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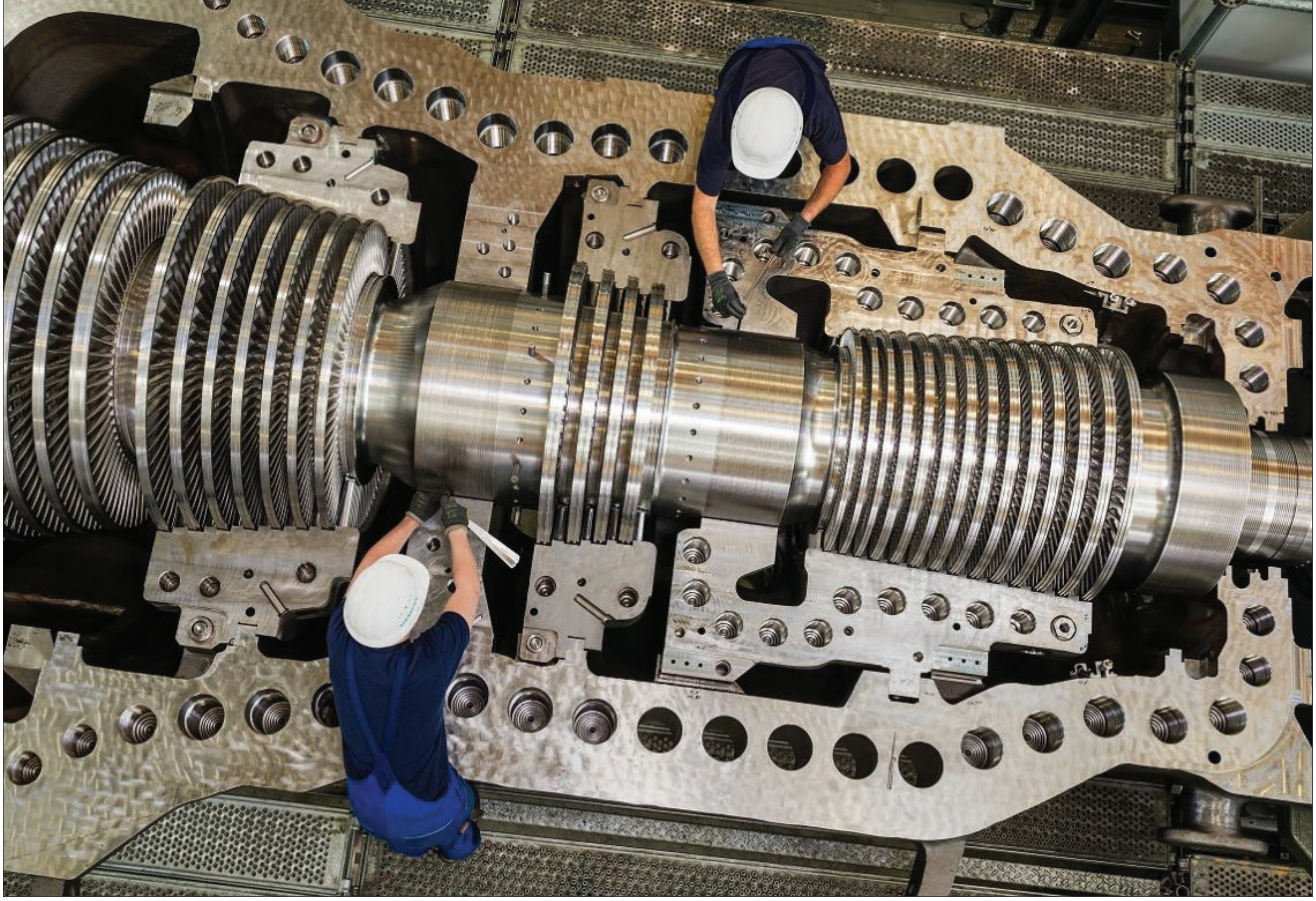
STEL = Steam Turbine Electric Locomotive
GTEL = Gas Turbine Electric Locomotive



This Siemens SST-800 steam turbine is a modern unit designed for stationary electrical generation. Energy in high-pressure steam is converted to rotational power by many stages of precisely curved turbine blades. The "bucket" size and wheel diameter increase as the steam pressure and density reduce. Steam flow in this turbine starts near the upper worker's left hand and passes through the steam turbine's high-pressure section on the right-hand side of the photo. Steam flow is then reversed and redirected to the medium- and low-pressure sections on the left side of the photo. *Siemens*

Steam turbine locomotive energy efficiency

Steam turbines have played an important role in stationary electric power plants and marine applications where their efficiency can be maximized. But applying this technology to locomotives was challenging.

