HOW TO PRESERVE STEAM FOR HERITAGE RAILWAYS? STORE IT!

Emission & other advantages of fireless locomotives

Hendrik Kaptein

Introduction

Brexit &c. partly motivated by fear of far-reaching EU emission regulations? (Any other good reasons?)—Anyway: *a "smokeless" future is not that very far away …*

Though this "fireless" story better be of no practical importance at all in any (near) future …

Still it's time to think ahead: *How to preserve the real thing, i.e. working heritage steam, without locomotive firing & attendant pollution?* → FIRELESS LOCOMOTIVES?

1. Countering emission restrictions by biocoal &c.
2. Fireless history / varieties
3. High pressure + superheat
4. (Stationary) (solar) steam supply
5. Operational & other advantages
6. Problems incl. “lack of the right exhaust sight & smell”
7. Rebuilt / new fireless engines
8. Supplementary measures incl. scrap iron firing
9. Agenda

1. Countering emission restrictions

Already practised (on conventional steam loco's):

* Coke firing (intermediate at best)
* GPCS coal firing (may not meet future standards: † …)
* Light oil firing († as well)
* Wood firing (with or without GPCS): "circular" but still (†)
* Biocoal (with or without GPCS): "circular" but still (†)
* (Vegetable "biodiesel" oil firing?) (†)
* (LPG &c.?) (†)

Countering emission restrictions

More options on ± conventional steam loco's:

* Hydrogen
* Iron (again to be explained later)
* Ammonia (NH_3)
* …

(all electrically recyclable, by solar, wind, water &c. power)

May be more "future proof" than today's best practices & improvements of them but still …

Countering emission restrictions

Or hoping & lobbying for exemptions (would be totally rational, heritage steam being a subliminal "part of the problem")

Probably too risky in the end … (Also given other contemporary & future threats)

Countering emission restrictions

Next step: changing or even improving (cursing in the church?!) the conventional steam locomotive?

Much better combustion &c.? (NZ LaMont boiler project)

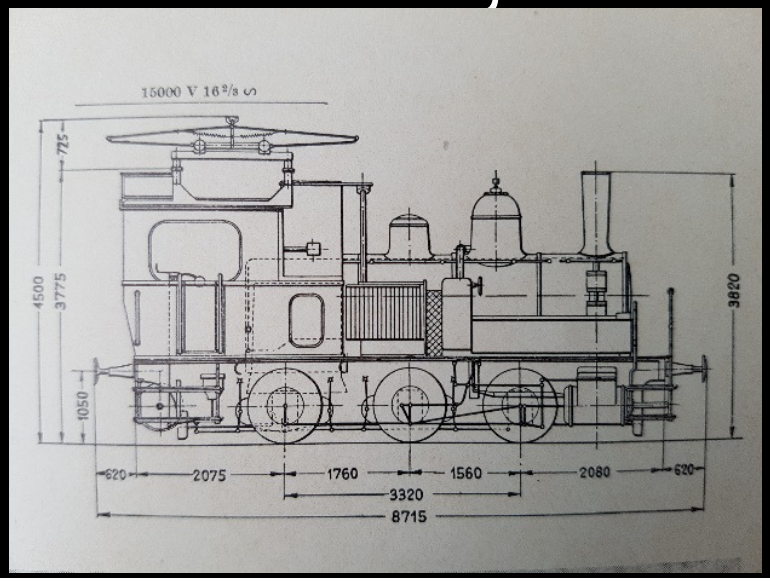
(Has been attempted a couple of times before, with rather limited success …)

But still & approaching fireless steam:

Fireless history & varieties

Fireless history & varieties

SBB Ee 3/3 (WW2): side electrical heaters combined with electrical 36V circulating pumps, boiler itself ± unchanged (unlike "real" fireless locomotives), including "last mile" facility: w/o overhead current enough hot water left for minor shunting work &c., the loco then working as a "real" fireless accumulator engine



Fireless history & varieties

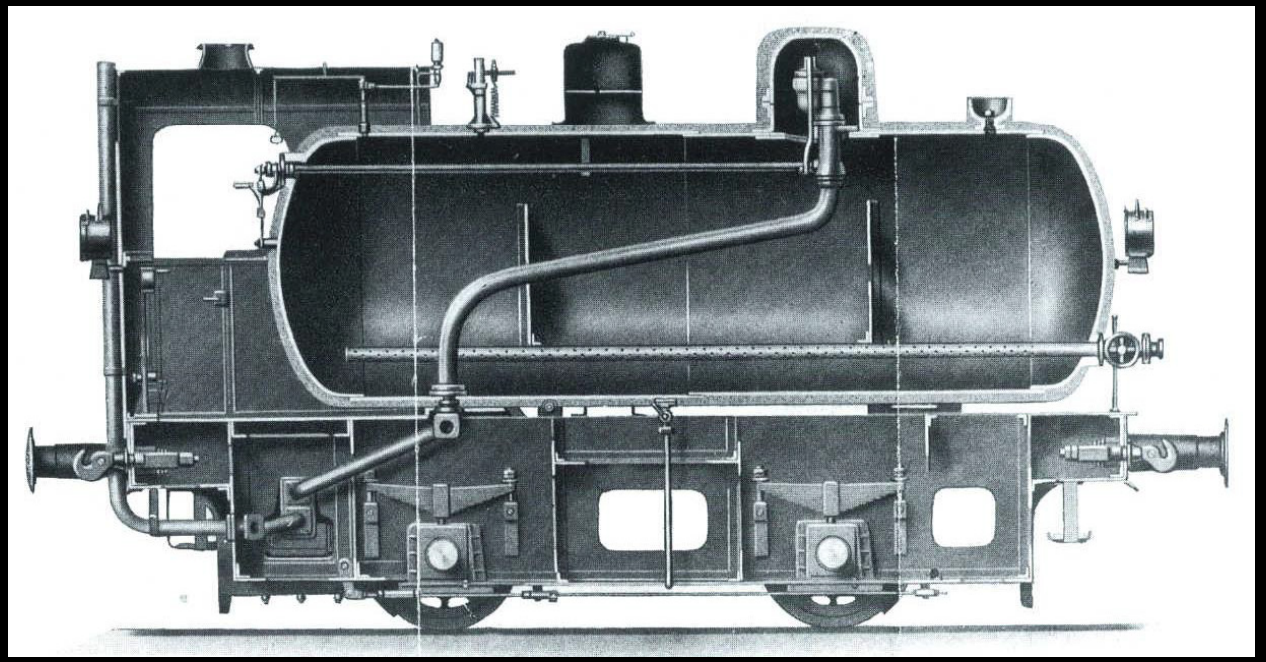
Probably not really practicable in more "normal" circumstances (given aesthetic, financial &c. costs of catenary & other infrastructure) →

