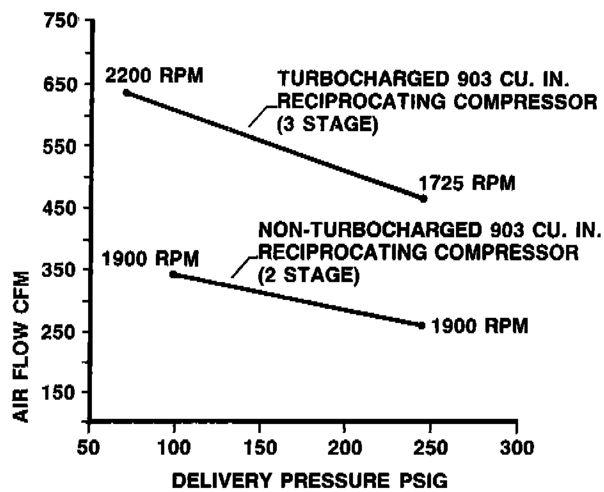


FIGURE 6 - A THREE STAGE COMPRESSOR WITH TURBOCHARGER FIRST STAGE – 100 PSIG OR 250 PSIG DELIVERY PRESSURE.

stage unit are very interesting since this machine will produce from 630 CFM at 70 psig to 470 CFM at 250 psig without any adjustment or valving. With a slightly increased air induction boost to the engine, over 600 CFM may be expected at 250 psig discharge.

The three stage machine is still under development but its potential is already proven as the performance comparison shows in Figure 7.

FIGURE 7 - PERFORMANCE IMPROVEMENT BY TURBOCHARGING TWO STAGE POSITIVE DISPLACEMENT COMPRESSOR.



ADVANTAGES OF TURBOCHARGING

Comparing the turbocharged production machines with their unturbocharged predecessors shows that their physical size is reduced by nearly 50%. Figure 8 shows the size relation between the new TwinTurbo unit and a composite of other types of 600 compressors. Weight is also reduced considerably. In the instance of the 600 CFM unit this

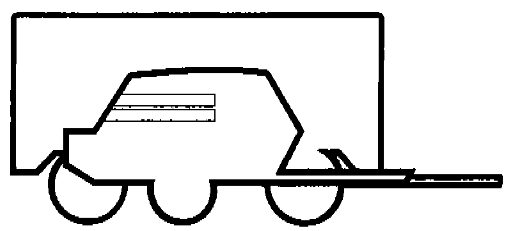


FIGURE 8 - THESE ARE ACTUAL SIZE COMPARISONS BETWEEN A TWIN TURBO 600 AND A CONVENTIONAL COMPRESSOR.

amounts to 47% and for the 425 unit 25%. Both units are mounted on high speed single axles for towing behind pickup trucks.

Fuel economy was improved for both turbocharged units by a margin of 27% to 29% over the unturbocharged equivalent units, based on pounds of fuel/100 CFM. Engine efficiencies through turbocharging, plus the two stage effect on compression, provided the means for these reductions.

The well established turbocharger characteristic of maintaining engine performance at high altitude was expected to benefit the turbocharged compressors and altitude tests showed this to be true. Since all of the air aspirated by the compressor passes through the first stage turbocharger compressor, the unit's altitude characteristic is the same as the turbocharger's characteristic. Flow measurements at up to 10,000 ft. of operation are shown in Figure 9 which illustrates the additional energy available for work over equivalent unturbocharged single stage machines.

FIGURE 9 · COMPRESSOR PERFORMANCE DEGRADATION DUE TO ALTITUDE.

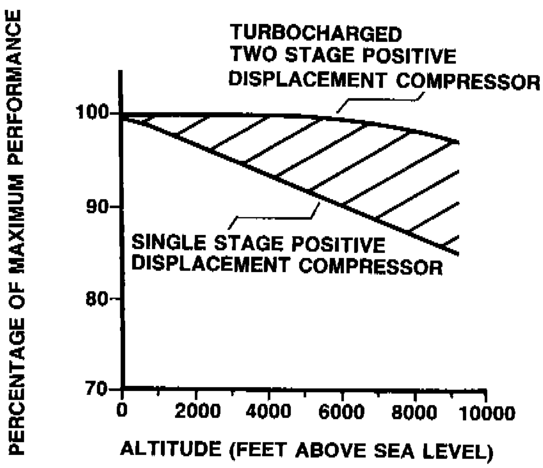


FIGURE 10 · 600 CFM PRODUCTION UNIT.

SUMMARY

Turbocharging compressors is a beneficial, feasible process. The advantages gained for the two new production units were:

1. improvements in capacity, 450 - 600 CFM and 250 - 425 CFM
2. reduction in package size (Figure 10)
3. reduction in weight
4. reduction in fuel consumption
   and
5. improvement in altitude performance.

Because of these significant benefits, we believe turbo compound compressors should ultimately dominate the larger unit size portable compressor market.