STEAM POWER FOR URBAN TRANSIT BUSES

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by

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SUMMARY

External Combustion Engines (the steam engine is the best known form) are currently receiving much attention, because of a clean exhaust and nearly silent operation. Earlier experience with steam vehicles had established the advantages of an engine that could provide self-starting, rapid acceleration, and reversing without a transmission. Steam developments lagged, however, when gasoline engines evolved into simple, cheap, and convenient forms for private automobiles. Today, technology is able to support a modernized form of steam power system that may be ideally suited to stop-and-go service in the urban environment. The California Steam Bus Project, recently begun with a grant from the Federal Department of Transportation, is a significant first step in determining feasibility.

HISTORICAL PERSPECTIVE

The Rise and Fall of the Steam Car

Private cars powered by steam enjoyed a brief popularity during this century's opening decade. Silent operation, freedom from gear shifting and hand cranking, and "stored power" were advantages. Equally obvious were the problems associated with high water consumption and tedious procedures in "firing up" from cold. Also damaging to the steamer's reputation was the common notion that the boiler might explode. So, even though all of these faults were overcome by later developments, interest in steam cars dwindled when gasoline engines became simple, cheap, and convenient to use.

A Steam Bus Heritage

A fascinating history could be compiled in the application of steam power to buses. Some brief highlights include:

- 1906-1912: The Darracq-Serpollet Omnibus Co., Ltd., produced in Paris. Flash boilers were used.
- 1903-1919: Clarkson steam buses, fueled by kerosene, were operated in England.
- 1920's: Coal-burning Sentinel buses (England) failed to overwhelm the market, possibly because they required two men to operate.
- 1920's: Two Doble-powered steam buses were tested by the Detroit Motorbus Co., acculating over 32,000 miles of experimental service.
- 1929: A Doble steam power system was installed in a Yellow Coach for General Motors.
- 1930's: Henschel buses, powered by Doble steam systems, were operated in Germany. The intent was to reduce national dependence on high-grade fuels.
- 1944: William B. McGorum, General Manager of the Lehigh Valley Transit Co., Allentown, Pa., wrote on the advantages of steam power for city buses: (1)*

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*Numbers in parentheses indicate references given at the end of this paper.

> "Steam is the only power medium other than electricity which can deliver silent motion.
> ...As a practical matter exhaust fumes will be non-existent.
> ...The driver will have power braking at his disposal (From reversed engine torque).
> ...The amount of brute maintenance work will begin to decrease sharply."

We may, at long last, soon have the opportunity to verify these predictions.

INTERIM TECHNOLOGY: COLLECTIVE SIGNIFICANCE

During the years since 1920, development of light steam power systems has been sufficient to show that some of the earlier objections can be overcome, and to serve as an indicator of future potential. It is a matter of record that mobile steam systems have been built that:

- Develop 100 to 700 hp.
- Weigh less than 5 lb. per hp.
- Approach or exceed 20% overall thermal efficiency.
- Have very low levels of noise and chemical pollution.
- Can move the vehicle in less than one minute after a cold start.
- Are of inherently safe design.
- Have automatic control of the steam generating functions.

Not all of the above attributes have necessarily been embodied in the same prototype. However, the level of technology of the interim period is sufficient, if carefully understood and exploited, to build a demonstration power system for a city bus.

The specific cases that follow are cited, in order that the reader may have a base of credibility from which to judge the future potential of this form of power.

<u>Doble Steam Motors (2)</u>

During the 1920's, this California corporation produced around two dozen experimental steam cars. While this venture failed in the marketplace, the legacy of fine engineering may yet make its impact on transportation science. The heart of the Doble system was the monotube steam generator, combining the virtues of high power output and fast response with good efficiency and inherent safety. Electrical ignition and automatic controls were also important innovations.

Figure 1 is a general schematic of a modern steam system, based largely on the principles set forth by Doble. A key feature is the condenser, which allows the same tank of water to be used over and over again.

