USA-The Zenith of steam

The decline and fall of the Pennsylvania Railroad

Why I got into all this

- Wardale quotes Porta as saying ‘The design of American front ends could not have been worse’
- This sparked my interest in American designs- What was wrong with them? Could e.g. Chapelon’s thinking have helped? A job for ASTT!
- This led to a four year odyssey from 2006-10 going through as much American data as I could find- Joe Cliffe and Phil Atkins a great help.
- The conclusion was that the Americans built the fastest, most powerful, most rugged designs that outperformed anything else I know of, that could not be significantly bettered in their environment.
- Their influence on world steam development e.g. Chapelon was immense.
- My other interest was in evaluating modern day models of engine and boiler performance against this data.
- The models work on the other side of the Atlantic!
- 10 years on, more data to hand, everything still stacks up
- So let’s take a ride on the PRR, NYC, MILW, ATSF and UP!

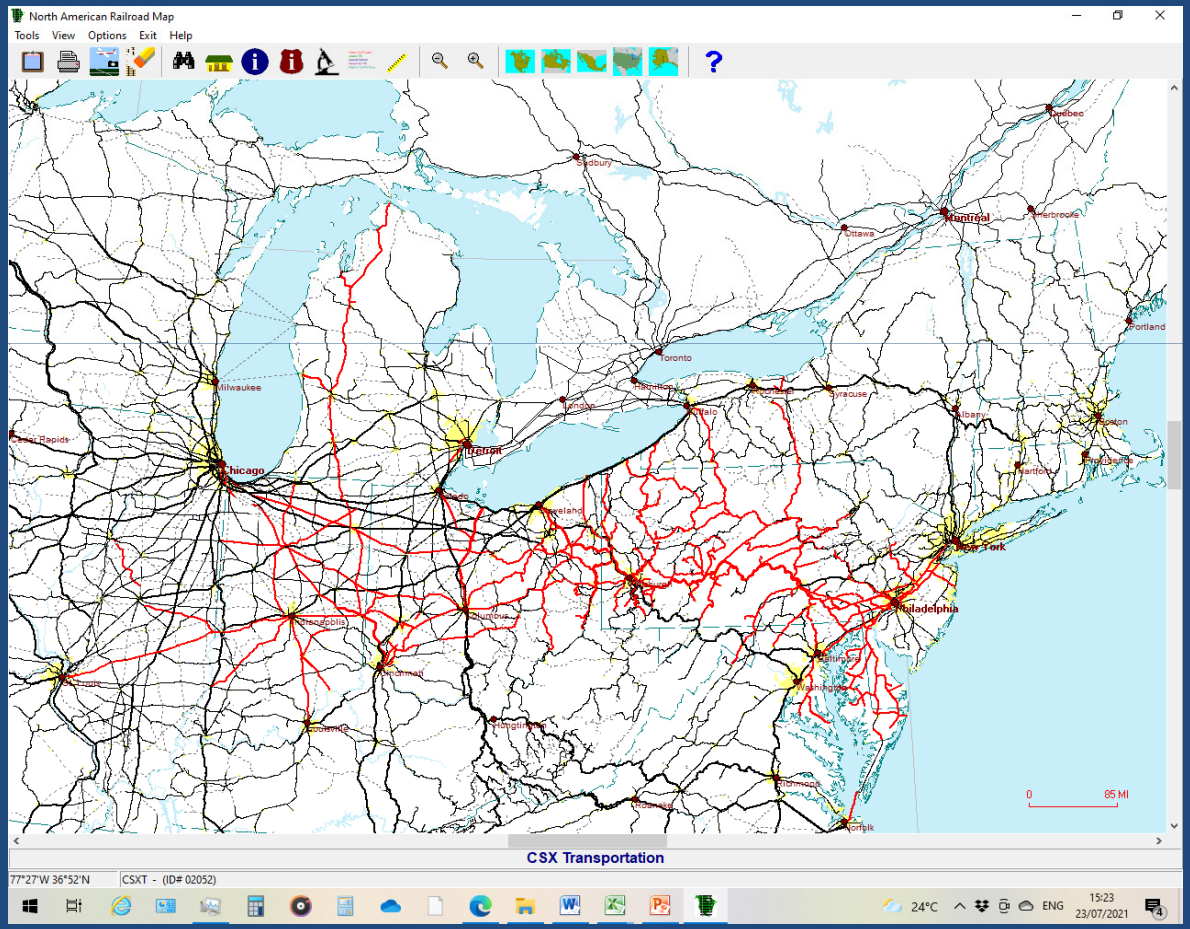
Some background

- Main goal was power- getting maximum tons over the road.
- For freight, this is about TE. At a maximum driver loading of ca 33 tons, the rule of 4 says this means ca. 8 tons TE per coupled axle.
- Hence maximum tons per coupled axle < 8* gradient e.g. 1 in 45 = <360 tons/axle.
- This led eventually to 8 coupled axles, though 12 tried, 16 patented.
- For passengers this is about boiler output (grate size) secondarily engine efficiency.
- Mech. stoking federally required for grates > 50 sqft, feedwater heaters common.
- As elsewhere, boiler outputs ca.650-700lbs/sqft grate/hr due to poor economy and maintenance cost (e.g. cinder cutting) at higher rates - more possible
- At this rate, you get about 45-50 IHP/sqft grate with Grade A coal.
- Speed limits were generally 80mph (e.g. NYC) to 90mph (e.g. PRR and ATSF)
- Inside cylinders were avoided at all costs, so 2 cylinder designs delivering 4500IHP at speed required serious attention to balancing, piston thrusts etc.
- Cast steel beds essential

A cauldron of creative activity- everything tried- few secrets !

