

Modernising the Fireless Steam Accumulator Locomotive

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The accumulator locomotive was traditionally a fireless steam locomotive used for shunting duties. All designs used a steam accumulator that was essentially a thermos bottle laying on its side. To be energised, the accumulator had to be at least 3/4 full of water. Heating of this water was done by an external steam source. While some designs used a coiled heat exchanger line, most later designs injected superheated steam directly into the accumulator tank, using a perforated pipe near the tank bottom. This design enabled rapid energy re-charges (15 to 30-minutes) to be undertaken every few hours. A cross-section layout of a fireless cooker is at <http://www.rr-fallenflags.org/porter/page44.jpg> .

The last fireless locomotives were 0-4-0's built in Germany during the early 1960's, by the Henschel group, based on research undertaken during the 1930's by Prof. Gilli. These locomotives were small in size and were designed to operate on accumulator pressures of 1,000-psig. Some models used onboard, natural gas fired heaters and a coiled monotube boiler. This arrangement used an external supply of natural gas to heat the boiler and water pumped at high-pressure from an external source. The fireless Henschel locomotives were smaller than American built Heisler fireless steam locomotives, which operated on lower accumulator pressures (200-psig). Nevertheless, a fully recharged American Heisler 0-4-0 fireless locomotive of pre-WW2 vintage could lumber along for distance of almost 95-miles on its own, or tow a train of 10-loaded freight cars for distances of up to 20-miles. Porter fireless locomotives operated on a tank pressure of 150-psig (see <http://www.rr-fallenflags.org/porter/porter-pd.html>). Using the performance data obtained from early fireless locomotive designs, extrapolations were undertaken to increase the operating range and power output of a modern accumulator fireless locomotive, using larger tanks storing higher pressures.

Modern manufacturing techniques can enable long, high-pressure accumulator tanks to be built out of alloy steels, at very competitive prices. A modern fireless design based on traditional concepts, could use multiple high-pressure tanks, each with its own perforated recharging pipe at tank bottom. Each tank could also be supplied with its own onboard coiled monotube boiler. Monotube boilers have been built that operate at over 1,000-psig, with 200-Hp thermal capability and up to 85% heat transfer efficiency from combustion to steam generation. Theoretically, such boilers would only be used for energy recharging where no external supply of high-pressure superheated steam is available. Performance improvements and extended operating range would result from increased thermal storage capacity and improved piston efficiency. Most thermal recharges would be done using stationary, high-pressure water-tube boilers (up to 2,000-psig) fired by gasified renewable (local) bio-fuels, or solar thermal energy stored at high temperature. A multi-tank accumulator fireless locomotive could be fully recharged within 15-30 minutes.

Research undertaken in Australia by Ted Pritchard (Pritchard Steam <http://prsteam.inventdata.com.au>) into modernised uniflow (inlet valve, exhaust ports) steam engines, has shown that in actual service, the efficiency levels of a properly designed uniflow engine could be double that of single-expansion piston engines. The modernised steam piston engine is insulated using modern technology along its outer

(third) layer. It is also jacket-heated outside the cylinder walls to yield higher performance levels. Modern valve control in the form of precise inlet valve cut-off operation, further enhances efficiency. Earlier fireless locomotives used only throttle valve control for speed/power control. Pritchard-type uniflow steam engines could be mounted directly on the trucks (bogies) of modern fireless accumulator locomotives. An alternative engine that can operate on the uniflow principle is the Quasiturbine rotary engine, which can also be mounted in the axle trucks/bogies (<http://quasiturbine.promci.qc.ca/QTIndex.htm>).

High-pressure accumulator tanks enable higher levels of energy to be stored. A lower-pressure downstream tank can allow high-pressure energy storage to be combined with lower-pressure pistons. This approach is analogous to the electronic "chopper" control used in DC circuitry. Small bursts of power are sent to capacitors for temporary storage, while inductors regulate and reduce levels of power flow. A similar system can be used in a steam storage system. In a steam "chopper" system, a valve from the high pressure accumulators would rapidly open (fully) and shut in response to pressure sensitive valves in the cylinder-feed accumulator tanks (the steam "capacitor"). The cylinder-feed accumulator could operate at pressures up to 300-psig, while main storage tank pressures would hold pressure levels of up to 2,000-psig.

A modern steam accumulator locomotive could be built to the same dimensions of the 3-level automobile carriers used on North American railway systems. These cars are nearly 100-feet (30-m) between couplers, 9-feet 6-inches (2.85-m) wide and with a height of 19-feet 8-inches (6-m) above the head of the rail. To carry the locomotive weight, a wheel/axle arrangement similar to that of the American PennCentral GG1 locomotives' 4-6-6-4 layout may need to be used, on a longer bogie/truck-centre spacing. The energy storage capability could be up to 20-times that of a 1960's era Henschel fireless, with at least 50% higher engine brake thermal efficiency than traditional piston designs. Lumbering on its own at 40-Km/hr, the modern accumulator fireless locomotive could have a range of up to 350-miles. A design built to the exterior dimensions of a passenger rail coach (10'6" or 3.2-m wide, 14'6" or 4.4-m high and 85' or 26-m between couplers) could still store over 10-times the thermal energy of a Henschel fireless loco. The main operating niche of such a locomotive type would be in developing countries, where few paved roads exist and where right-of way clearances would allow passage to large locomotives.