Besler (3)

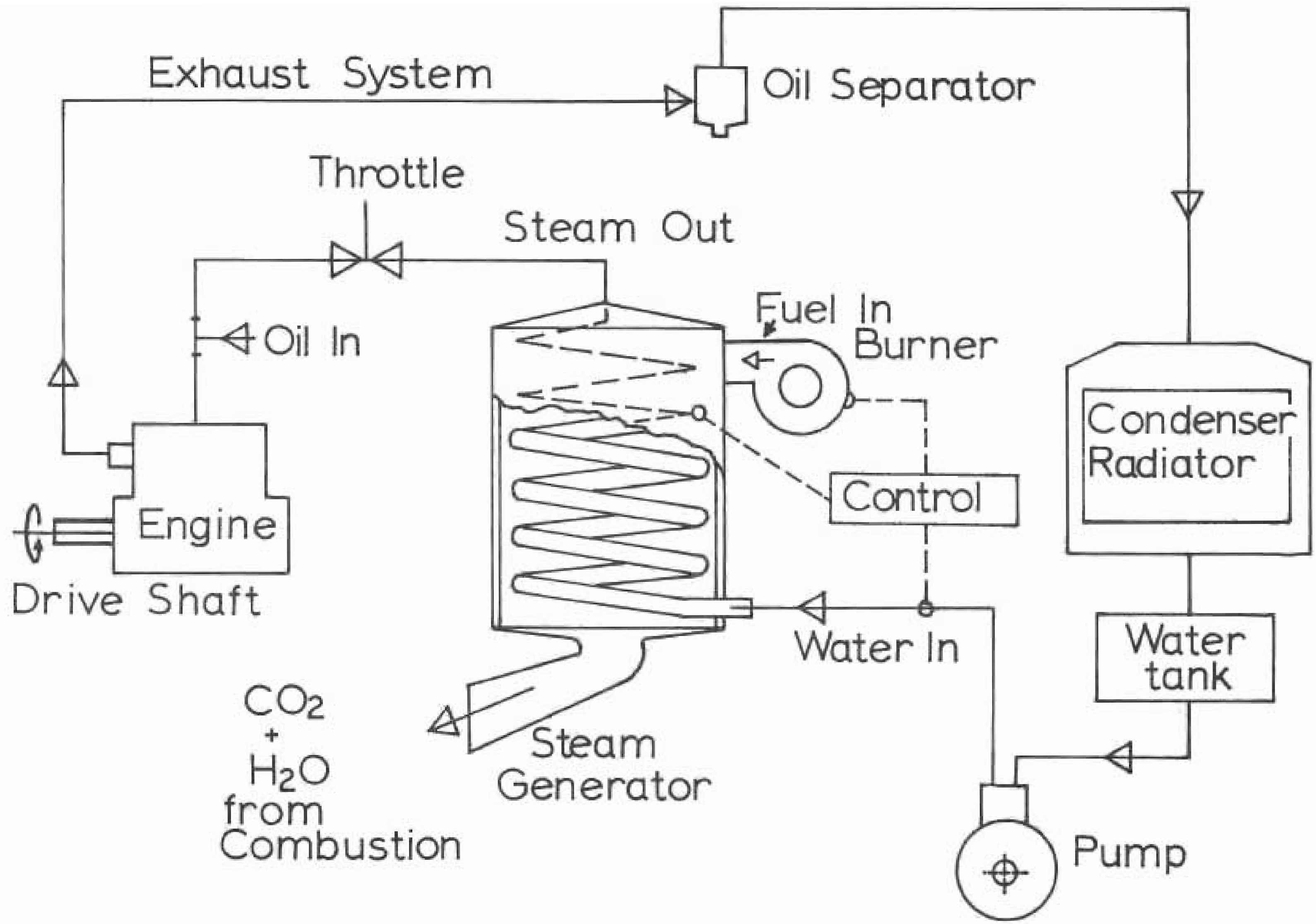
In the early 1930's, the Besler Corporation became the successor to Doble. April, 1933 saw a most remarkable demonstration: William Besler flew a Travelair airplane powered by a steam engine. This condensing power plant, with a dry weight of only 4.5 pounds per horsepower, is believed to be the lightest ever built for its output. One feature of the aircraft was its unusual silence: the pilot was able to converse in shouts with observers on the ground. A photograph of the power system Figure 2, is convincing evidence that steam power is not necessarily a cumbersome, outmoded concept.