- AAR committees studied everything and had standard methods and best practices.
- The Association of Master Mechanics devised the standard front end.
- 10s of large companies had sufficient resources to do extensive testing.
- Trade Journals published monthly topical articles on new thinking and developments
- Ideas were widely published e.g. Fry on Boilers, Cole ratios for overall design.
- Major Builders (Alco, Baldwin, Lima) bid to build each others' designs.
- University departments were dedicated to the study of steam e.g. at Urbana.
- White at Urbana did an exhaustive study of alternative front end designs.
- Suppliers e.g. Elesco competed vigorously to supply helpful adjuncts e.g. feedheaters, circulators, Foam control. Locos started to look like Christmas Trees.
- PRR tried steam turbines. Coal rich N&W and C&O built steam turbine electrics
- Baldwin built a 350psi 3 cyl Compound prototype with water tube firebox. NYC and CP built Schmidt high pressure water tube boiler Compounds.
- As everywhere, no quantitative principles. Empiricism ruled. Not all rules were right!

Pennsylvania Railroad- in 1900 the largest corporation in the world



St Louis Exposition 1904- the PRR stationary test plant

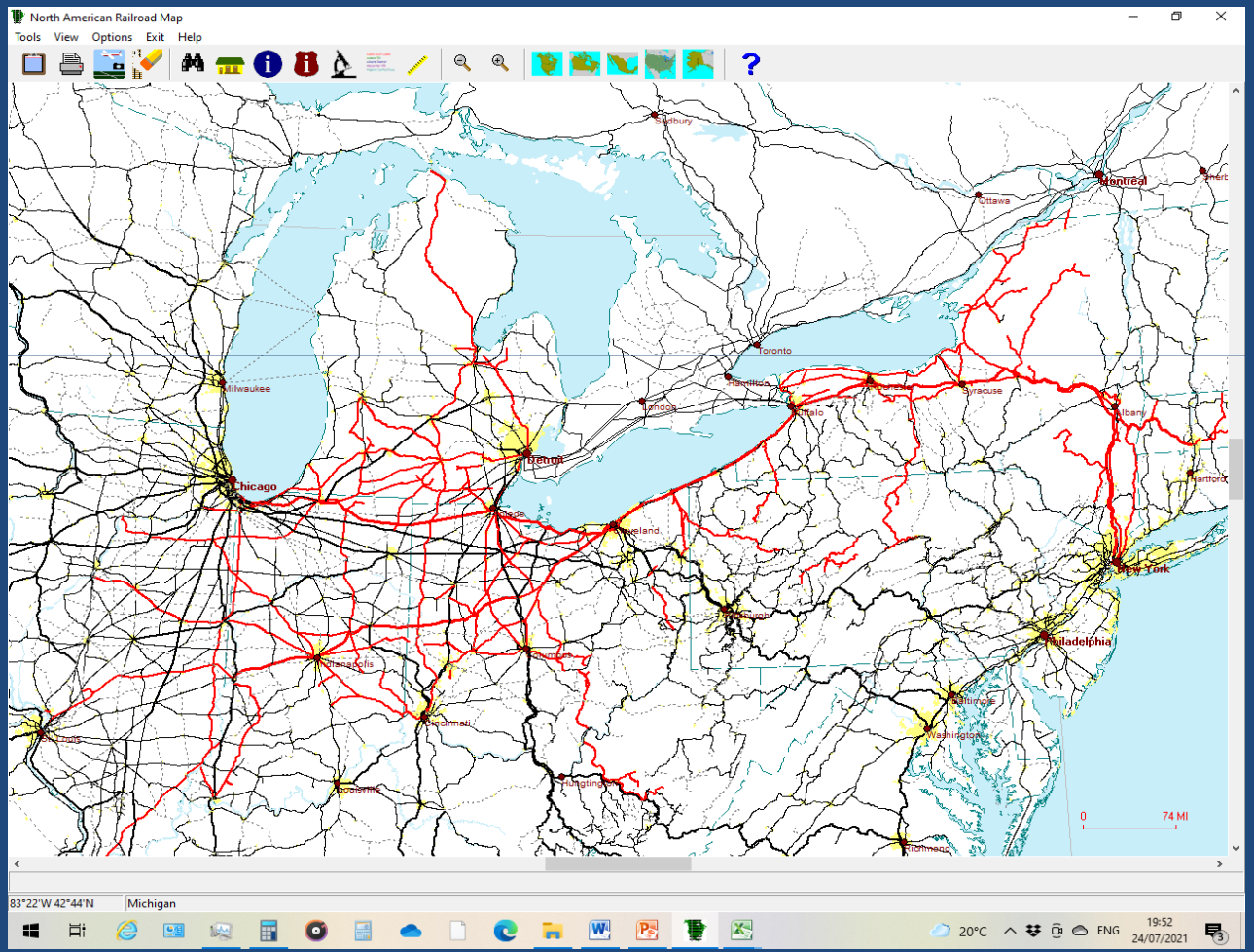
Altoona test plant 1905-26

- Clear protocols. Reporting and analysis of results perfect. Only cared for the facts.
- Tested new technology as soon as it became available.
- Showed benefit of high superheat on engine efficiency, + cylinder wall temps.
- Showed the benefit of half return loops, and bringing elements closer to firebox
- Showed E type superheaters had no benefit over A type but used on the 4-8-2 M1
- Developed the saturated K2 Atlantic to the superheated K4 Pacific (1912).
- Invention of superheat meant compounds were rejected.
- Studied the ‘steam circuit’ showing e.g. the effect of valve size on power.
- Tested many front ends for draught at low back pressure- led to the Kiesel star.
- Measured the impact of mechanical stoking on boiler efficiency.
- Studied self cleaning plates and boiler tube ratios.
- Measured the benefits of feedwater heaters.
- Analysed the performance of the Baldwin high pressure 3 cylinder Compound.
- The Great depression hit very hard, and development stopped ca 1926.

