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RAILROAD EXPERIENCE WITH A TURBOCHARGED TWO CYCLE DIESEL ENGINE

By

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Written discussion of this paper will be accepted at SAE Headquarters until September 20, 1956. Three double-spaced copies would be appreciated.

For presentation at the
SAE NATIONAL WEST COAST MEETING
Mark Hopkins Hotel, San Francisco, California
August 6-8, 1956

SOCIETY of AUTOMOTIVE ENGINEERS, Inc., 29 West 39th Street, New York 18, N. Y.

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The Union Pacific Railroad between Omaha, Nebraska and Pacific Coast operates at altitudes varying from sea level to 8,000 feet and at summer ambient temperatures ranging from 80°F to 120°F. A large percentage of the locomotives used, are powered by two cycle diesel engines built by the Electro-Motive Division of General Motors.

The largest group of freight power units are EMD GP-9 units powered with EMD Model 16-567C engines having a sea level rating of 1750 hp into the main generator for traction. These engines lose approximately 14% of rated power at altitudes of 8,000 feet and approximately 5% of rated power at engine inlet air temperatures of 120°F. Engine air inlet temperatures average about 40°F higher than ambient temperatures due to locomotive arrangement.

Operating experience indicates that at altitudes above 4,000 feet and at ambient temperatures above 90°F the engines suffer from marginal air-fuel ratios. This condition results in excessive smoke, overheating and short life of pistons, cylinder liners, cylinder heads and valves.

Early in 1955, discussion of this problem between Union Pacific and the Garrett Corporation resulted in analytical studies by AiResearch Industrial Division of Garrett Corporation. The studies, which have been described by Dr. W. T. Von der Nuell in the paper "Notes on a Turbocharged Two Cycle Diesel Engine," showed enough promise that a cooperative experimental program was agreed upon.

The immediate goal was to develop a multiple unit turbocharging system which would give a definite improvement in altitude operation without major changes to the engine or locomotive.

Consideration was given to the future possibilities of increasing the engine rating and burning a lower grade of fuel to combat the rising trend of fuel prices.

Fig. 1 shows an EMD GP-9 "A" unit with dynamic brakes. This was the type of unit selected for the experiment because it presents the most difficult problems of space and ventilation. If the multiple unit turbocharger application could be successfully accomplished on the GP-9 it could be adapted to any other locomotive unit of this manufacture.

Fig. 2 shows the turbochargers and manifolds as applied to the engine for the initial experiment. Space limitations dictated that the four turbochargers be placed on the centerline of the engine in the space formerly occupied by the standard exhaust manifolds. Stainless steel exhaust collectors having an oval cross section approximately 4 inches by 8 inches divided the engine exhaust into quarters. A pair of double inlet exhaust turbines at each end of the engine were supplied by four cylinders in each bank.

The turbines at each end were placed back to back with exhaust from each pair discharging into a common stack located at the same point as the stack on the standard engine.

Compressor air inlets were covered with coarse screen for the initial experiment with filtering being supplied by filters in the standard hood openings. Air from the double discharge compressors was carried in parallel manifolds, through air to water intercoolers, to the roots blower inlets.

Fig. 3 shows the application at the blower end of the engine. Note the motor driven crankcase exhauster fan mounted over the standard oil separator.

Fig. 4 is a closer view showing turbocharger and manifold arrangement.

Fig. 5 shows exhaust manifolds and turbochargers with method used to support turbochargers.

Fig. 6 is a view of the turbocharged engine mounted in the locomotive to show the physical problems involved in adding equipment in these hood type units.

Turbocharger lubrication was supplied from the engine lube oil system at reduced pressure with return oil being discharged to the rocker box.

Air box inspection covers were reinforced to withstand the higher charge pressure.

Initial standing tests showed that better engine sealing was required. The standard engine operates with zero to slightly negative crankcase pressure. The turbocharged engine had positive pressure of approximately 6 inches of water. Cylinder liner seals were improved and four exhaust aspirated vents were added to the rocker box covers. See Fig. 7.