FIRELESS "ACCUMULATOR" STEAM LOCOMOTIVE?!

Fed by stationary boiler: steam heating of water in loco "boiler" (steam entering loco boiler as long as loco pressure is lower than feeding boiler pressure) (water level = ± constant ← condensation v. evaporation)

Fireless history & varieties

In Germany alone from ± mid 19th century until 1986 more than 3.500 built:



Fireless history & varieties

Fireless history & varieties

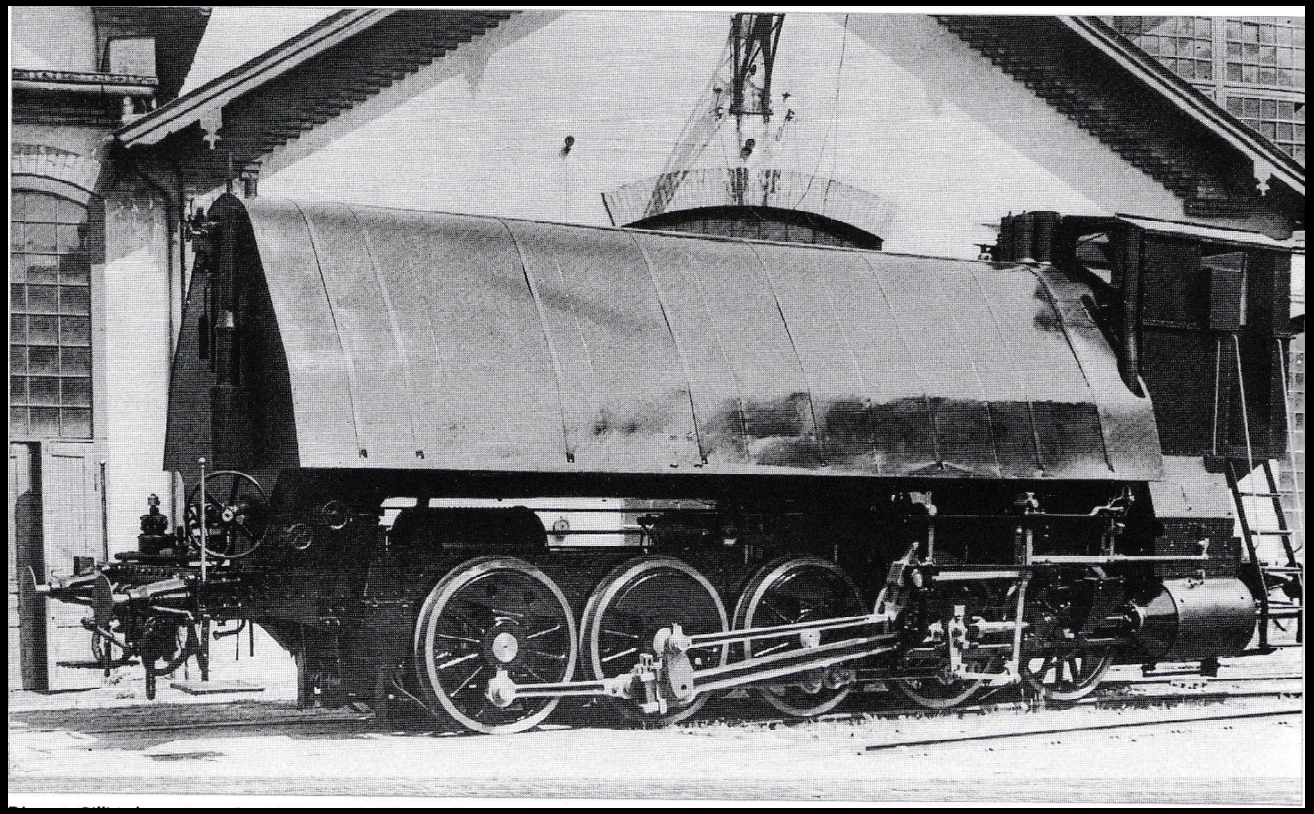
Simplest locomotive of them all!

Working pressure ± 10-30 at (like normal steam locomotives)

Largest low pressure variety (in contintental Europe): 0-8-0, 71 t, 30 at, hauling 700 t goods trains 17+ km (shunting with up to 4.000 t)