PRR K4 Pacific- Standardised Edwardian simplicity

- Revered, long lived, but not the zenith- you often needed two!

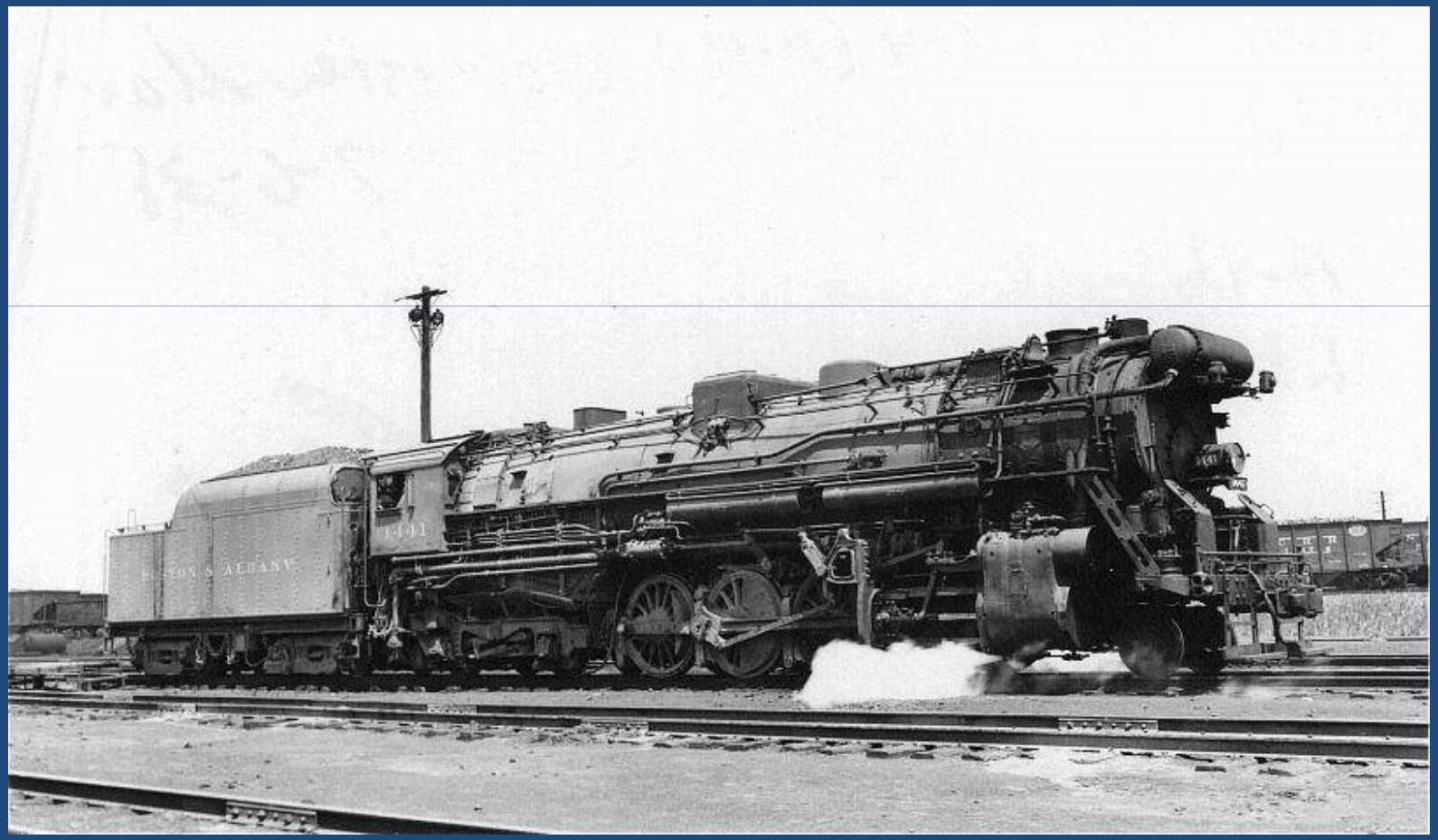
New York Central RR- The water level route ‘You Can sleep’



Super power from Lima

- Lima was #3 in a two horse race between major American Locomotive builders, Alco and Baldwin
- It therefore needed to be plucky and boss William Woodard was.
- In the mid 1920s he challenged the conservatism of the other two with the 'Superpower' concept, incorporating all best practice design features:
  - Higher boiler pressure
  - Feedwater heater
  - Higher superheat
  - Better draughting
  - Optimised steam circuit
  - Booster on trailing truck to raise starting TE
  - Limited maximum Cut off to raise efficiency at speed
  - And- genius thinking(!)- a four wheel trailing truck to allow a larger grate
  - More grate=More steam=More power= more tons= more money- A winner!
  - Wardale 70 years *avant la lettre*