The steam turbines used in the locomotives discussed here achieved less than 20% efficiency. In other words, under the best conditions (what can be called design conditions), they wasted over 80% of the energy in the steam they produced.

Generally speaking, steam turbine locomotives were inefficient because they exhausted huge volumes of steam that still contained much of its energy. However, at least one such locomotive, Union Pacific's Bunker C fuel oil-fired STEL, was designed to recover some of that energy by condensing waste exhaust steam and using the energy in it to preheat boiler feedwater.

It takes a lot of energy to produce steam from water—970 BTUs per pound of water. Condensing the steam releases that energy, some of which can then be captured and reused.

However, while steam turbines operate with maximum efficiency at full speed and load, their efficiency decreases when speed and load decrease. Thus, steam turbine efficiency tended to be poor under normal locomotive operating conditions, including starting, stopping, varying speeds, and changing loads.

The further loss in efficiency during normal operation could be dramatic such as in the case of the Pennsylvania RR's class S2 6-8-6 direct-drive steam turbine locomotive. The steam consumption of this locomotive at 5 mph was four times greater than that of a highly wasteful conventional steam locomotive with similar boiler capacity at that speed.[7] However, at full speed and load, the S2 was more efficient.

Of course, the efficiency of the steam turbine itself was only part of the turbine locomotive's efficiency story. The energy efficiency of an entire locomotive was a function of the efficiency of the turbine multiplied by the efficiency of the boiler (which would include the firebox) and the efficiency of the rest of the locomotive's drivetrain.

For a direct drive steam turbine locomotive, the rest of the locomotive's drivetrain would be the gears, bearings, and wheels. If the design or peak efficiencies of these components were representative values—such as 75% for the boiler, 17% for the steam turbine, and 95% for the gears and bearings—then the design fuel-to-rail efficiency of this locomotive would be 12.1%, calculated as follows:

$$0.75 \times 0.17 \times 0.95 = 0.121 \text{ or } 12.1\%$$

For a steam turbine locomotive with an electric transmission, the rest of the locomotive's drivetrain would be its