The unit was then connected to load through its own dynamic braking resistors and taken out for standing tests at various altitudes up to 4000 feet. Following completion of the standing tests it was placed in helper service out of San Bernardino, California. After about five trips the roots blowers failed and it was necessary to replace them. Inspection of the failure showed that the aluminum rotors rubbed on the case at the inlet due to differential expansion. Rotor length expansion also caused rubbing at the end opposite thrust bearings. As an expedient the rubbing was eliminated by turning down rotor diameter and shimming the thrust bearing end of the rotors. Blower clearances on the standard engine are very sensitive and have been increased between the B and C model engines. Fig. 8 shows the interior of a failed blower case and Fig. 9 shows one of the rotors.

While the locomotive was out of service to cure the blower problem the two oil control rings on the piston skirts were replaced by standard compression rings and the oil drain holes plugged. This reduced air leakage to the crankcase slightly but was disappointing because of excessive lube oil consumption. The unit was again assigned to helper service and performed very creditably except for the excessive lube oil use.

It was then learned from the builder that a large part of the air leakage could be traced to the blower shaft seals. These were reversed and the crankcase pressure dropped to a respectable figure. Development of a double lip seal is under way.

At the same time a new type of oil control ring was tried. This ring in the top oil ring groove of the skirt had a triangular section and was forced against the cylinder by a helical spring expander. The new ring was too severe and resulted in scoring after five hours of load test. Since then a standard compression ring in place of the top oil control ring with ring groove drain holes plugged has proved satisfactory.

Throughout the experimental period the exhaust stacks were troublesome because of cracking and expansion joint leakage.

At the present time there is very little in the way of formal performance data available. Efforts have been concentrated on finding the mechanical weaknesses and learning which parts of the engine-turbocharger combination can be improved within the original limits of no basic changes to engine or locomotive arrangement.

Analysis of the current data show that for comparable conditions of loading and fuel flow the turbocharged engine at sea level delivers approximately 4% more power than the standard engine and approximately 5-1/2% more at 4000 feet elevation.

Firing pressures up to 1450 to 1500 psig show no apparent damage in the comparatively brief period of 120 full load hours. Later testing at increased fuel rates resulted in firing pressures of 1750 to 1850 psig and caused noticeable damage to piston pins and connecting rod top ends.

At the higher fuel rates scavenging was less efficient and exhaust temperatures over 1000°F were recorded. At these conditions power increase over the standard engine with standard settings was on the order of 20 to 35 per cent.

These later experiments make it apparent that compression ratio must be reduced from the nominal standard 16 to 1 before serious attempts are made to increase the engine rating more than 10%.

Fig. 10 shows curves which demonstrate results with the hastily constructed experimental manifolding. These show a moderate but definite improvement throughout the range of engine loads.

It was observed during test runs that noise level was noticeably less both in the cab and outside the locomotive. Enginemen were favorably impressed with this result and were surprised that no "turbo whine" was heard. At the normal injector rack settings there was noticeably less exhaust smoke. This was especially remarkable during engine acceleration, when the four small turbochargers responded more rapidly than the standard engine and much more rapidly than engines equipped with large single turbochargers.

Currently a new set of manifolding for application to 3 units is under construction. This will be a constant pressure system with a single tubular exhaust collector feeding all four turbochargers. Energy recovery in exhaust stacks will be improved and the system will be cleaned up generally for better flow. Initially one unit will be equipped to take engine air from outside the hood. This should show some gain over standard units which force the engine to breathe a restricted flow of preheated air.