First Lima 2-8-4 super power sales went to a NYC Subsidiary

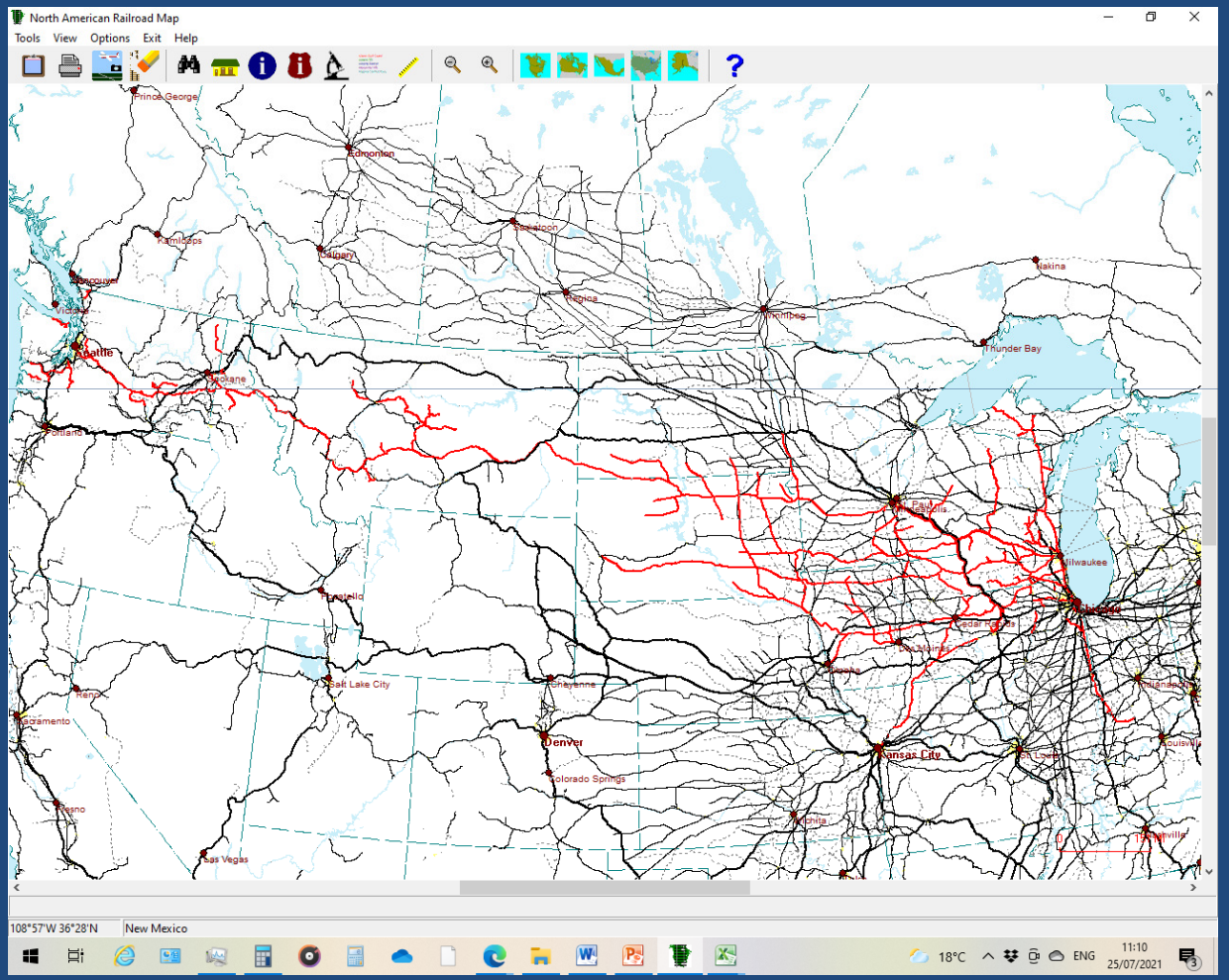


The NYC ‘Steel fleet’ of passenger trains and the Hudsons

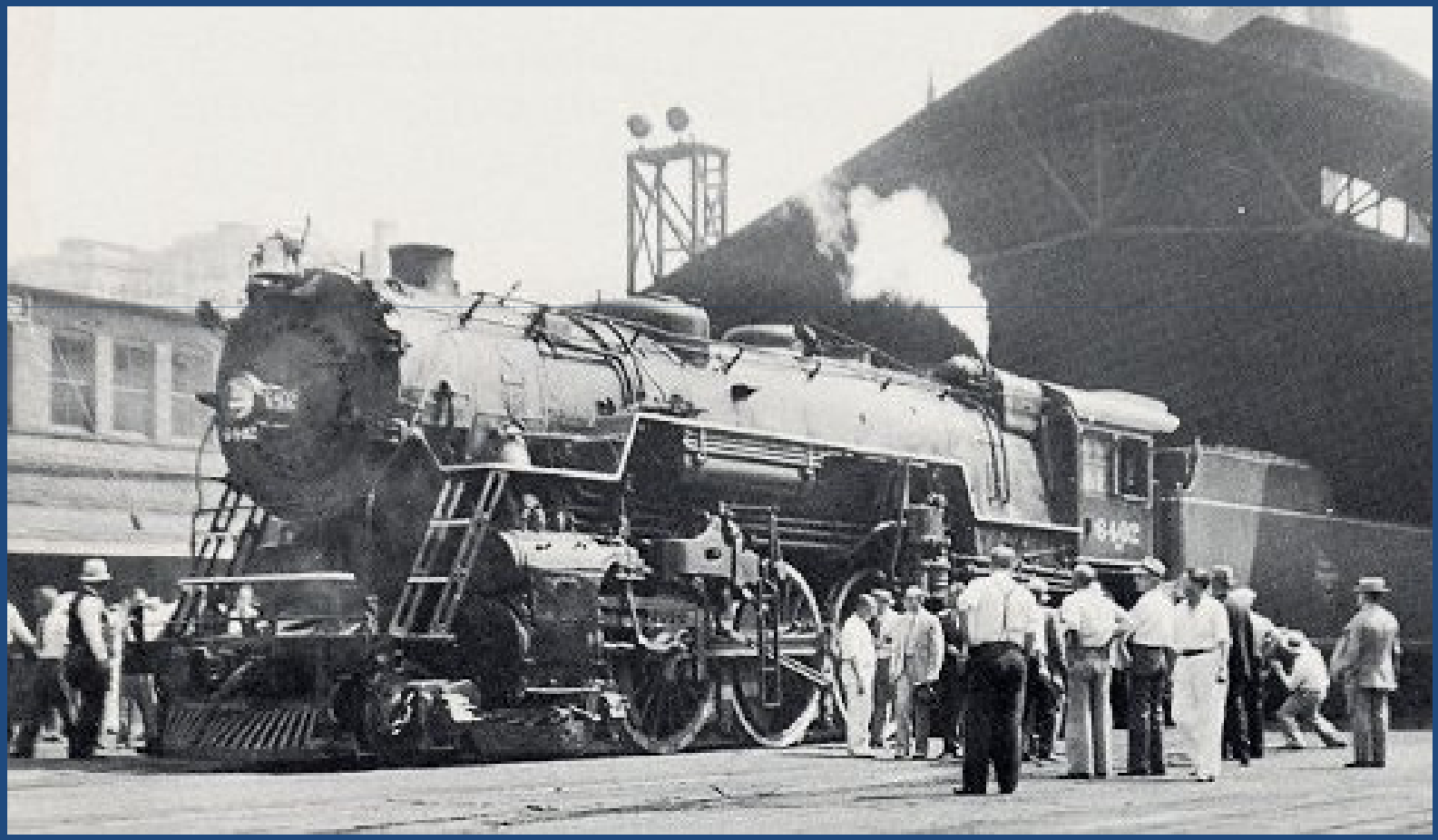
- The NYC became the major player passenger market NY to points west.
- NYC chief engineer Kiefer recognised that, as trains grew to exceed 1000 tons in the mid 1920s, their Pacific designs had reached the limit.
- His (Lima’s) solution was a larger firebox and a four wheel trailing truck.
- The NYC president saw the 4-6-4 Baltic design, looked out of his Manhattan office and said ‘we’ll call them Hudsons’.
- Original 1927 J1s were 225psi. Intensive development and testing at Selkirk led to the J3s with 265 psi, roughly 50% more powerful than a K4. De Laval nozzles.
- Time to Chicago came down to 16 hours for the 960 miles (80 mph speed limit).
- The Hudsons (41tons of coal in tender) could work right through 900 miles from Croton Harmon to Chicago and the J3s ran 130000 miles/year.
- Worked into C-H in the morning, cleaned out with asbestos suited staff and headed the parade back west in the afternoon. Everyone studied.