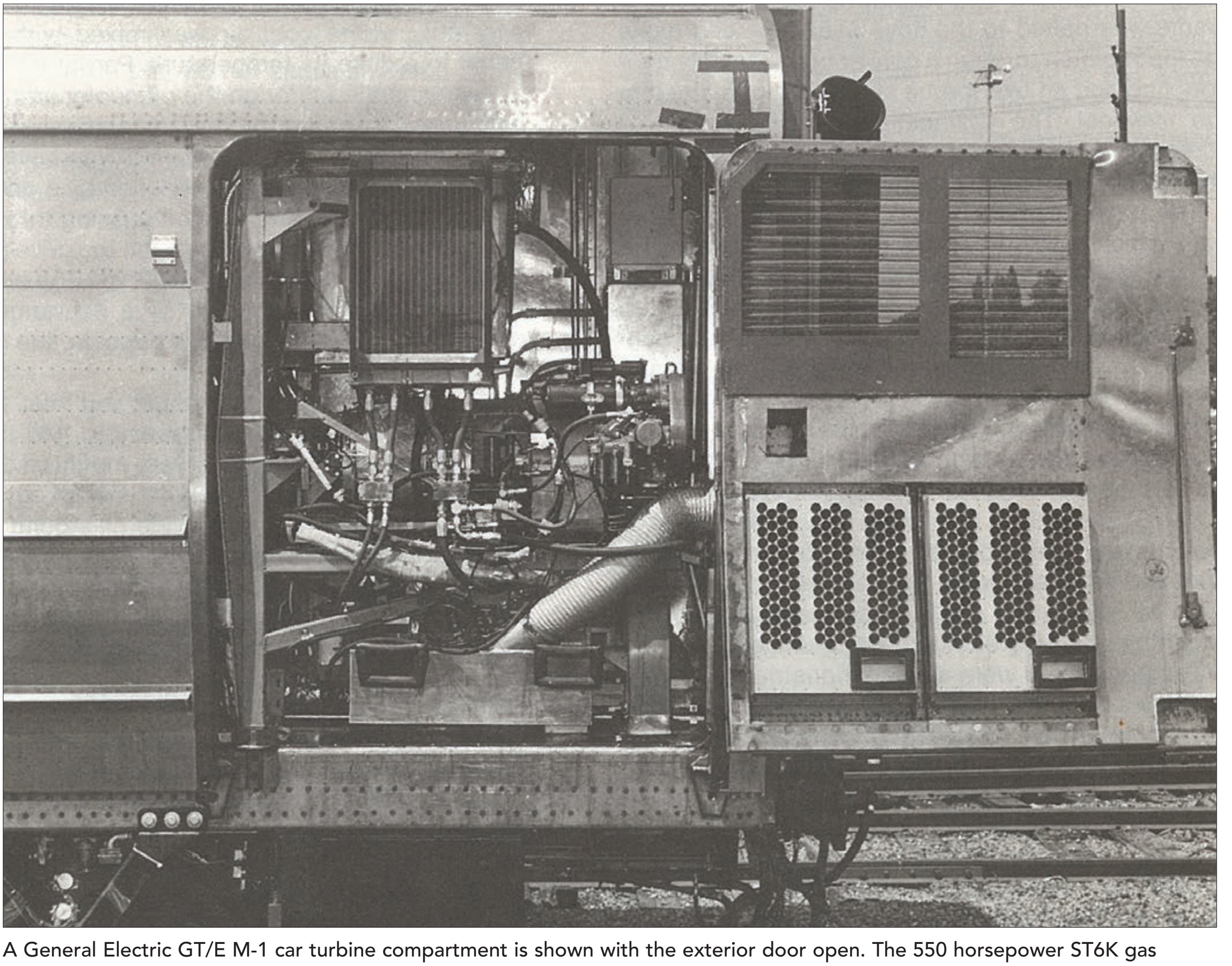
Jawn Henry as possibly "the last stand of the iron horse," *Popular Mechanics*, January 1955. *Popular Mechanics*

Steam turbine energy losses could have been reduced by recovering some of the heat in the turbine's steam exhaust being vented to the atmosphere. One analysis concluded that the overall (fuel-to-rail) efficiency of the TE-1 could have been boosted from 11% to 16% if it was designed to recover heat from the turbine's steam exhaust using an air-cooled condenser similar in concept to those used in Union Pacific's previously discussed unsuccessful STELs.[52] However, this would have required an even longer locomotive with a specially designed tender. As it was, the TE-1 was already too long to be turned on N&W's turntables.

Theoretically, energy from the turbine's steam exhaust also could have been recovered by mimicking a stationary steam power plant and sending the steam exhaust to a second (low-pressure) turbine that would generate additional electricity for use by the locomotive. But, as previously explained, this strategy would have required additional space within the locomotive. Plus, there would have been more complexity, impacting reliability and maintenance.

Most of the power produced by locomotive prime movers directly serves tractive purposes, though some is siphoned off to run auxiliary equipment. In the case of *Jawn Henry*, smaller turbines tied to auxiliary functions consumed 170 horsepower worth of steam.[53] Boiler combustion air drafting problems were addressed with a forced-draft boiler blower.

While improved energy efficiency



A General Electric GT/E M-1 car turbine compartment is shown with the exterior door open. The 550 horsepower ST6K gas turbines were industrial versions of Pratt and Whitney Aircraft of Canada Ltd. PT6 aircraft engines and were designed for quick-change replacement. The turbine, gear box, and generator were an integral assembly installed on rubber vibration isolation mounts. *Courtesy of Metropolitan Transportation Authority*