However: 1. limited range + 2. pressure drop below workable range →

High pressure + superheat



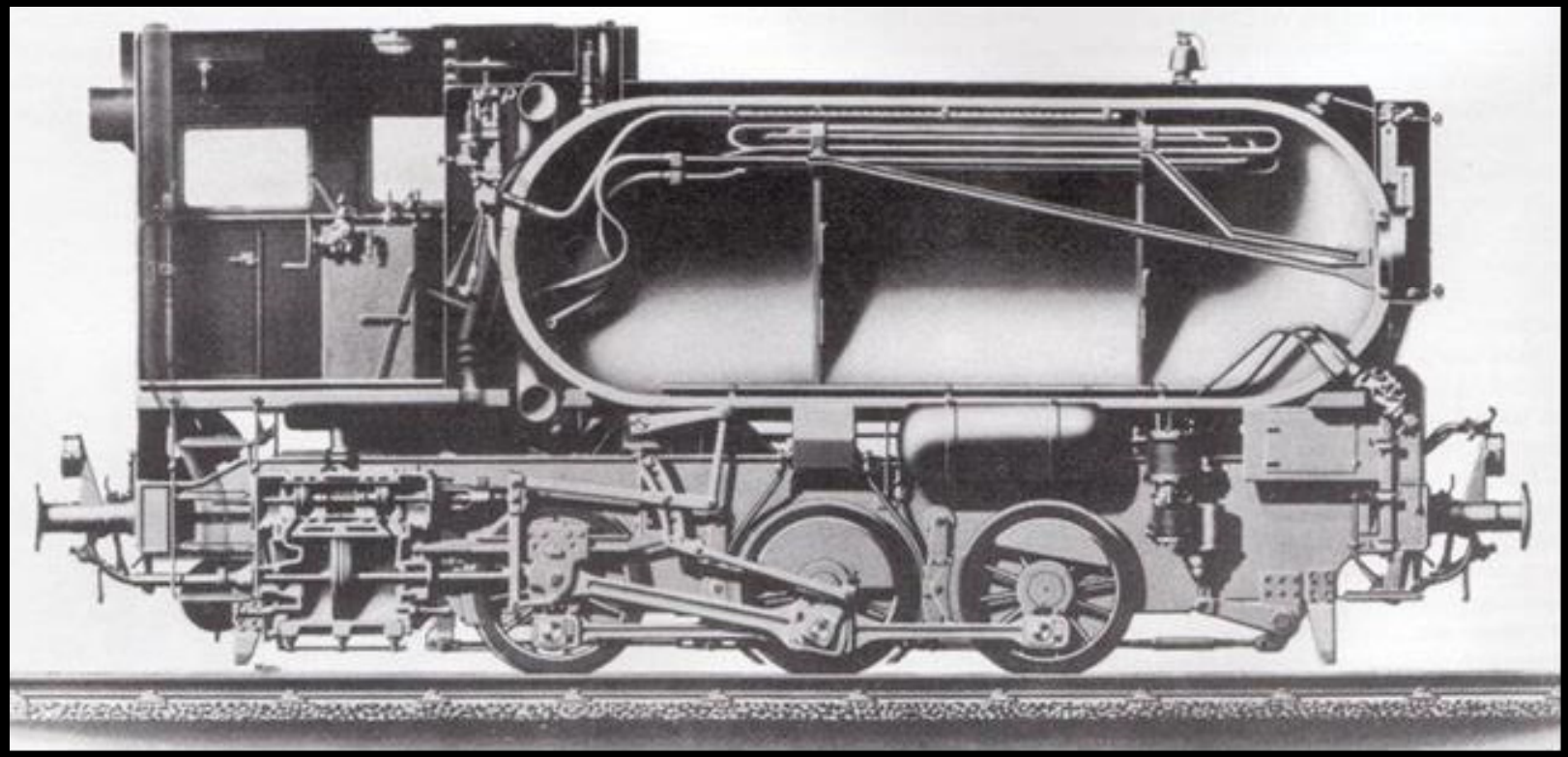
High pressure + superheat

First Gilli locomotive (1934), three drums, 120 at, superheated, gave excellent service, like its numerous successors

Based on Gilli's pioneering work on high pressure stationary steam accumulators

("Overtaken" by diesel & electric "fashion" from the fifties + appendages no longer available / repairable e.g. steam air pump parts …)