The 20th Century Limited -The classiest train of all time? Up to three sections

The Milwaukee Road- you are a fan!

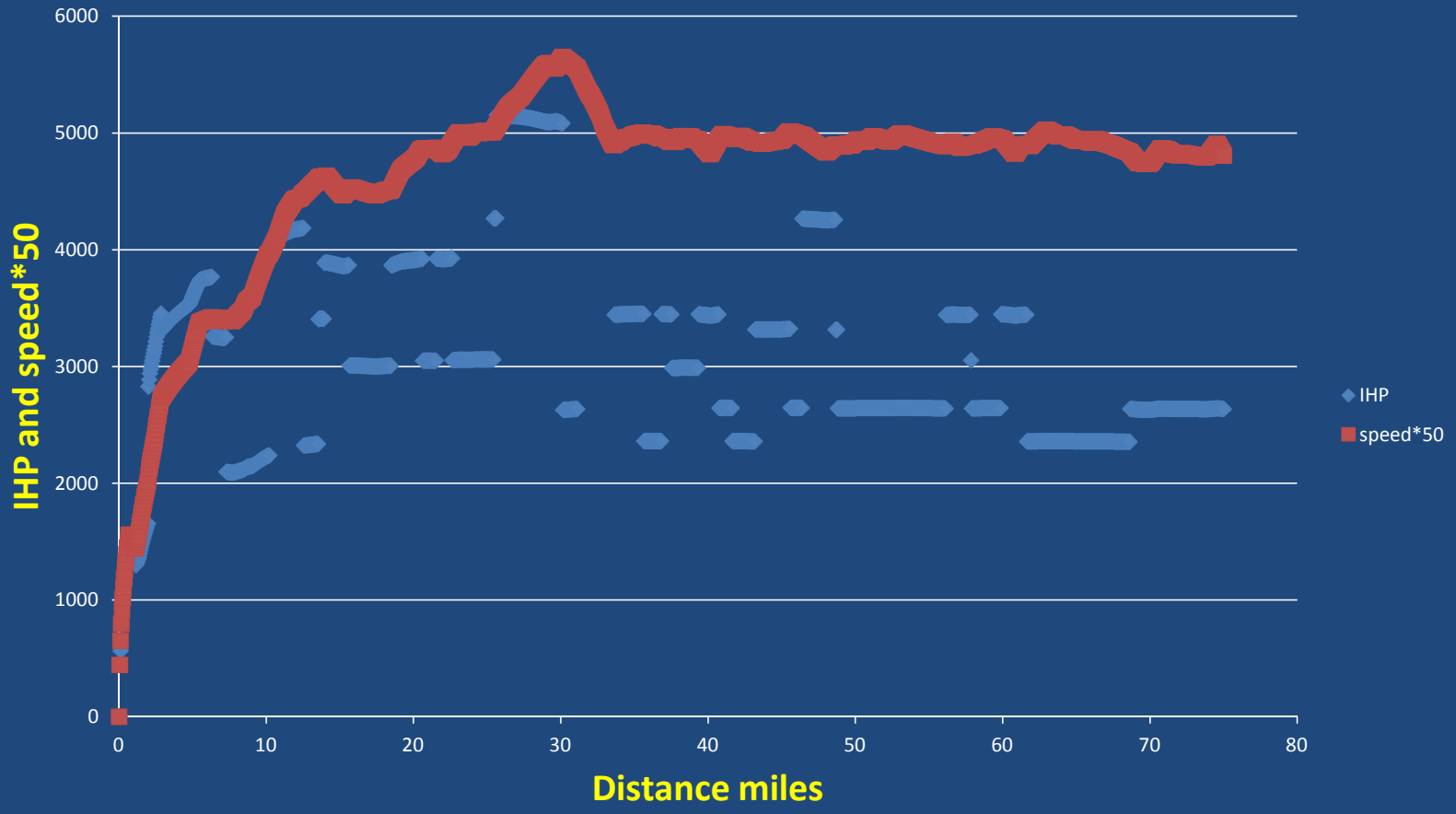


Prelude to the Chicago Twin Cities Hiawathas- First 100mph steam locomotive (July 1934)