Besler also applied high pressure steam to drive a two-car commuter train, operated by the New Haven Railroad in the late 1930's. Utilizing steam at 1,500 psi and 750°F, the powerplant delivered 700 hp and was operated for almost a million miles. Because this was a condensing system, the train could be run 500 miles before replenishment of the water supply was needed. Overall thermal efficiency at the wheels was on the order of 20%.

Henschel (2)

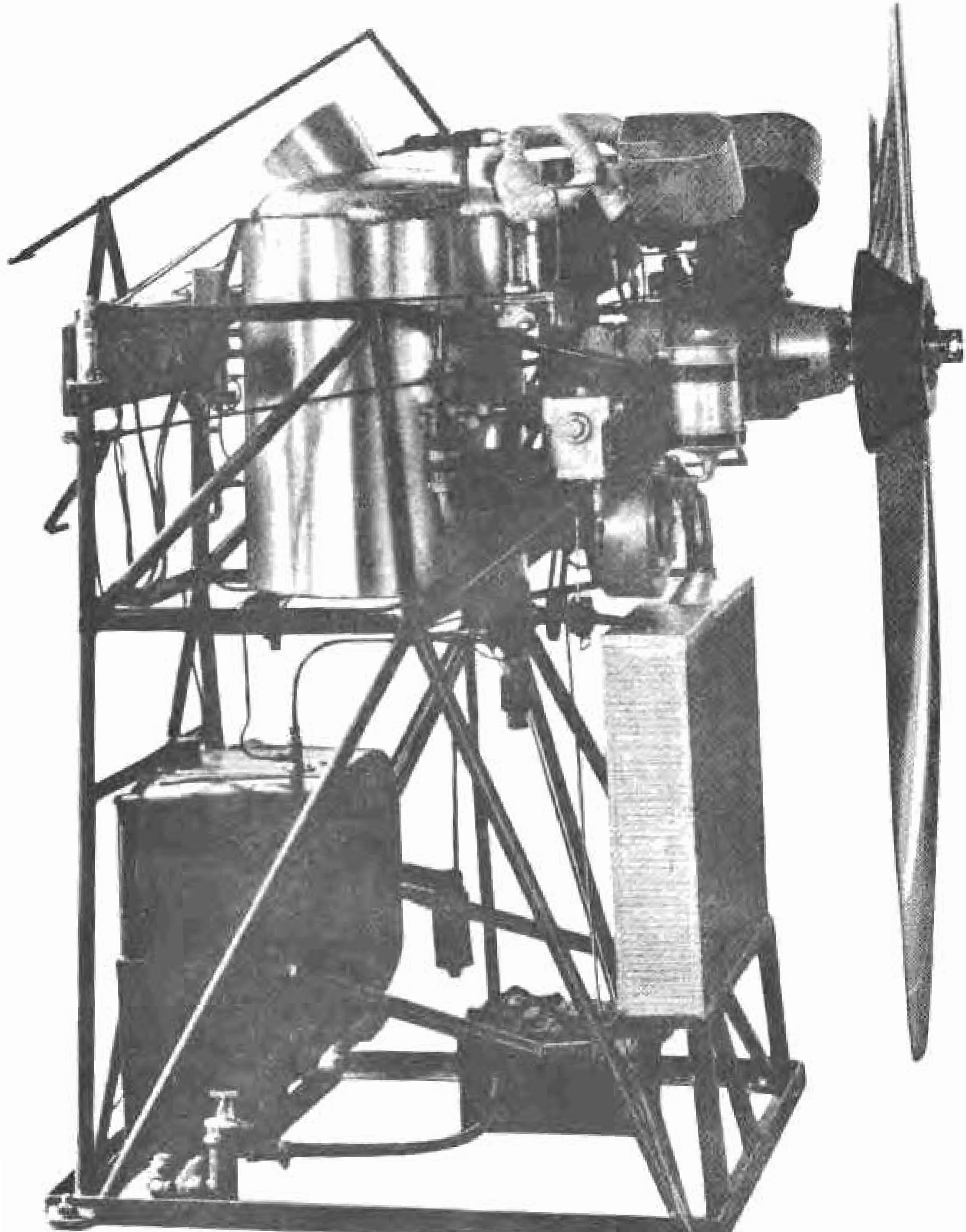
Shortages of high-grade motor fuels in pre-war Germany led to experiments with steam-powered commercial vehicles. During the period 1932-34, Warren Doble was retained as a consulting engineer by the Henschel Works at Kassel, to aid in such developments. Doble steam power systems were subsequently installed in buses, trucks, railcars, and motor launches.