High pressure + superheat



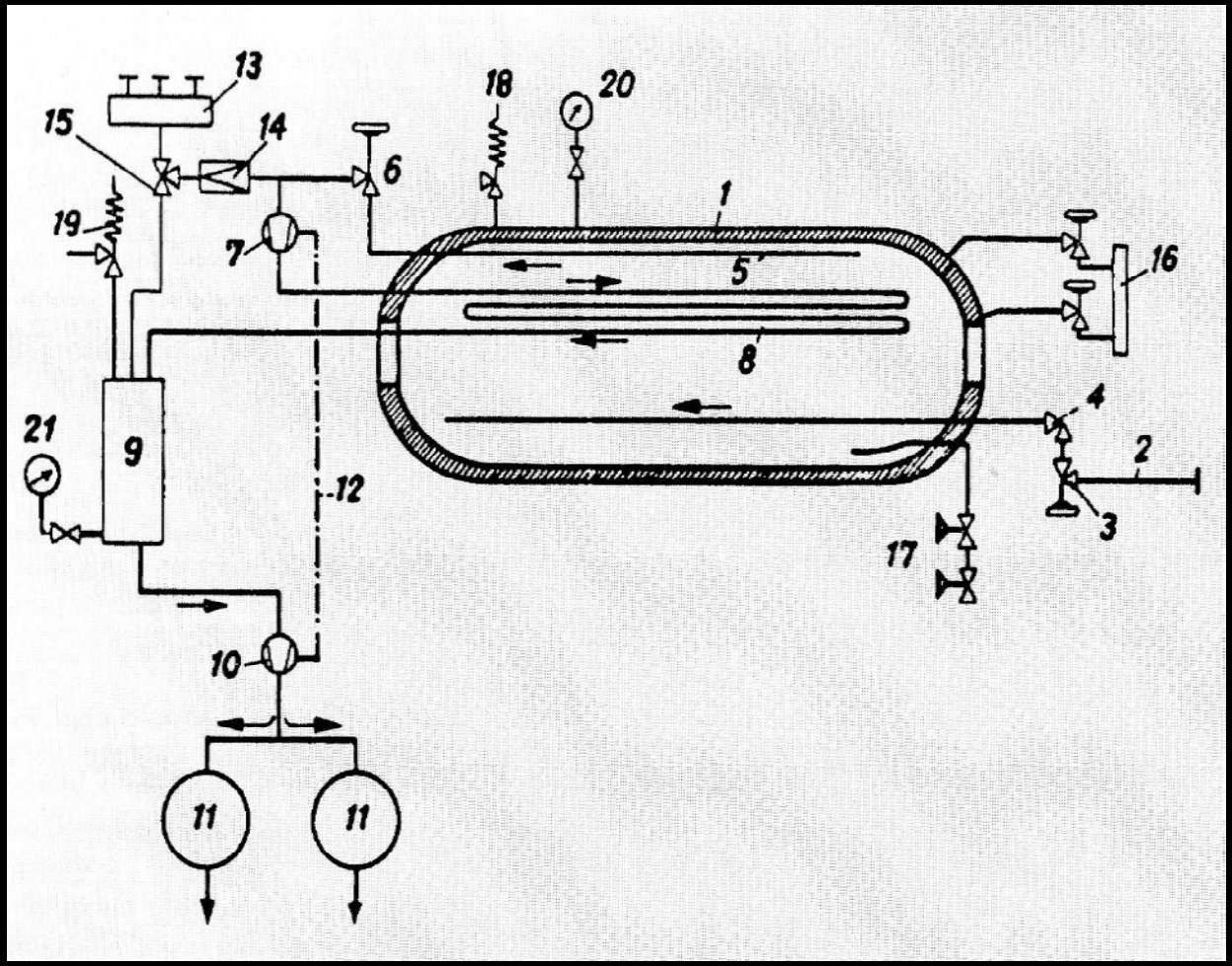
High pressure + superheat

* *High boiler pressure* (theoretically up to critical pressure, in practice up to 120 at) & temperature (320° C at 120 at, 370° C at 200 at) → low(er) pressure *superheated* working steam

* *Working pressure ± 15 at* (saturation temperature = 200° C), related to:

* *Constant pressure* over ± complete working range → much better engine efficiency than lp, again incl. overload

High pressure + superheat



High pressure + superheat

Slightly more complex than lp: incl. reducing valve / hp regulator, superheater, receiver, lp regulator &c.

Storage capacity (120 at, may be higher up to critical pressure) about *double* that of lp (14 at).

Higher weight (← stronger boiler drum) no problem: steel drum(s) is / are part of heat accumulator

(Some later versions [Krauss-Maffei] w/o superheater: balancing of efficiency v. storage capacity, superheating not very effective at low / shunting speeds anyway)

Steam generation

Simplest solution: “back to Ee 3/3” (not that stupid in the end), without pantograph: electrical heating *in situ* by heating elements in boiler drum

Specific advantages (given acceptable financial + environmental costs of electricity): still safer than normal fireless loco, given low voltage and absence of (superheated) steam feeding including “weak spot” in boiler drum

Loco may be used as stationary steam accumulator as well (then to be fitted with steam inlet / outlet valve, otherwise water valve only)

Stationary steam supply

* Conventional *combustion heat sources* (again: coal, wood, [vegetable] oil &c., preferably "circular" / sustainable): much better combustion compared to loco's but probably not future proof + other problems
* *Waste heat* from stationary power plants, steel works, other industries: heat transport problems &c.
* *Electricity* (generated by renewable / "eternal" sources)
* *Iron* &c. (again: to be explained later on)
* *Combinations* of the above

Stationary steam supply

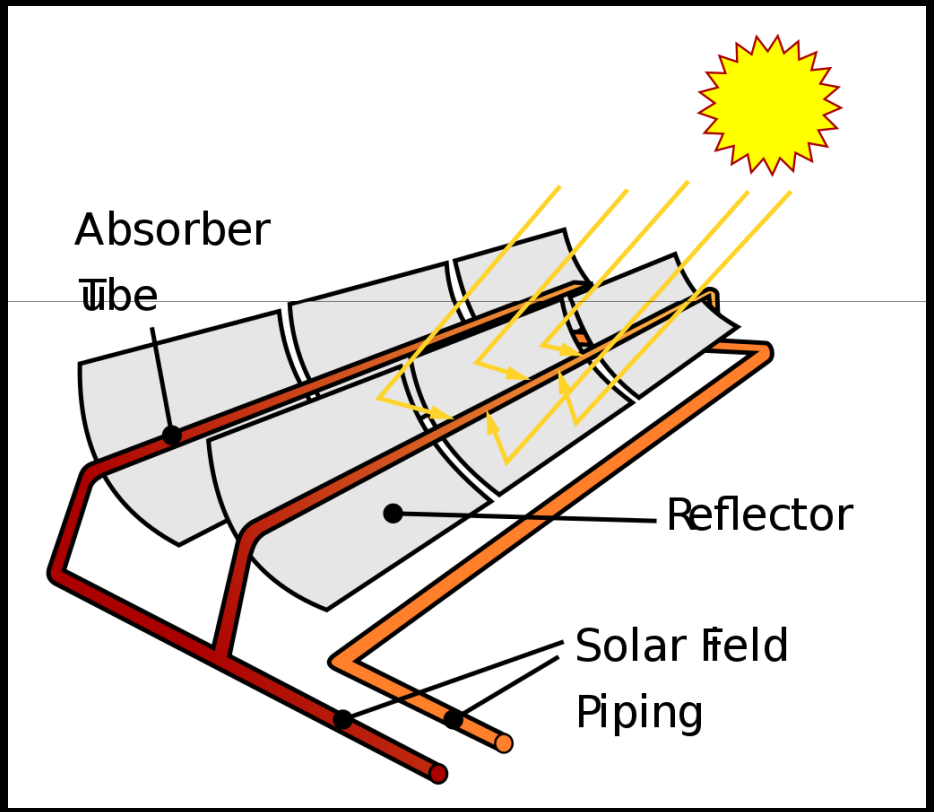
* DIRECT SOLAR POWER: “simple”, leaving out the 60+% efficiency loss in generating electricity by mechanical power (Carnot / Kelvin)

    + May be combined with other energy sources

    + Given (state of the art) insulation technology: cheap, safe & environmentally friendly (general) energy storage as well

(Stationary solar steam power by reciprocating engines again!)

