Chapter 6

STEAM ENGINES

The first source of mechanical power used in vehicular applications was the steam engine. The heat energy utilized to produce steam was obtained from burning wood, coal, or hydrocarbons.

The basic types of steam engine are the reciprocating, the turbine, and the combination of these two. Each of these three types can be operated as a noncondensing system (which expends exhaust steam into the atmosphere) or as a vapor cycle (which condenses exhaust steam and reuses it in the system). The noncondensing system requires the constant addition of purified water to replace the water expended. The vapor-cycle engine requires a heat exchanger and a cooling fan to condense the steam after it passes through the exhaust ports. Although replenishment of water is not required, the heat exchanger and cooling fan make the vapor-cycle system larger and heavier than the noncondensing engine (see Figs. I-102 and I-103).[1]

When internal-combustion engines and hydrocarbon fuels became readily available at a reasonable cost, the steam engine was replaced by the reciprocating internal-combustion engine. The railroad locomotive was the last holdout for steam-powered engines. However, these steam engines were eventually replaced with internal-combustion diesel engines after industry developed the diesel engine to meet the horsepower, size, speed, and torque requirements of the railroad locomotive.

DISCUSSION

Interest in vehicles utilizing the steam engine is revived every few years, in particular with regard to those vehicles incorporating the vapor-cycle system. In 1949 the Yuba Manufacturing Company of Benicia, California, announced the development of a prototype steam tractor, for the civilian commercial market, that incorporated four reciprocating steam engines, one for each wheel. The power plant, a vapor-cycle system, had a common steam generator for the four engines. Each engine had four cylinders, horizontally opposed, and produced 50 hp. The engines were mounted vertically to an angle drive that drove the planetary axle end. A heat exchanger and a cooling fan were incorporated to condense the exhaust vapors. The system was operated for approximately 10 years. Although firm records do not exist to show the frequency or extent

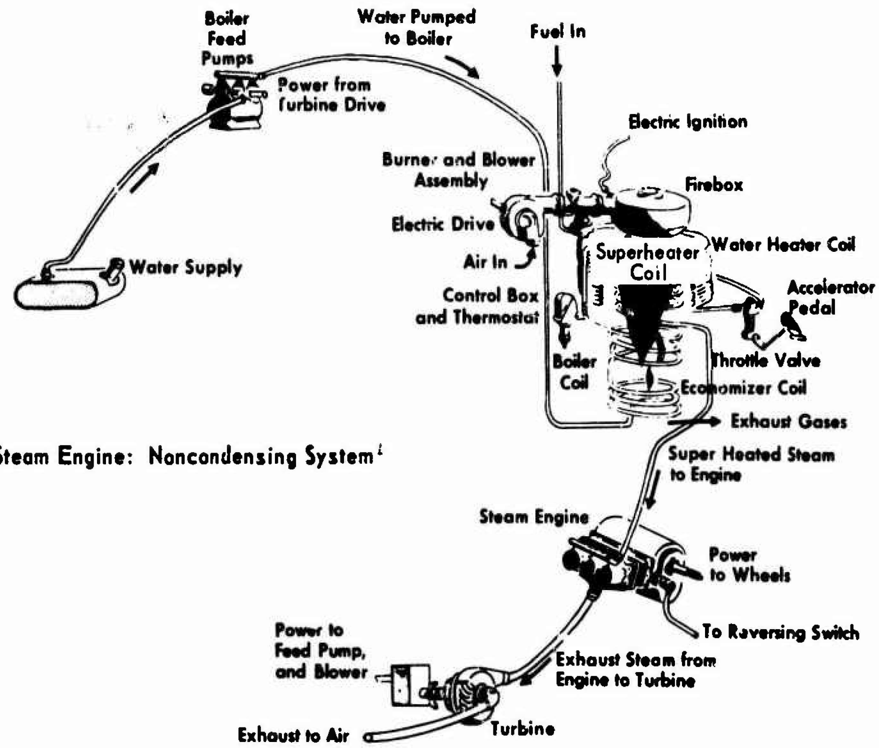

Fig. I-102—Steam Engine: Noncondensing System[1]