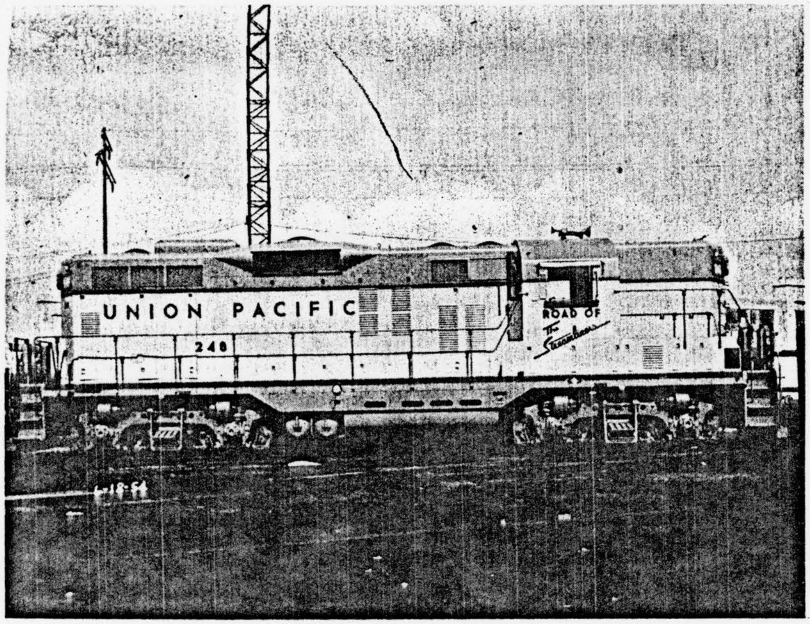

FIG. I EMD GP-9 DIESEL ELECTRIC UNIT

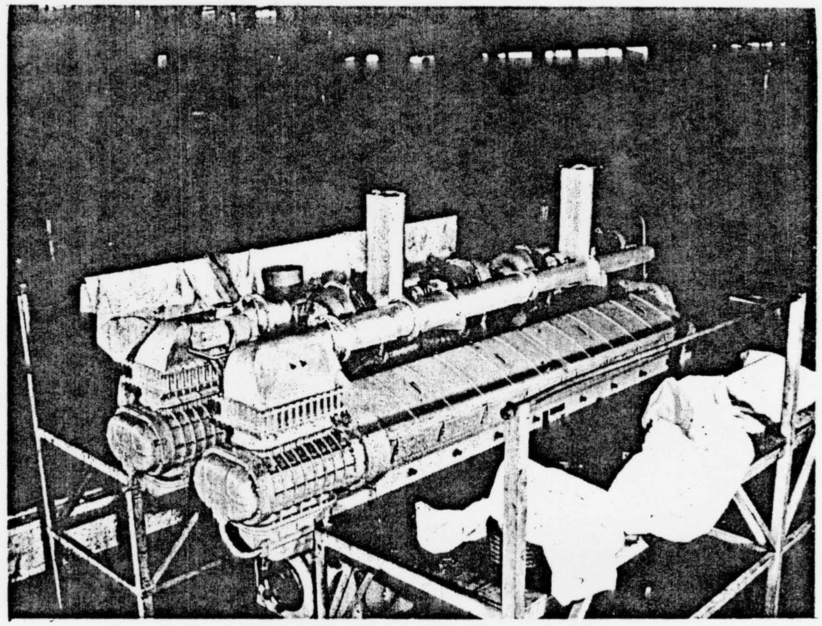

FIG. 2 FOUR AIRESEARCH TURBOCHARGERS ON EMD MODEL 16-567-C DIESEL ENGINE

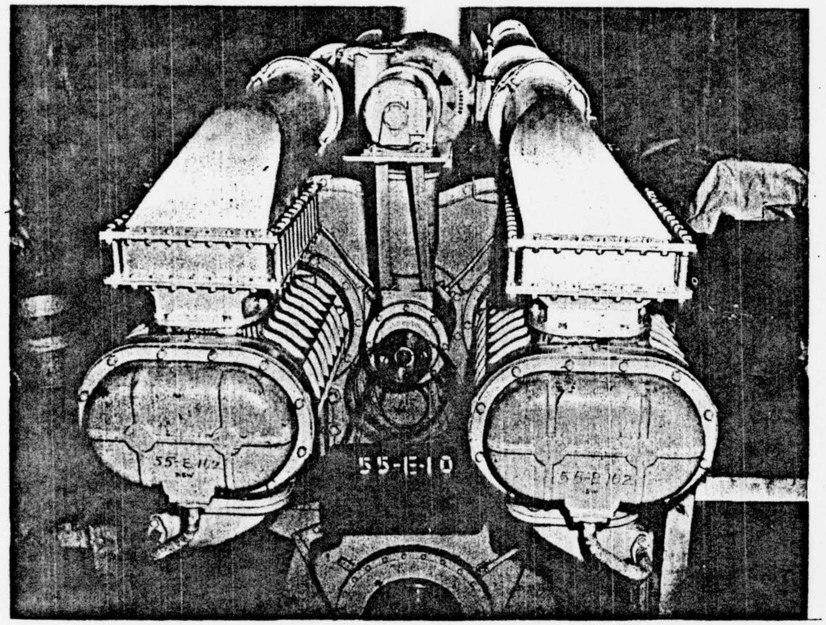