Stationary steam supply



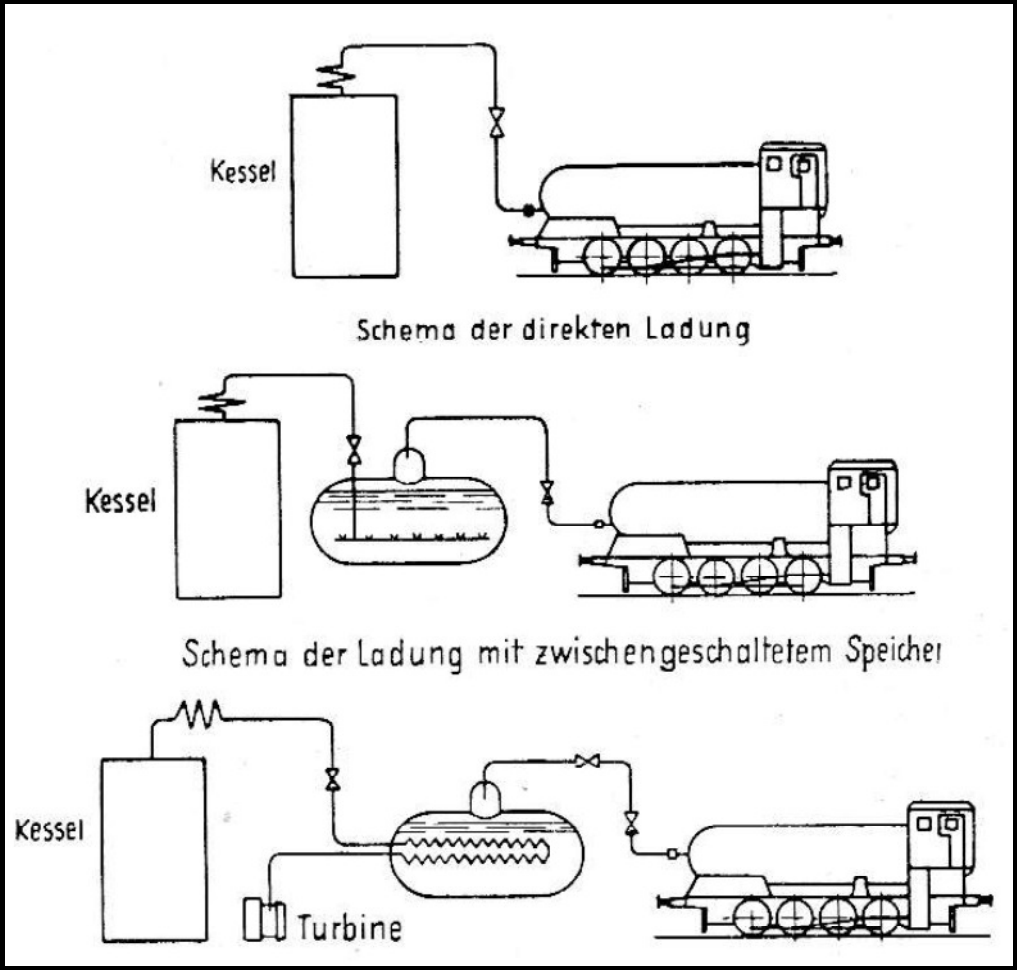
Stationary steam supply

May be low pressure even for high pressure fireless loco's: again by superheating (given relationship of water / steam temperature + pressure)

E.g. 320° superheated steam (at ± any low pressure e.g. 15 at) → 120 at (saturated) steam pressure achievable in boiler drum

(See before on things "the other way round" in the loco itself, feeding lp superheated steam to the engine)

Stationary steam supply



Advantages

* *Environmentally friendly* / future-proof (as long as visible exhaust steam = water will not be limited / prohibited) (+ no sparks → no fire risks)
* Like "normal" steam locomotives (for in / outsiders)
* *Cheap, low tech*, simple(r compared to fired steam loco's) mainly in boiler construction & maintenance (= ± 2/3 of normal steam loco total maintenance costs …)
* *Safe*(r than conventional steam locomotives) (even at speed)
* *One person operation* (+ no need for fireman training)

Advantages

No ± fixed relationship between boiler & cylinder size as for "normal" steam locomotive (!)

E.g. high power needed over short distances: small boiler & big cylinders (within adhesion limits)

Light loads over long distances: the other way round (within limits of dead weight / mechanical efficiency)

(Related to wide margins of overloading as discussed before)

Advantages

* Good / better overall efficiency (big boilers better than small ones, "loco boiler too small", no back pressure, ...)
* Much less "stand-still" time compared to normal steam loco's
* Stationary steam plant not necessary ← further "Ee 3/3" simplification (if electricity is available at acceptable cost)
* Heritage Ry stationary steam plants may be parts of larger energy networks, either as main plants or as auxiliary plants (apart from long distance transmission problems by pipeline and/or possible rail / water / road transport of high pressure steam containers)

Problems

* (Still) LIMITED RANGE? Not really a problem with "big" engines with light loads on short heritage lines. (Waller: hp loco with 100m^3 boiler with 250 t train load = 200+ km range*)
* DEPENDENCE ON CHARGING STATIONS (no issue for local heritage lines)

Main line steam: big engines*, high pressure (± doubling storage capacity) + (mobile) charging stations (see before) along the line (± 20 mins) (See later on the Wendler project in Eastern Germany)

Problems

* Internal acceptance ("conservative" staff, not always bad)
* Transition costs
* Part of traditional steam locomotive mechanical problems (frames &c., to be discussed later)
* Public acceptance: sight, smell & some sound deterioration (environmentally friendly oil perfume + colouring? Counterpressure to be put up again so as to avoid too much "hush-hush"?)
* Loss of heritage status? Rebuilts acceptable? … … …

Problems

Quantification of overall costs & benefits presuppose specific application at least → p.m. for now

On the other hand: the stronger the environmental "pressure", the less relevant such quantifications are (unless they imply [total] lack of feasibility …)

Rebuilt / new engines

Rebuilts probably restricted to low pressure thus w/o superheating (but see later)

Retaining outer form, removal of firetubes, firebox to be filled with insulation material / removed / …

(Freeing of exhaust, balanced against too silent "hush-hush"?)