Henschel-Doble buses were used by the Suburban Railway of Bremen (Figure 3). High torque characteristics at the rear axle provided smooth, rapid acceleration (Figure 4). Another advantage was the ease of operation; the



Schematic, Vehicular Steam Power System

FIGURE 1

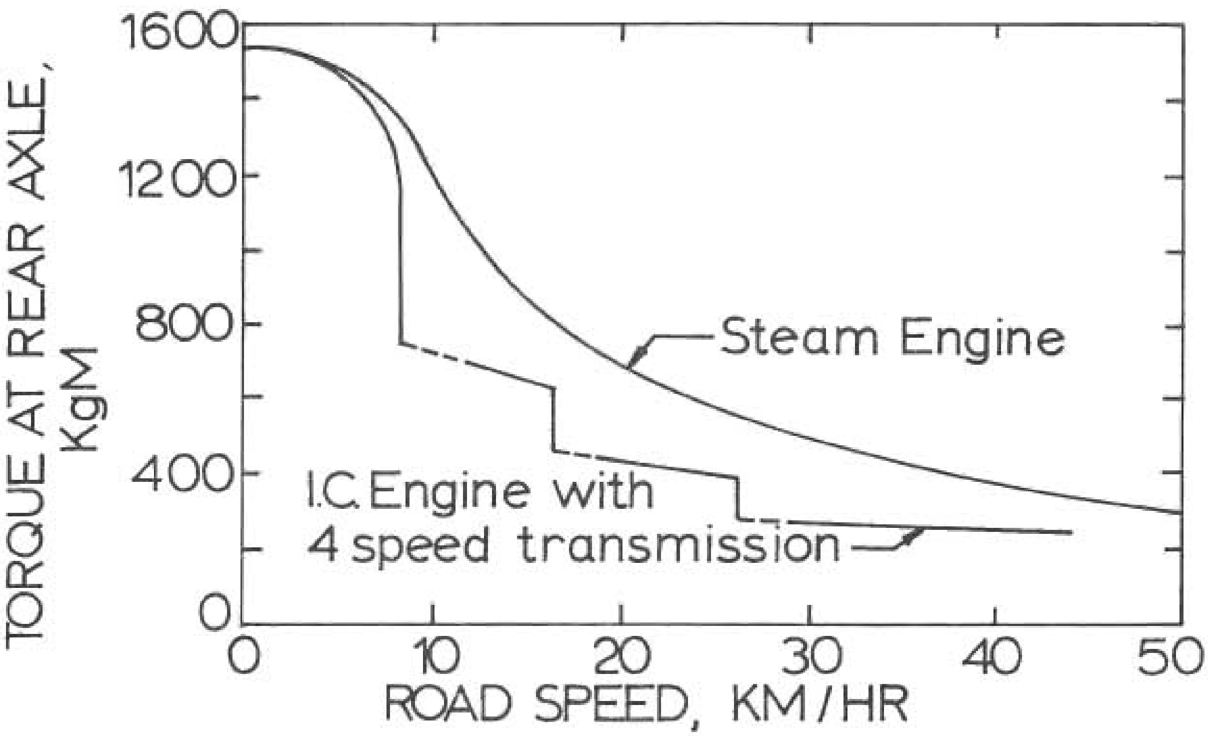


Besler Steam Aircraft Engine (1933)

FIGURE 2

Henschel-Doble Steam Bus, operated in Germany prior to World War II

FIGURE 3



Comparison of Torque at Rear Wheels,
German Steam Bus vs. Same Bus with I.C. Engine (1934)

Reference 2

absence of a transmission eliminated the need for thousands of gear changes per day in city traffic.

With the approach of World War II, German steam vehicle developments were suspended. Henschel did, however, continue to supply Doble-type automatic steam generators for industrial applications until at least 1952.

The Yuba Steam Tractor (4)

Immediately following World War II, there was an increasing demand for large tractors suitable for earthmoving, logging, and other off-road activities. Sensing this growing market, the Yuba Manufacturing Company (San Francisco) developed a steam-powered, pneumatic tired, all-wheel-drive prime mover during the years 1946-51. While production plans did not materialize, the prototype tractor represented a significant advance in this branch of engineering.

The prototype tractor used a separate steam engine to drive each wheel. Since the front wheels could be cramped 90° either side of center, an extremely short turning radius was attainable. A two-speed transmission allowed a choice of high tractive effort (up to 32,000 pounds drawbar pull) or maximum road speed (40 mph). The tractor had a rating of 200 drawbar horsepower.

McCulloch Corporation (5)