The condition of rail lines in some developing nations are such that intercity trains rarely travel at speeds above 30-miles per hour (50-Km/hr) and often slower. This type of operations allows for use of low-powered locomotives that develop less than 1000-Hp (745-Kw). Stops and lay-overs are frequent, operating characteristics that would favour a large accumulator fireless steam locomotive. Recharging of accumulator tanks could occur at rest stops or at terminals, every 25 to 50-miles. A large steam accumulator locomotive could pull a passenger, freight or mixed train over a 50-mile journey segments, distances that are not uncommon in developing countries. Certain rainy

regions in Asia, Central Africa (Congo area), Central and South America would be potential candidates for modernised and improved traditional accumulator locomotive operations. These are regions where rainfall is frequent and water for locomotive operation would be available.

Such locomotives would require very low levels of maintenance and are easily repairable. Fuel supplies for the stationary water-tube boilers would be predominantly locally supplied. A small number of wayside water-tube boilers could supply energy to a relatively large fleet of accumulator locomotives, provided that they do not all need to be re-charged at the same time in the same location (an extremely rare occurrence). The cost of such a fleet of locomotives would be comparatively low, while their availability levels would be quite high (due to modern thermal insulation around the accumulator tanks) and the speed over which fireless accumulator steam locomotives could be re-charged (rarely more than 30-minutes using the perforated pipe with a baffle above it). One person locomotive operation would prevail, while added manpower (stationary engineers) would be needed to staff the stationary water-tube boilers.

In sunny tropical countries where adequate water for steam locomotive operation is available, solar thermal energy could be used to assist in replenishing locomotive energy supply. Large solar heliostats would collect intense solar thermal energy. Insulated fibre-optic lines made from processes aluminium-oxide (purified & clear industrial sapphire) would transmit the intense solar thermal energy into very large, stationary, ceramic-lined and insulated thermal energy storage tanks. Thermal energy would be stored in the high heats of fusion from various metal-oxides. A low-cost material thermal storage material, lithium-nitrate, occurs quite naturally across Southern Africa. The addition of steam converts it to lithium-hydroxide, which has a latent heat of fusion of 185-Btu/lb at 460-degrees C. Superior thermal storage materials include a new generation of metallic oxide polymers (super-molecules) such as aluminium-oxide polymers, having latent heats of fusion up to 500-Btu/lb, near 500-degrees Celsius.

To prevent tank and water-tube corrosion, tank interiors and water-tube exteriors would have to be lined with a corrosion resistant material like carbon fibre or a high-temperature fluoro-plastic. Such tanks can be used on board accumulator fireless locomotives to improve performance and efficiency, by superheating steam prior to entry into and expansion in the engine. A wide variety of thermal energy storage materials have life expectancies of several million alternating deep-drain and full-recharge cycles, with no loss of energy storage capacity. The high cost of replacement electrical batteries may be deferred indefinitely, by using such thermal storage technology. By comparison, electric batteries become spent after several hundred cycles of deep-cycle draining and recharging, requiring costly replacement. A battery-electric system only returns some 50% of the energy put in to it, dissipating the rest as heat mainly during the charging cycle.

A modernised traditional fireless accumulator locomotive could be economical to operate in terms of fuel supply and efficiency. It would also be well suited to operating conditions that presently exist on several "short-line" rail systems or railways in many developing countries. Such locomotives would also be able to operate commuter service (rapid energy recharge at the end of line) and tourist train excursion service. They may even have application in commuter service along non-electrified rail lines in some developed nations. In arid/dry regions of the world, fireless locomotives would need to use a water replenishing technology such as multiple expansion valves and condensing radiators on the exhaust steam. Condensing effectiveness may be improved by using an onboard sealed "cold-tank" containing either ice or dry ice.

A variant of the fireless steam locomotive was the compressed air locomotive, built by the same locomotive manufacturers (Porter, Baldwin, Whistler, Henschel) as conventional and fireless steam traction. The two concepts can be combined into one, for short-distance operation only, in extremely dry climates. The pressurised, saturated water would be used as a thermal storage medium, instead of driving the wheels directly and exhausting steam to the atmosphere. Externally energised onboard water-pumps and monotube boilers would allow for energy re-charging, much in the same manner as the extensively modified locomotives that came from DLM. Compressed air (5,000-psi) stored in tanks in a separate car, would be heated in tubes passing through the water tanks, prior to expansion in a traction engine (such as a quasiturbine). Heat may also be stored in a molten metallic oxide polymer in a lined (to combat corrosion) and insulated tank, with coated (corrosion resistance) tubes passing through the thermal storage tank.

The energy in such thermal storage tanks may also be used to energise a closed-cycle Brayton turbine, using atmospheric air at varying pressure levels as the working fluid. The Escher-Wyss division of Sulzer built a 2,000-Kw closed-cycle regenerative turbines operating on variable pressure atmospheric air, delivering its optimal efficiency (15% in hot weather to 32% in cool weather) between 20% to 80% of maximum power output. In California, USA, the Power Now company has been testing a 7-Kw closed cycle turbine (<http://www.companydr.com/vanaar/PowerNow/FAQs.htm>) using variable pressure air. This type of "steamless" variant of the fireless locomotive would have to store its thermal energy supply in the latent heat of fusion of a metallic-oxide polymer. It could operate in short-line/branch-line operation on several types of railway systems. In passenger service, it could pull tourist/excursion trains, operate in low-frequency suburban commuter and pull short, light intercity trains up to 300-km (at 100-km/hr). It could also pull light intermodal trains (highway trailers on rail axles) of up to 50-cars, on intercity journeys of up to 300-km.

<http://www.internationalsteam.co.uk/trains/newsteam/modern21.htm>