FIG. 3 END VIEW OF ENGINE SHOWING INTERCOOLERS AND CRANKCASE EXHAUSTER

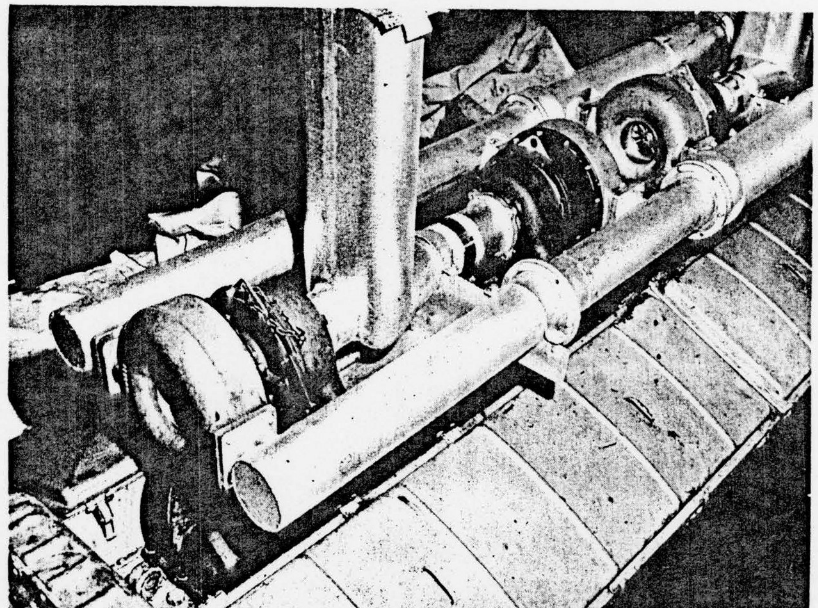

FIG. 4 TURBOCHARGER MANIFOLD ARRANGEMENT

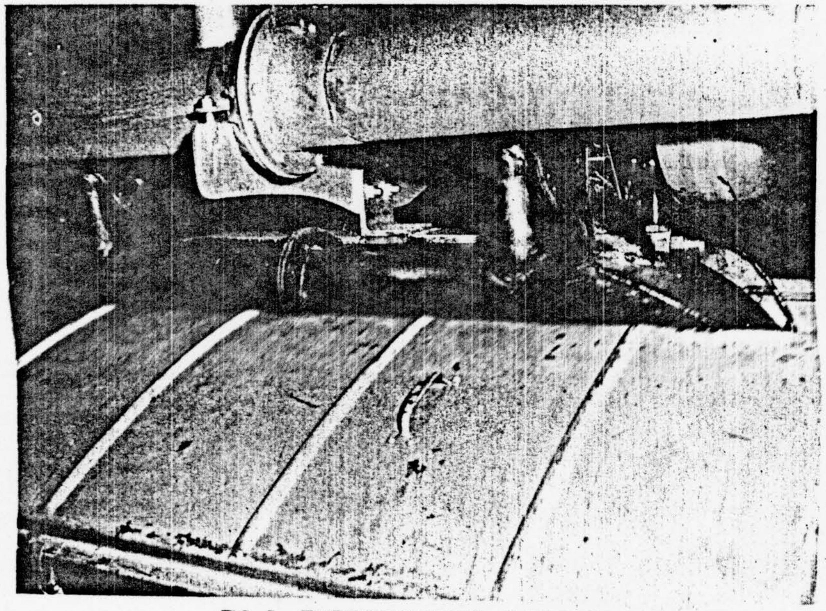

FIG. 5 TURBOCHARGER SUPPORTS

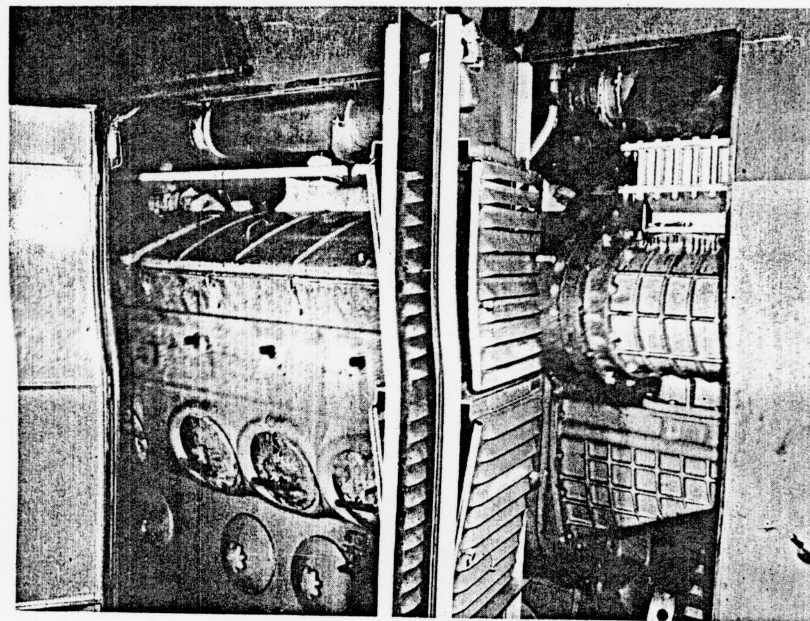