The McCulloch Corporation of Los Angeles is well known for the manufacture of chain saws and lightweight gasoline engines. No so well known is the fact that this company built an experimental steam automobile in 1951-54. With the help of Abner Doble, a system was evolved that was considerably smaller, lighter, and more efficient than earlier Doble designs. The steam pressure was 2,000 psi--the highest ever used in an automobile, so far as is known. And yet, because the steam was generated entirely within a continuous coil of small-diameter tubing (monotube boiler), the system was considered to be entirely safe.

Williams Steam Car (6)

The Williams Engine Company of Ambler, Pennsylvania has, with experiments over a few decades, evolved high-speed steam engines of very good thermal efficiency. A Williams car was demonstrated to the writer in 1968; contemporary performance was achieved with an engine displacing only 43 cubic inches. Judging from the rather small size of the condenser on this car, efficiencies are probably high enough to support a claim of better than 20 miles per gallon of fuel consumed.

Williams engines can be used as retarders; a worthwhile saving in brake wear and an increase in operational safety would result if this principle were applied to buses and trucks.

Emissions testing on the Williams car show the possibility of reducing exhaust pollutants by a factor of 10 below I.C. engines employing the best present practice in control devices. Table I gives a general comparison of steam system emissions with gasoline and diesel engines.

THE CALIFORNIA STEAM BUS PROJECT

Following hearings on possible "clean" engines in 1968, the California State Assembly decided that some form of public sponsorship would be needed to spur development. Recognizing that others were already working on gas turbines, electric vehicles, and modified I.C. engines, focus fell upon the neglected area of the External Combustion Engine (ECE).

With the aid of a Federal grant from the Urban Mass Transportation Administration, the Assembly is sponsoring the experimental conversion of three diesel buses to steam power. The first trials of this "new" form of power are scheduled for mid-1971. The objective will be the demonstration and evaluation of feasibility. Ultimate perfection is not necessarily expected at this early date, however.