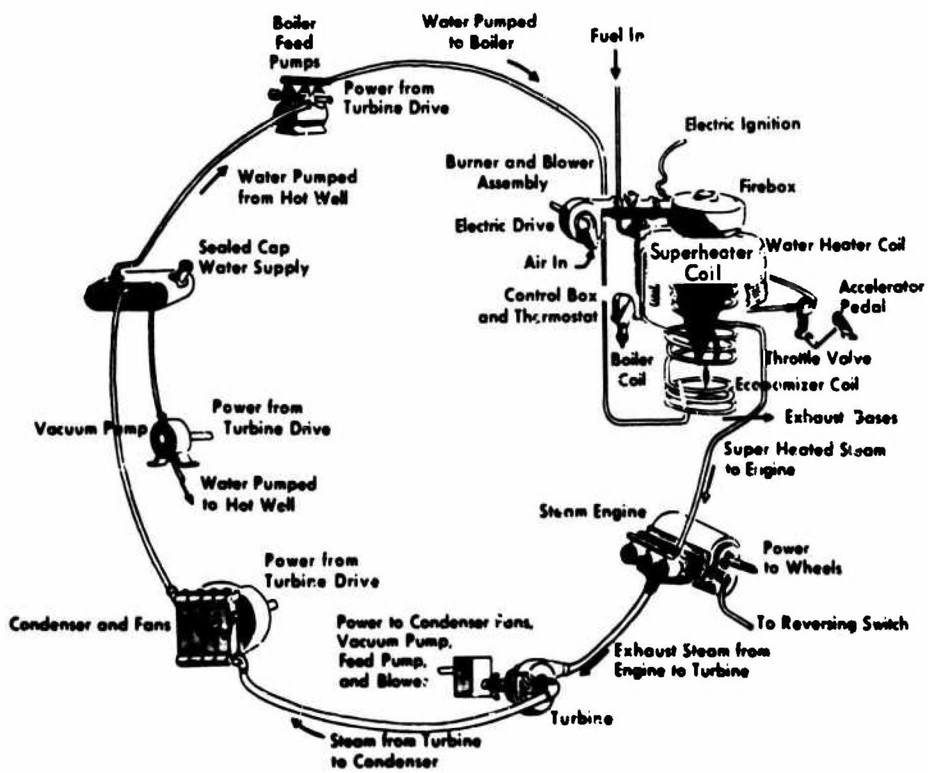

Fig. I-103—Steam Engine: Closed Vapor Cycle System[1] of maintenance required for this system, miscellaneous information received indicated minimum maintenance requirements.

Personnel at the Yuba Manufacturing Company stated that the steam power system is heavier and bulkier than an internal-combustion reciprocating engine offering comparable performance features. The inference was made that it would be difficult to reduce the size and weight of the steam power system. However, the fact that Yuba was not concerned about the additional weight and size of the steam tractor was made evident during the discussion. Statements were made that the tractor was large enough to handle the engine size and that the system did provide additional traction for increasing tractor drawbar pull. The system could generate sufficient pressure in 30 to 40 sec to propel the tractor. A market survey made by Yuba marketing personnel resulted in the decision to discontinue the steam-tractor program.

In 1957 the Operations Research Office of Johns Hopkins University and the Chrysler Corporation prepared a joint mobility study report that presented the advantages of a vapor-cycle power system for a 10-wheeled vehicle.[2] (The concept was similar to that employed in the development of the prototype steam tractor produced by the Yuba Manufacturing Company.) The estimate that the engine would produce 25 hp per wheel was made, yielding a total of 250 hp for the 25-ton vehicle envisioned. A weight of 4540 lb was estimated for the complete system.

The vehicle, as proposed, was expected to operate for 2000 miles before breakdown. The routine maintenance of the system would be less than that required by present-day internal-combustion systems because the vapor-cycle system has fewer moving parts. An analysis of the system indicated that by current standards the vehicle appears to be underpowered, too large, and too heavy, considering the total horsepower output (see Fig. I-104). Specific reasons why this vehicle was not developed were not determined by the study group, but from the data obtained it can be assumed that the proposed steam-powered system did not provide sufficient advantages over comparable and available internal-combustion systems to justify further development.

In July 1962 the Convair Division of General Dynamics Corporation completed a study[3] made to determine the feasibility of applying principles of a vapor-cycle steam-turbine system to any tactical vehicle of the US Army. The results of the study indicated that it was feasible to design and develop a 500- to 600-hp steam-turbine power system for a battle tank. The results of the study were presented to the Army, and a design for the battle tank proposed.

Two turbines, each rated at 250 to 300 hp and driving independently, were proposed for the battle tank to eliminate the need and complexity of a steering-transmission unit. The overload capability of the turbines allowed for an emergency power output of from 50 to 100 percent above rated capacity. This power system was designed to have a multifuel capability, low noise level, and high reliability. Calculations indicated that this steam-power system would have an overall efficiency of 27 percent and that the turbines would furnish 880 lb-ft of torque at stall. Sufficient steam pressure to propel the vehicle could be obtained in 30 to 40 sec. At maximum battle-tank speed 440 lb-ft of torque would be furnished.

An estimate of 4000 hr of tank operation before major engine overhaul was given. The maintenance requirements of the power system would be less than those of an internal-combustion system owing to fewer moving parts.