FIG. 6 TURBOCHARGED ENGINE IN LOCOMOTIVE

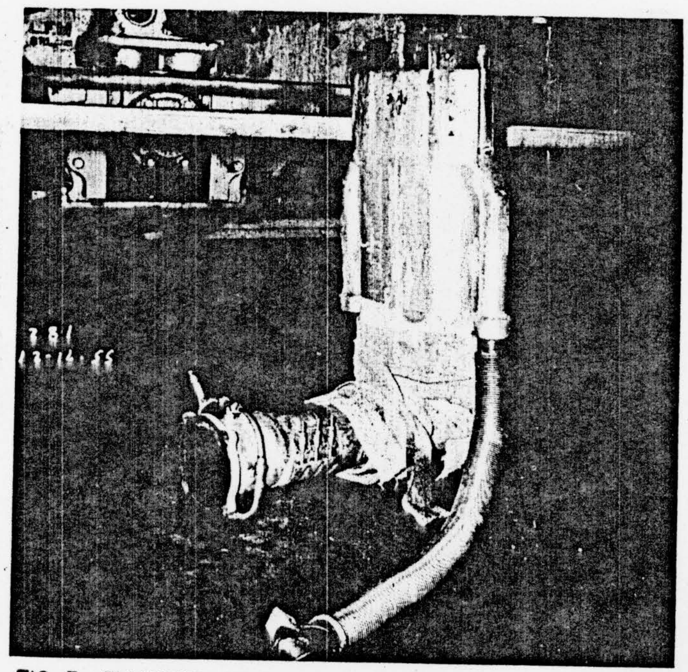

FIG. 7 EXHAUST STACK WITH CRANKCASE EXHAUSTERS

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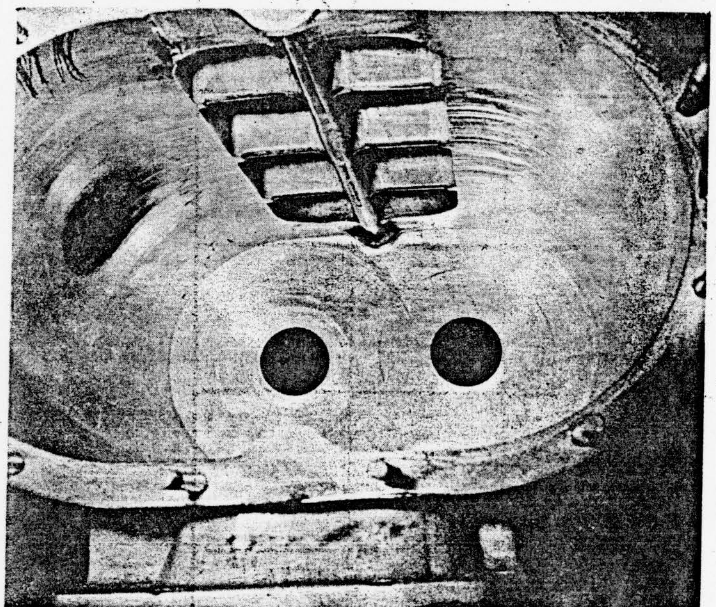