The legislature will accomplish its purpose through subcontracts. Overall business management is by a San Francisco firm, the Scientific Analysis Corporation. The International Research and Technology Corporation has the responsibility for the technical management of the development and evaluation phases of the work. Engineering development and installation work will be performed by yet other organizations. William M. Brobeck & Associates of Berkeley, California, will be developing one of the power systems. At this

TABLE I

Emission of Pollutants, by steam, diesel and gasoline engines. All figures are parts per million (PPM) by volume for typical power systems.

	Gasoline Engine*	Diesel Engine	Steam System
Carbon Monoxide	15,000	2,000	500
Unburned Hydrocarbons	275	150-500	20
Oxides of Nitrogen	1,000	2,000-3,000	40
Particulates (smoke)	Very low	Noticeable	Very low
Lead Compounds	Present**	None	None

*With present pollution control devices.
**About 2.5 cm^3 of tetraethyl lead is used per U.S. gallon of fuel.

Source: U.S. Senate Commerce Committee Report, "The Search for a Low-Emission Vehicle" (1969) and U.S. Department of Commerce, "The Automobile and Air Pollution: A Program for Progress," Part II, December, 1967.

time, negotiations are proceeding with two other vendors, each of whom will independently construct and install a steam power system.

Local and State agencies will also be heavily involved. Two Bay Area transit fleets, the San Francisco Municipal Railway and the Alameda-Contra Costa Transit District, will supply buses for conversion, as well as facilities and operating personnel. At the State level, the California Air Resources Board and the California Highway Patrol are participating.

Testing and Evaluation Program

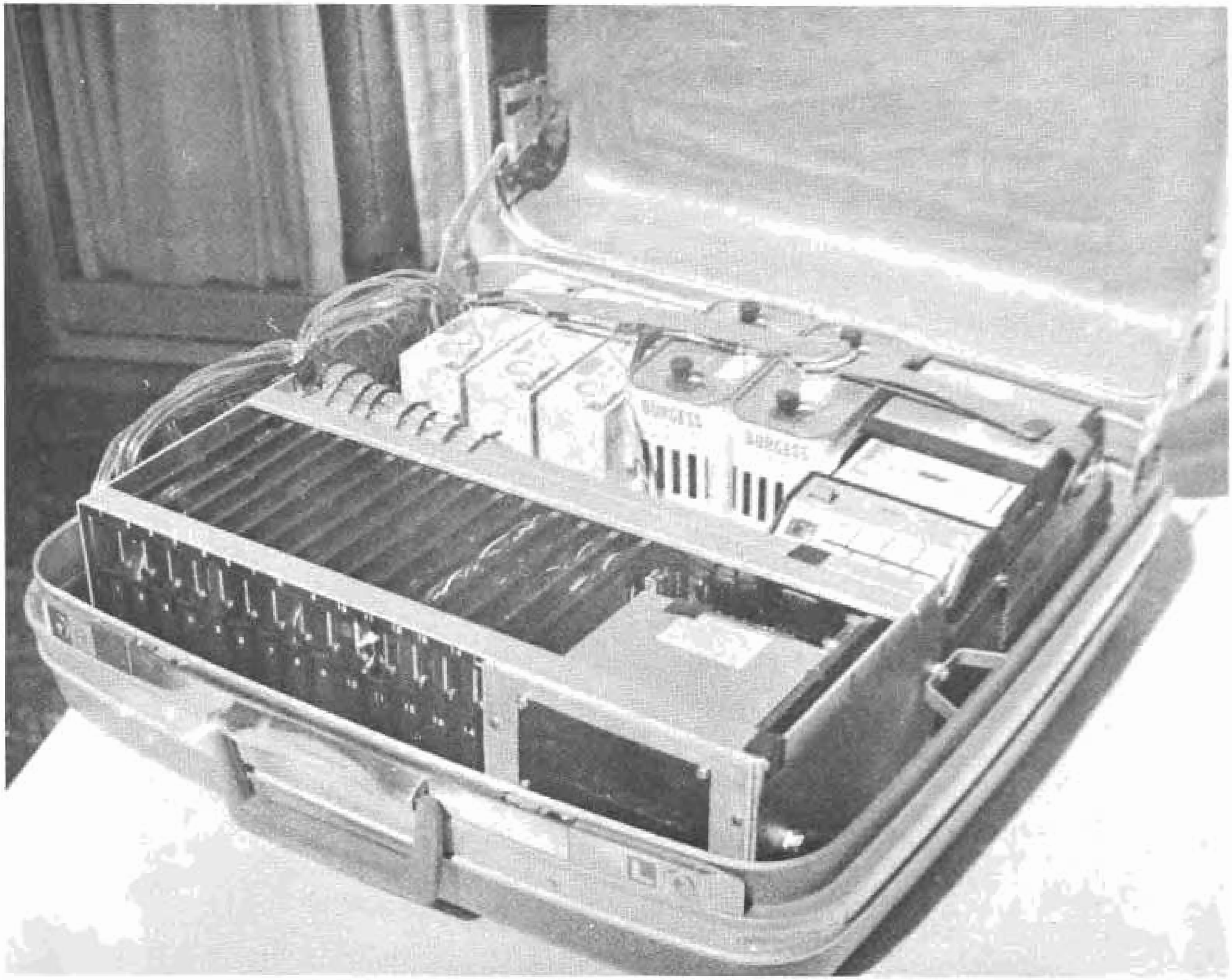
The Steam Bus Project will involve extensive testing, to compare the characteristics and the acceptability of steam vs. diesel power. Such things as road performance, exhaust emissions, noise levels, fuel consumption, and factors relating to operation and maintenance will be evaluated. A public reaction survey and a documentary motion picture are also planned.