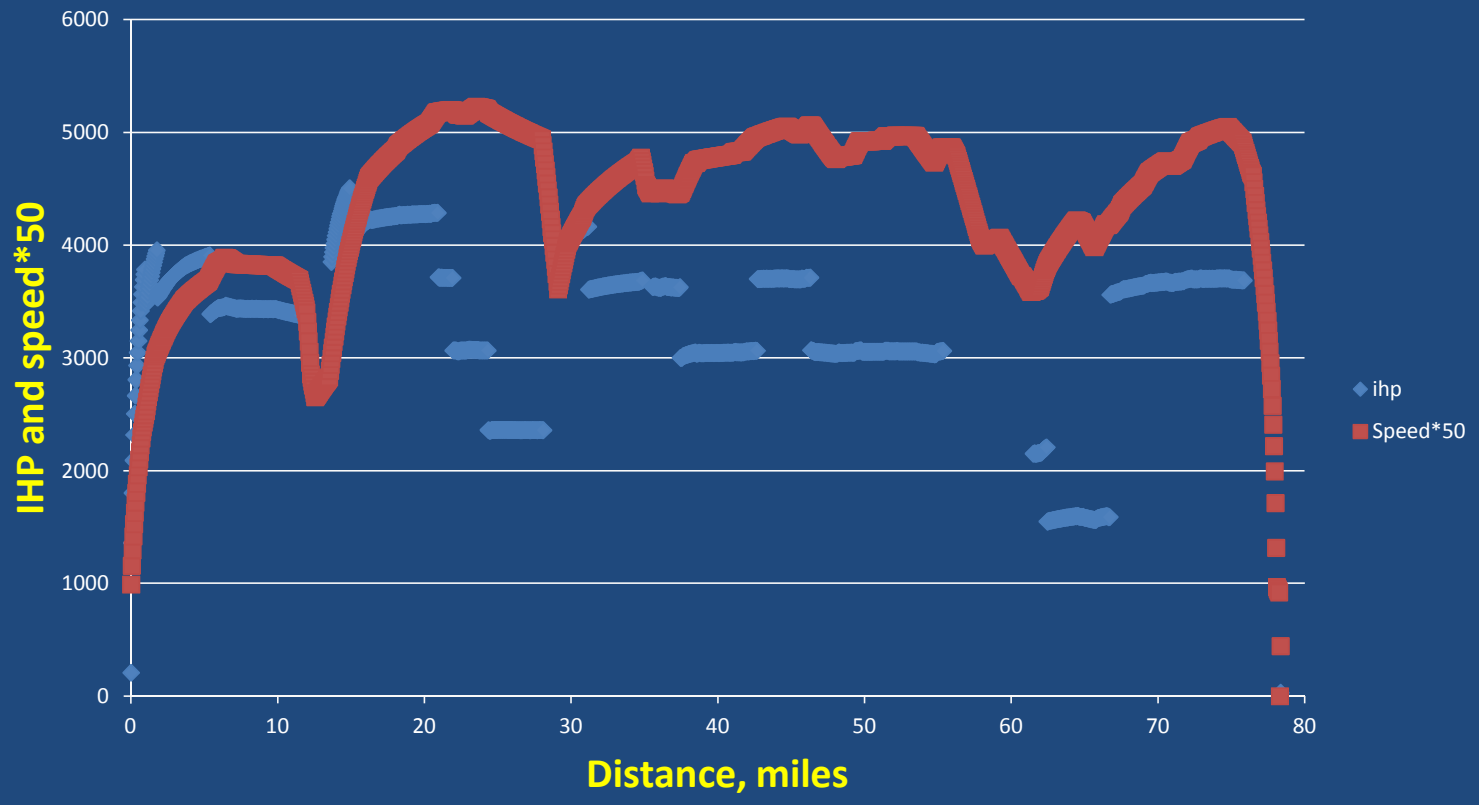
Hiawatha power Mk2 – F7 Hudson- 6.5 hours for 420 miles to Twin Cities

Daily F7 IHP and speed Milwaukee- Chicago- 50+miles flat lined at 100mph



F7+Hiawatha, ca 100mph at Deerfield

Fastest ever steam schedule-81mph Sparta to Portage



The arrival of diesels and a five year reprieve for steam?

- In 1936 EMD Diesels launched the ATSF ‘Super Chief’, and in 1939 a EMD freight diesel demonstrator amazed. RR engineers hated EMD’s intrusion.
- The declaration of war in 1941 meant the War Board would not sanction RR diesels- internal combustion was for planes, tanks, warships etc.
- Steam building to haul war traffic was authorised, especially to take men and materials from the east to the Pacific theatre. War babies!

Back to the PRR

- Kiesel tried to match the NYC Hudson with a 250 psi Pacific (K5, 1929)- later proved to be the most efficient Pacific.
- This failed because he believed they needed to increase boiler heating surface to produce more power-wrong. (Empirical rules!). The larger boiler in the restricted loading gauge caused water carryover and poor steaming.
- An oscillating cam poppet valve version was a disaster as Gresley found at that time.
- In the mid 1930s, the Franklin valve company bought rights to Lentz poppet valves and spent a lot of money developing oscillating cams for the US market - Franklin A, fitted to K4 5399, tested on the plant and road.
- Some performance improvement did result, but, with hindsight, not for the reasons claimed, but prosaic ones. And the valves leaked badly.
- PRR was desperate to innovate, and were happy to go along with the wildly optimistic and flawed interpretation of the test plant results. Poppet valves were ‘it’, putting the PRR back on top.