Then still eligible for heritage status?

→ Ee 3/3 style: unaltered boiler, fed by "outside" steam

Less capacity, may still be feasible for short distance / light load heritage work

Rebuilt / new engines

New engines preferably high pressure superheated

(Though low pressure w/o superheat has first cost + operational advantages possibly outweighing better hp efficiency & range)

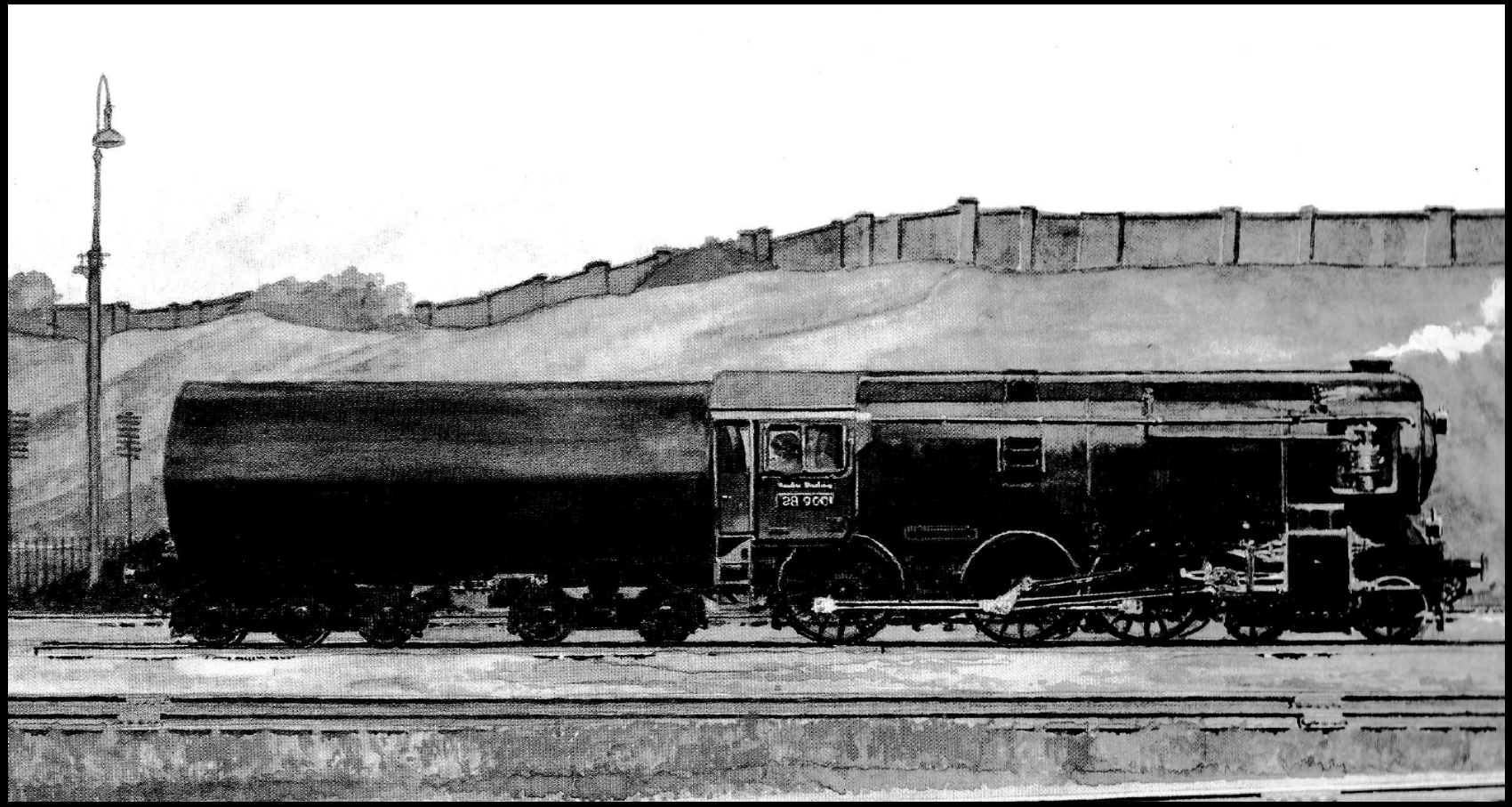
Outer form like conventional steam locomotive

Cylinder jacketing (certainly so with lp engines)

(Compounding) (+ bigger cylinders ← lower back pressure)

(No "improvements" w/o previous successful track record, apart from Jamie Keyte suspension &c., doing away with the second largest / costliest maintenance issue)