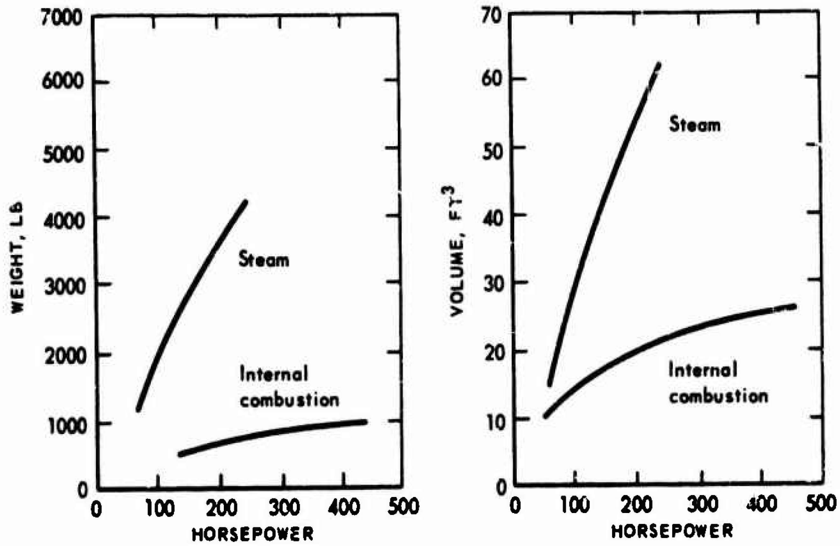

Fig. I-104—Physical Comparison of Steam Engine with Internal-Combustion Engine

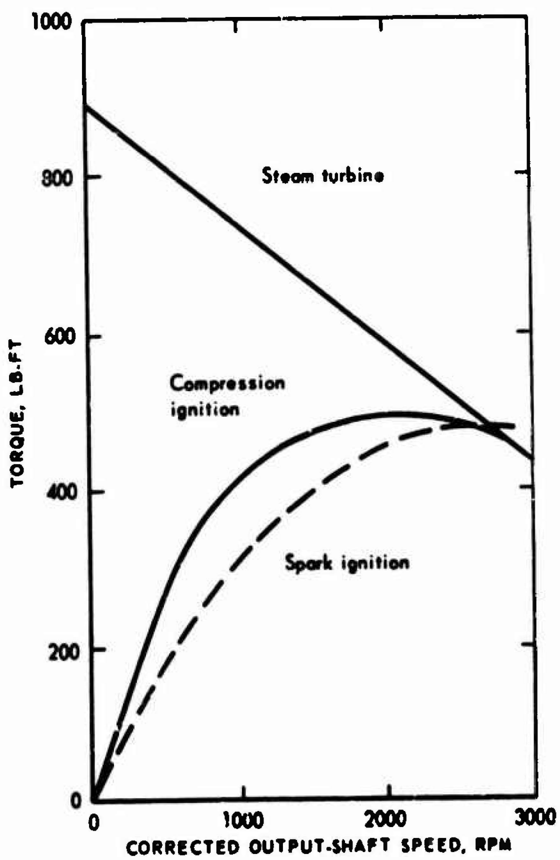

Fig. I-105—Torque Comparison of a 250-hp Steam Turbine with Two Typical Internal-Combustion Engines

A favorable feature of the steam-turbine engine is its excellent torque output at low engine speeds when compared with that of an internal-combustion engine operated at the same speed (see Fig. I-105). Although the steam-engine power system would be improved with the development of better and lighter materials, and the overall weight and size would decrease, these improvements are predicted to be marginal.

CONCLUSIONS

One advantageous characteristic of the steam engine, unsurpassed by most other types of engine, is its quiet operation. This characteristic assumes major importance in those situations where vehicles must operate in silence. In addition, steam-power systems may be operated with various types of fuel and therefore can comply with the present fuel policy of the military.[2,3,4]

The disadvantages of a steam engine for a tactical vehicle, as compared to an internal-combustion engine, are given in the following paragraphs.

Weight. Steam engines are heavier than gasoline or diesel engines of equivalent horsepower. Concepts have not been proposed that would reduce the weight of steam-power systems in the foreseeable future.

Size. The steam engine is considerably larger than a present internal-combustion engine. A noncondensing system would require a large water reservoir. A closed vapor-cycle system would require a heat exchanger and a cooling fan.

Efficiency. The fuel efficiency of a steam engine, at optimum three-quarter throttle, is approximately 27 percent. The fuel efficiency of an internal-combustion gasoline engine is approximately 35 percent, and that of an internal-combustion diesel engine is approximately 38 percent.

Warm-Up Time. Tactical vehicles that use steam engines require start-up time to generate a head of steam sufficient to permit any high-level power output in excess of that required to propel the vehicle at a limited speed.

Maintenance. Steam-engine maintenance time may be regarded as minimal when compared with present system requirements. A strong disadvantage is that personnel would have to be indoctrinated to maintain the vapor-cycle system, thereby necessitating an increase in maintenance training.

Spare Parts. Additional spare parts would be required in the military supply system for vehicles having a steam engine since the spare parts for these engines are not common to internal-combustion engines.

The RAC analysis of various steam-engine concepts and prototype installations indicated that steam engines for tactical vehicles do not offer any significant advantages over present internal-combustion engines. Therefore R&D programs for steam engines applicable to tactical vehicles are not warranted unless the development of vehicles offering silent operation is considered more important than overall volume and weight limitations.

REFERENCES

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4. Robert L. Harris, Robert E. Hulbert, and Marcus Lothrop, "Steam Power Package for Military Vehicles, Concept Study," report on Contr DA-20-089-ORO-36695, Yuba Mfg. Co., Benicia, Calif., 20 Oct 53.