The passenger dream and the T1

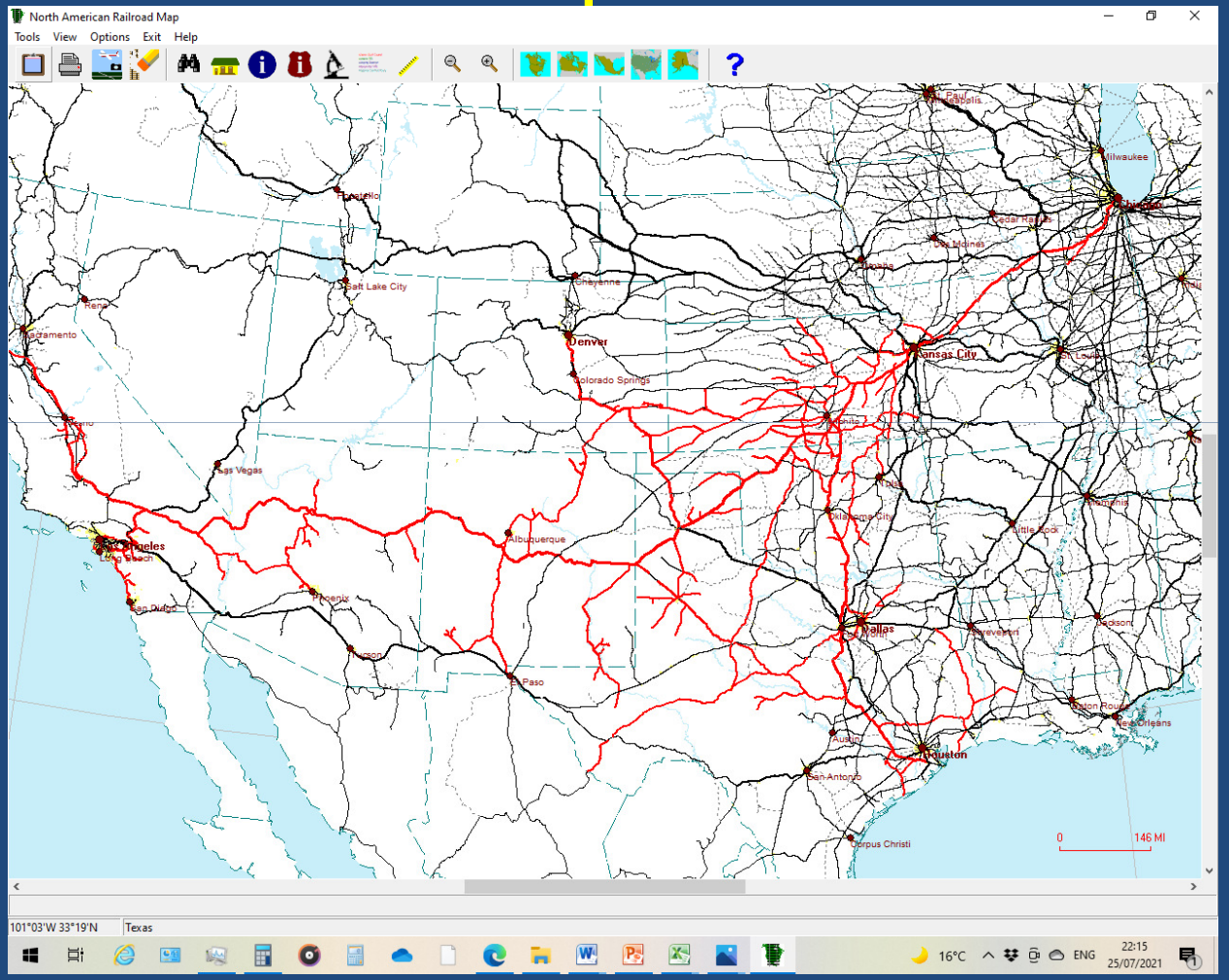
- Meanwhile, in the late 1930s a blue ribbon AAR committee decided that the future required locomotives able to haul 900 ton trains at 100mph- about 6500ihp needed.
- Baldwin sold the PRR on a duplex drive design. An enormous show pony 6-4-4-6 resulted, which was slimmed down to the 4-4-4-4 T1-even this too big for Pittsburgh!
- Oscillating cam poppet valves were used- two big innovations in one design.
- A prototype was tested at Altoona, and, under extremely forced conditions with a narrow blastpipe this produced 6552IHP at 100mph. Joy at the Board, and 50 were ordered in 1945. NB Engineers had wanted rotary cam.
- Superheat of 800 deg F deemed 'too high', and cylinder power too high for normal service - 2.5 times the K4 at a given cut off- so part regulator needed.
- T1s slipped badly and were a mechanical disaster. Double headed K4s came back.
- The Board started buying diesels as soon as possible in 1945. The T1 was irrelevant before it was built. The PRR could not afford to upgrade infrastructure for 100mph.
- A Duplex 4-4-6-4 freight locomotive (Q2) produced 8000IHP at Altoona but class a failure, again possibly water carryover. PRR reverted to 2-10-4s. Keep it simple!
- The PRR had become an arrogant company who believed its own myths about itself.