FIG. 8 FAILED BLOWER CASE

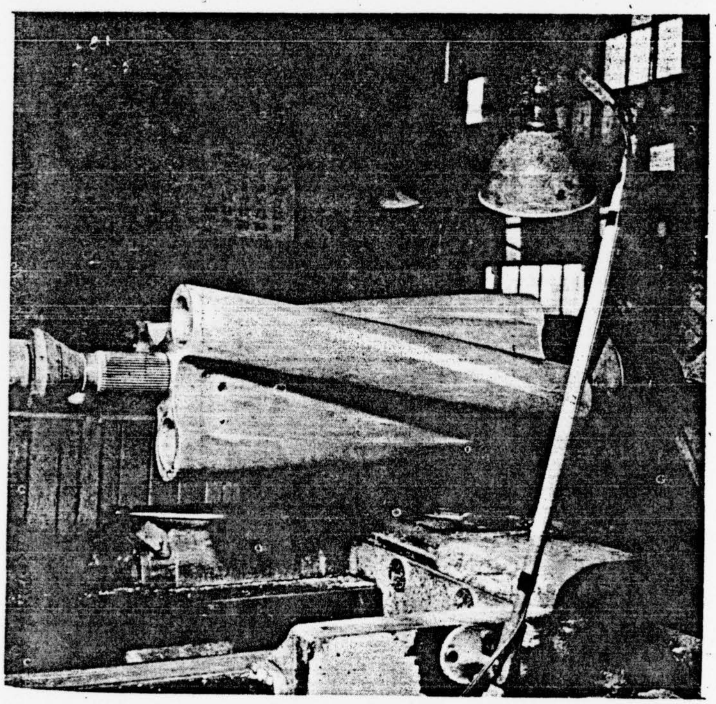


FIG. 9 FAILED BLOWER ROTOR

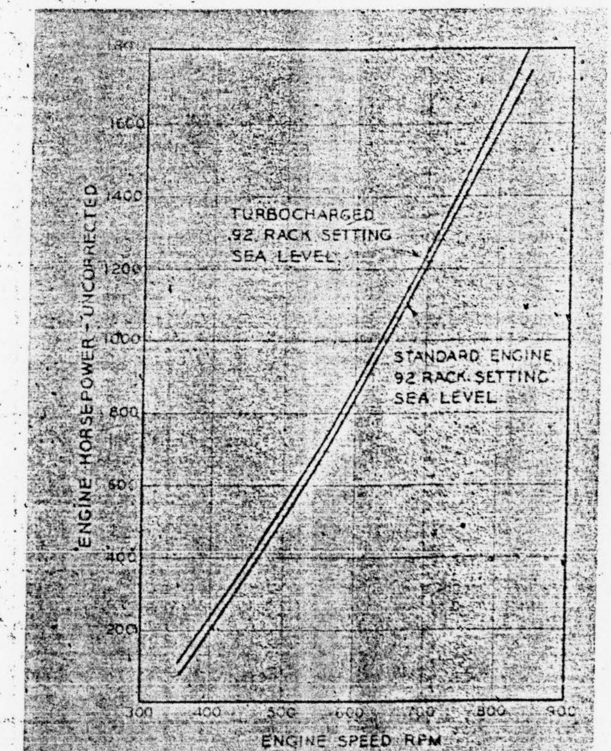
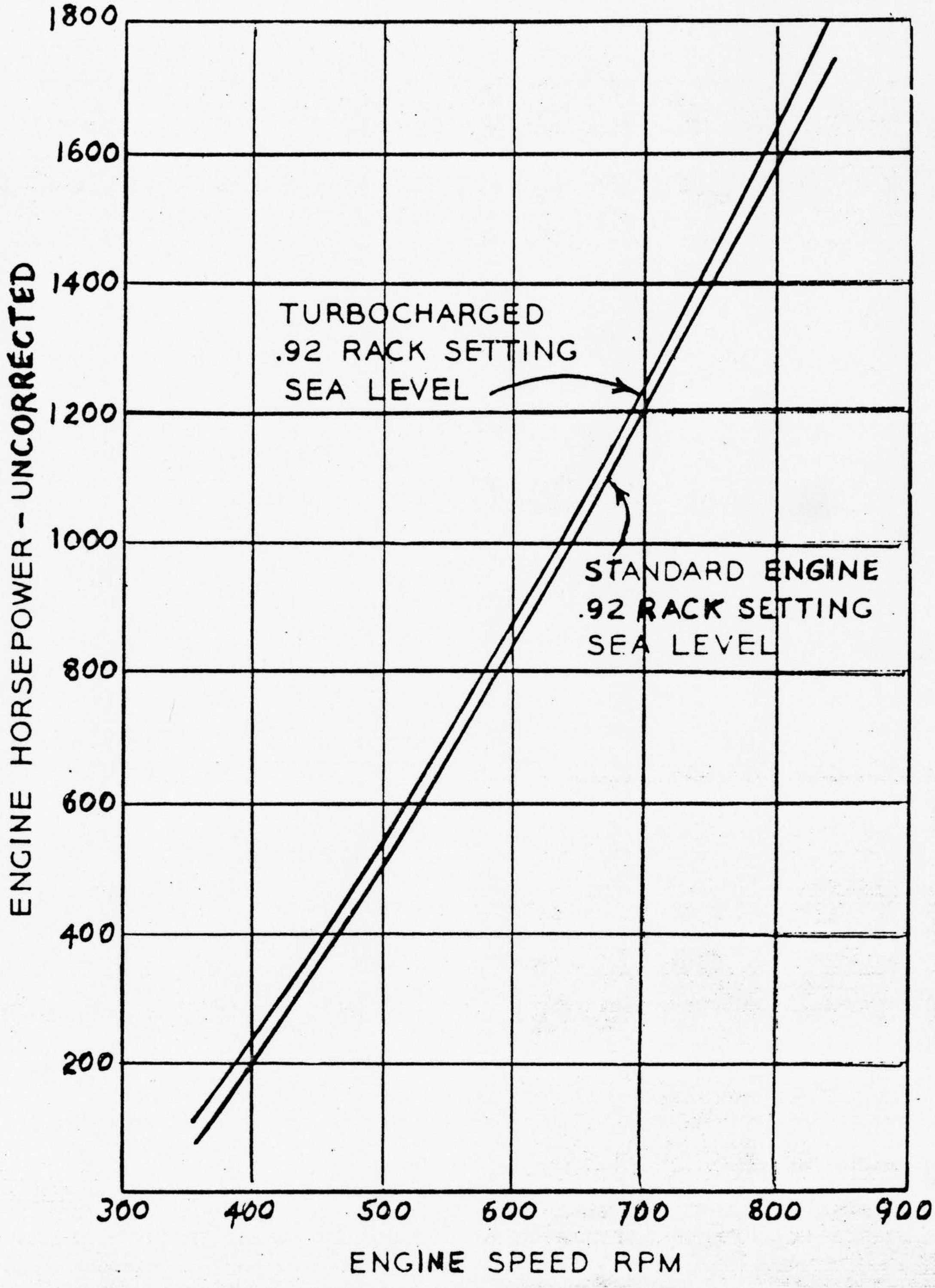


FIG. 10
POWER OUTPUT
OF TURBOCHARGED ENGINE
COMPARED TO STANDARD ENGINE

(See Other Side)



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