Rebuilt / new engines



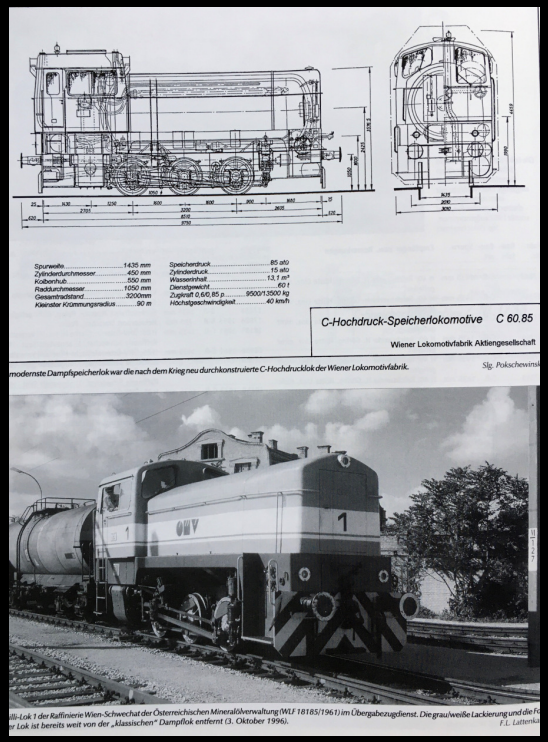
Rebuilt / new engines

Plan for 11 rebuilt P8 / 38^{10} loco's, by Hans Wendler (rightly renowned steam loco engineer), Gilli-style high pressure reservoir (13 t) incl. tender (6,5 t) reservoir, to be charged at one central point, running 220-480 km per day, 70 trains daily, covering considerable distances between Eisenach, Meiningen, Ilmenau, Arnstadt, Saalfeld, Nordhausen, Erfurt, … (200 km+ return trips). (Again) sparing a lot of fuel, maintenance costs &c.

(From Robin Barnes, *From the files*, 2018)

Rebuilt / new engines

Even non-heritage? For developing countries as well? But then the history of transport + so much more is not necessarily rational …



Supplementary measures

Again: recyclable IRON powder firing? ($Fe \rightarrow Fe_2O_3$ and back again), high energy content (// electrical batteries), no CO_2!

Firing scrap iron including rest material from newly redundant coal fired engines → no recycling costs

Small scale plants already in succesful operation (big brewery in The Netherlands &c.)

Supplementary measures

More advanced heat storage material: stationary or even "on board" (molten salt, …) (Look for "Thermal energy storage": interesting discussion)

&c.: see also & generally Roger Waller / DLM: knowledgeable & enthousiastic proponent of fireless steam!

Best technical source: A. Giesl-Gieslingen, "Die Hochdruck-Dampfspeicherlokomotive" *Lok Magazin* (118, 1/2-1983), pp. 32-41

Conclusion

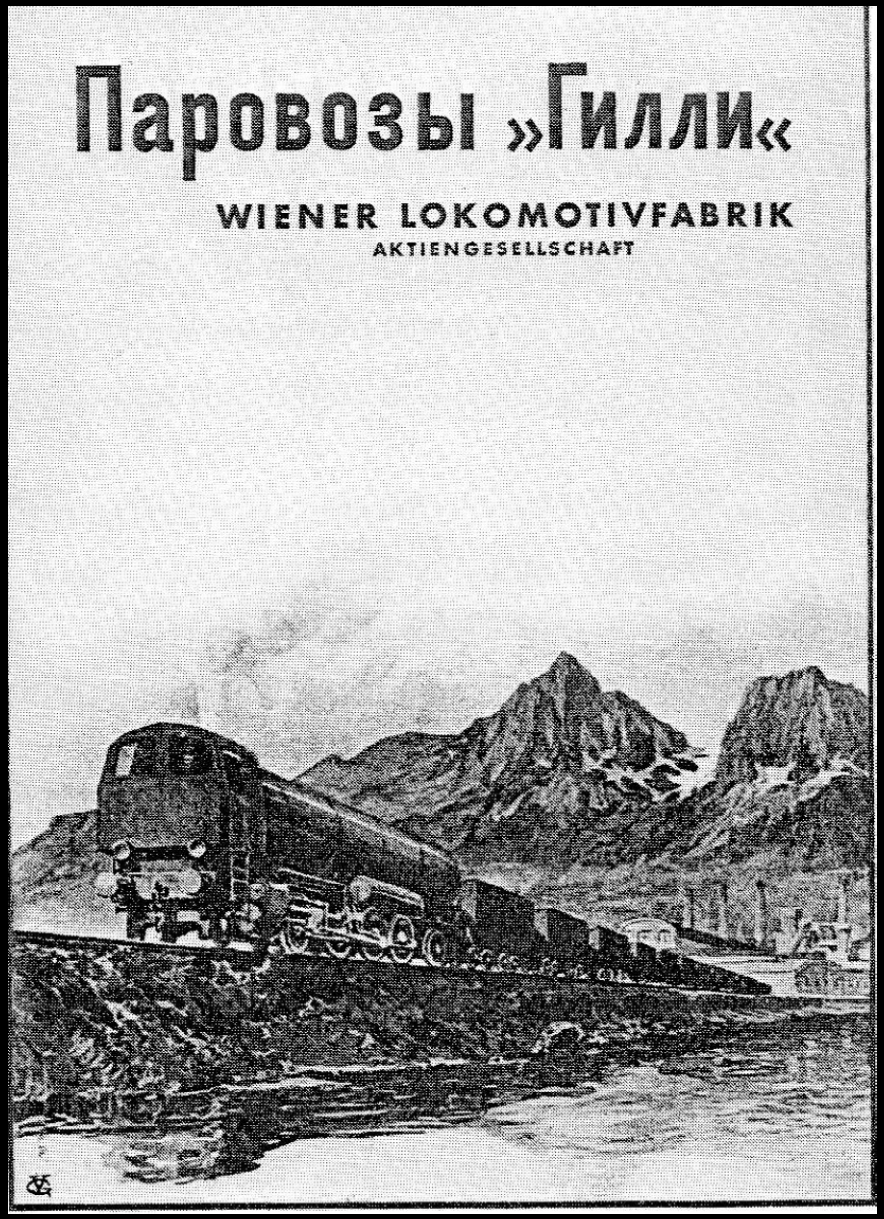
For now:

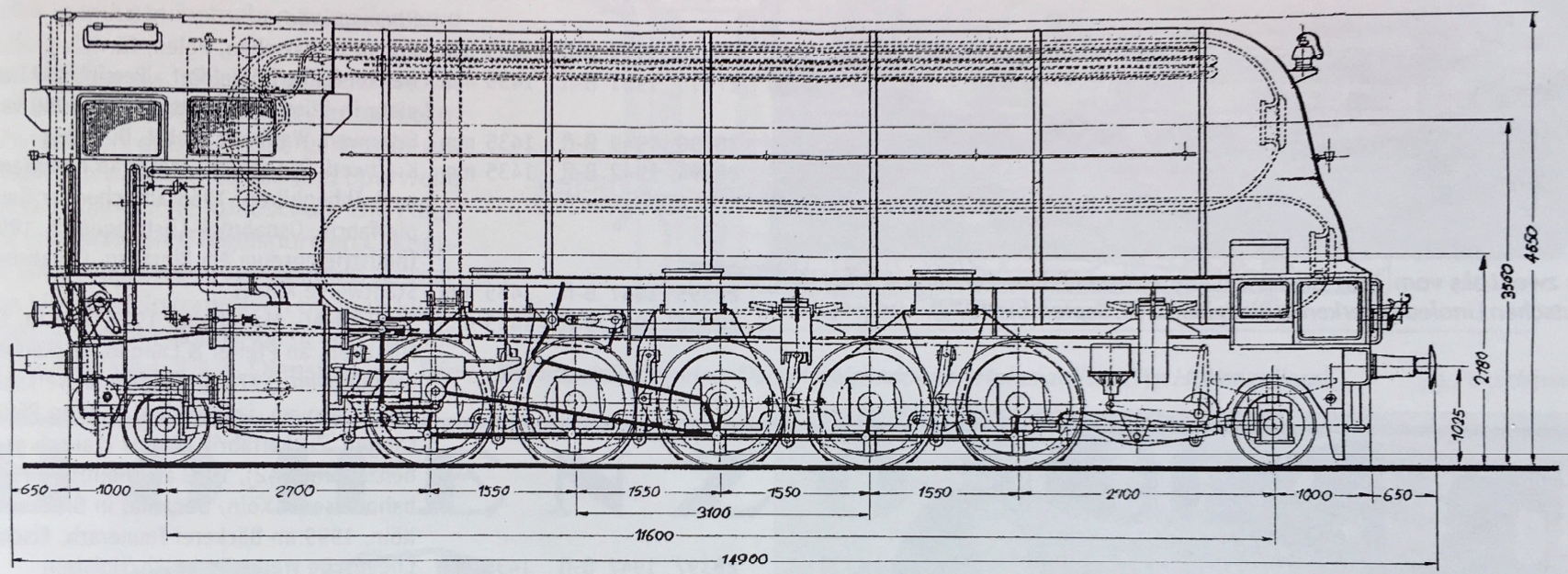
Why not go for a FIRELESS *REVOLUTION*? Or something like it?—though *Revolution* is still very much smaller than a "normal" heritage locomotive (scaling issues here as well: radically less energy content size-wise)

+ Many more issues & (your) good questions + sound criticisms please!

Паровозы »Гилли«

WIENER LOKOMOTIVFABRIK
AKTIENGESELLSCHAFT



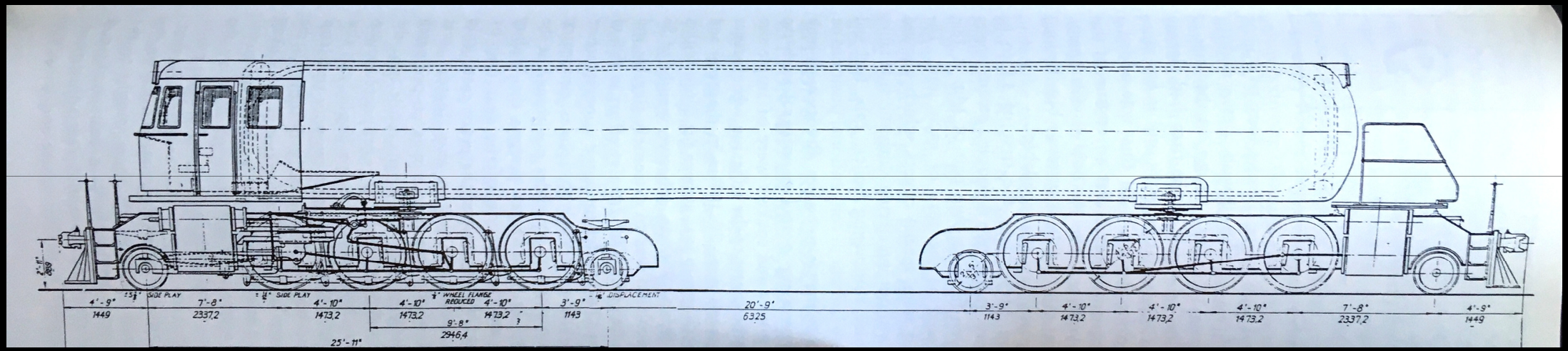


Hauptabmessungen:

Spurweite	1435 mm	Wasserinhalt des Speichers	40,5 m³
Zylinderdurchmesser	720 mm	Leergewicht	etwa 107 t
Kolbenhub	660 mm	Dienstgewicht	etwa 136 t
Treibraddurchmesser	1300 mm	Reibungsgewicht	etwa 100 t
Laufraddurchmesser	850 mm	Achsdruck	etwa 20 t
Fester Achsstand	3100 mm	Größte Breite	3150 mm
Gesamt-Achsstand	11600 mm	Größte Höhe	4650 mm
HD Speicherdruck	84 kg/cm²	Zugkraft 0,75 p	27600 kg
Arbeitsdampfdruck	14 kg/cm²	Kleinster Krümmungshalbmesser	150 m
Gesamtinhalt des Speichers	45 m³	Größte Geschwindigkeit	50 km/h

1' E 1' Hochdruck Dampfspeicherlokomotive

Bauart Henschel-Gilli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