Test Techniques and special instrumentation are now being developed for the technical evaluation. Figure 5 shows a self-contained data recording system assembled for vehicular testing in this program. With this apparatus, over 20 operating variables can be continuously recorded on magnetic tape. This tape can then be played back into a computer for statistical and analytical treatment of the data. Any variable that can be translated into an electrical signal can be recorded. Sensors have been developed for continuously monitoring distance traveled, road speed, acceleration, road gradient, and rear axle torque on a common time base. With additional sensors, a simultaneous record can also be made of engine rpm, fuel consumption, noise levels, and various system pressures and temperatures.

Even though this data system was evolved specifically for the steam bus project, uses for solving other operational problems may become apparent.

LOOKING INTO THE FUTURE

The present inventory of engineering knowledge is sufficient to allow an early demonstration of ECE power in city buses. Judging from developments to date, even the early prototypes should be capable of adequate power,



Electronic Data Recording System for
Vehicular Performance Testing

FIGURE 5

low emissions, low noise levels, and can be designed to insure public safety. Other qualities, such as competitive levels of cost, reliability, and fuel economy, will probably evolve only after subsequent refinement of designs. Ordinarily, such advancements require some years of concentrated effort, and product development is expensive.

A frank acknowledgement of technical problems is helpful, to focus attention on needed areas of improvement. Mobile steam systems still face hard questions on lubrication, adequate condensers, sealing techniques, and engine valves. The question of freezing may not be as serious in supervised fleet operations, as it would be with private automobiles, but the search for alternatives to water as a working fluid needs to be continued.

"Space-age" technology (including new knowledge about combustion and heat transfer, new materials, and new concepts of automatic control) is indeed relevant.(7) There will be a need, however, for improvements in the art of transfusing this technology into the requirements of our civilian economy.

Throughout this paper, it has been inferred that the ECE has properties that are well suited to the arduous stop-and-go duty of public transit vehicles. In the light of potential advantages, it is no time to press forward with an adequate level of exploratory work. Then, if the forecast still looks promising, the transit industry should seek the means of insuring an early availability of the ECE.

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