1944- The NYC Niagara

- In 1944, Kiefer designed ultimate NYC passenger loco- the 4-8-4 ‘Niagara’ built by Alco, whose balancing made a duplex drive unnecessary.
- Alco had been building 4-8-4s for UP since 1937, but the Niagara was pure NYC (!)
- Tests showed it could accelerate 900 tons to 75mph in 5 minutes, in the process developing 6600IHP. Cut off at 75mph was 58%(!)
- In ‘above average’ service IHP was around 4000- OK for 80mph.
- In comparative trials with contemporary diesels in 1947, it was able to achieve 25000+ miles/month-unheard of.
- Financial analysis said it was even-stevens.
- The great steam hero Kiefer analysed competing tractions in 1947 and more or less admitted that the future was diesel. He was proved right.
- Niagaras all disposed of by 1956; none, nor any Hudsons preserved because NYC President AE Perlman wanted to look to the future

Racing the PRR from Englewood- only one winner?

The Atchison Topeka and Santa Fe



The Chicago -Los Angeles Road (Declaration of interest- a personal favourite!)

- ATSF had the premier passenger route to CA, the Chief and later Super Chief being the ultimate in luxury.
- The line rises from 750’ to 4100’ over 550 miles from Kansas City to La Junta CO, but the gradient is negligible.
- 80 miles on the line rises from Trinidad CO (6000’) in 15 miles to 7600’ at Raton Pass, 5 miles of 1/30, (some 1/28), then 1/30 down to Raton.
- Three more summits rising from 5000 to 7000+’ at Glorieta NM, the continental divide at Gonzales, and after Flagstaff at Riordan.
- Then down to 500’ at Needles CA, 220 miles on, much at 1 in 70.
- Back up to 3800’ at the top of Cajon Pass, 25 miles down at 1 in 45 to San Bernadino, final drop from 1 in 45 Pasadena to Los Angeles.

1930s ATSF steam

- Final steam designs were oil burning 300 psi 4-6-4s, 4-8-4s and 2-10-4s. No coal from CO west, plenty of oil!
- 3460 class 4-6-4 Hudsons quite capable of taking 800 ton trains over the first 1000miles to the Rockies at La Junta from Chicago.
- La Junta to California definitely 3765 and 2900 4-8-4 class territory!
- 4-8-4s could haul 850 tons up the 1 in 45 of Cajon pass.
- Mixed traffic 5000 class 2-10-4s, (74” drivers, 109000lb TE) likely had highest ever piston thrust (219000lbs)- 15” axles and 7” frames.
- Kiefer recognised oil was better than coal- not dealing with coal waste was a big plus.
- But if you’ve got oil, why waste it in a furnace to produce steam which can only be expanded inefficiently?

Beauty and the Beast on Raton Pass

Cajon Pass today with ATSF 3751

ATSF endurance

- Test results on 4-6-4s and 4-8-4s documented by Farrington
- Superheat and maximum output of oil fired boilers less than coal fired equivalents and oil more difficult to draught (SP tests show why), so 4 nozzle Layden exhausts plus stack extensions used to deliver full potential.
- ATSF more interested in e.g. bearing temps, lubricant use and drifting – reliable operation- than low superheat effect on engine efficiency.
- 4-6-4 3461+ 700-900 tons ran the whole 2230 mile LA- Chicago route on test, 91 stops, 65 hours - never matched to my knowledge. Hit a car in Pasadena, so lost a little time(!). Temp in Chicago 20 F.
- 4-8-4s Left Kansas City on Monday night, ran 1790 miles to Los Angeles arriving Wednesday morning, serviced and left late afternoon back to KC.
- Reliability, reliability, reliability? They had it! The N&W agreed.
- But 1000 miles of desert from CO west meant ATSF first to dieselise.

4-8-4 technologies

- Cast steel bed
- Roller bearing on all axles
- Automatic bypass valves
- E superheater
- American multiple throttle
- Worthington Feed heater
- Baldwin disc drivers and centers
- Foam meter, automatic blow off cocks
- Thermic syphons
- Throat sheet blow off cock
- Muchnic Bronze cylinder packing and bronze wearing ring
- Force feed grease lubricator to valves, cylinders, driving box, Batz engine truck and Delta trailer

ATSF saved quite a lot of steam - 2926 is about to be reborn

Things I am not going to tell you about:

1. Southern Pacific Coast Daylight- the most Beautiful train?

2. N&W J Class 4-8-4 -110mph with 70” drivers, 32 ton axle load

3. The most powerful -C&O 2-6-6-6, 7500 DHP

4. UP 8 nozzle Jabelmann exhausts

5. The largest- UP 4-8-8-4. ‘Firing with Dirt and shale (ex Hanna, WY) is never easy(!)’

Summary- engineered for exceptional performance in a hostile environment

- ***Speed***: Milwaukee F7s (and As) were the fastest ever locomotives.
- ***Monthly miles:*** An NYC 4-8-4 holds the monthly distance record of 28000miles. 10000-15000miles/month not unusual elsewhere.
- ***Through Running***: Coal fired 4-6-4s and 4-8-4s ran 920 miles unchanged.
  - Oil fired ATSF 4-8-4s regularly ran 1790 miles in normal service.
  - Oil fired ATSF 4-6-4 holds the all time distance record, 2224 miles.
- ***DBHP:*** C&O 2-6-6-6 holds DBHP record (7500); Larger Big Boy 4-8-8-4 could likely produce more with good coal.
- ***Boiler output and efficiency :*** Boilers easily draughted at the normal 650-700lbs water/sqft/hr. With coal firing exceeded 1000lbs/sqft/hr on test. FWH efficiency.
- ***Engine Efficiency:*** All best practice techniques used, T1 the best. Striving for the last few % in efficiency (inc. Compounding) more trouble than it was worth.
- ***Overall efficiency:*** As high as practicable given mechanical stoking.
- ***Operational practices***: Best US steam practices widely studied.
- ***All to no avail***: Steam building stopped rapidly after WW2. Few can remember the US steam heyday today.

UP 4-6-6-4 hauling 7000 tons up the 1/150 out of Cheyenne

UP 4-8-4 (Similar to Niagara) accelerates 700 tons from 20-55 mph in 2 minutes.