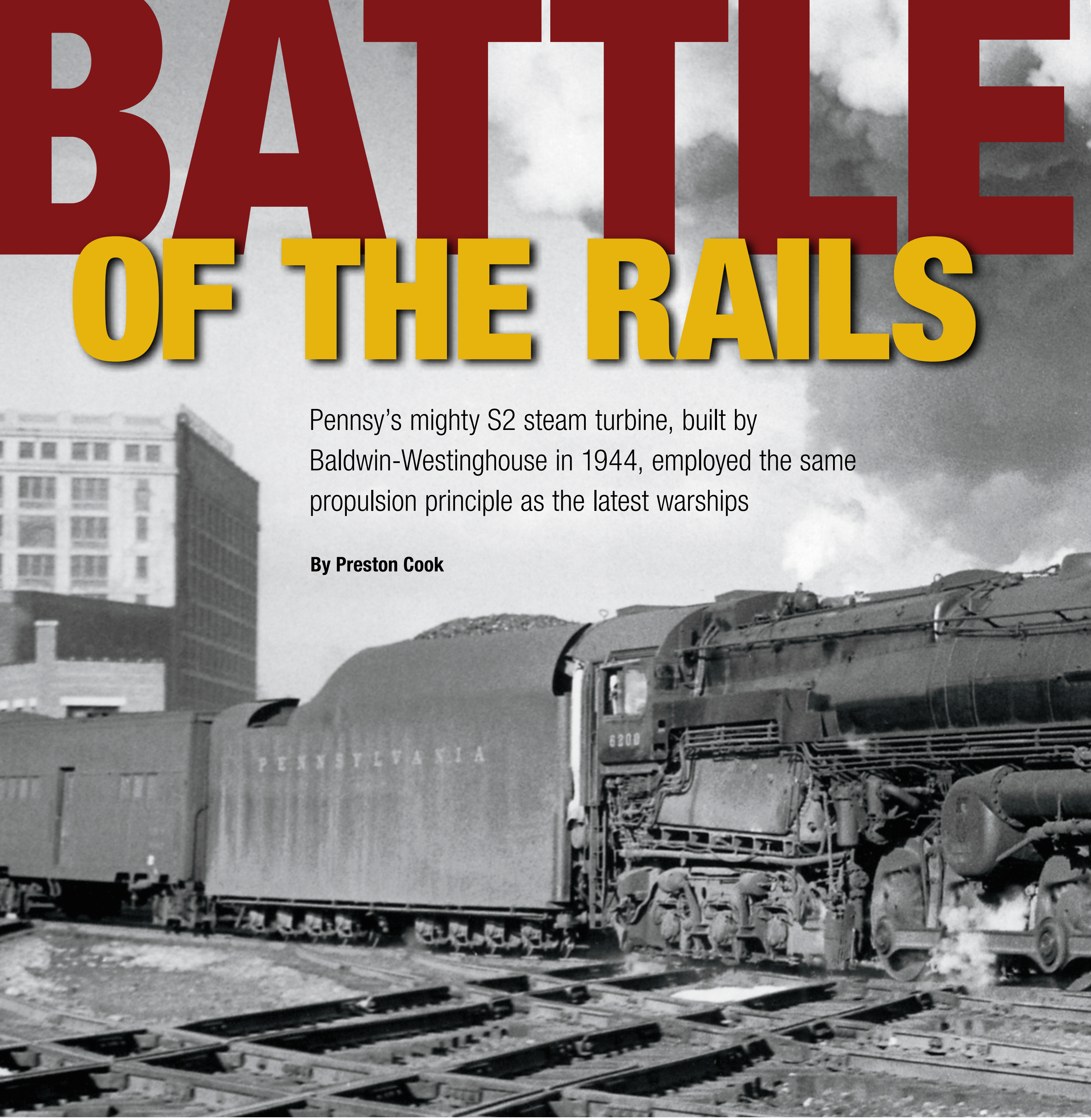
BATTLE OF THE RAILS



Pennsy's mighty S2 steam turbine, built by Baldwin-Westinghouse in 1944, employed the same propulsion principle as the latest warships

By Preston Cook

During the 1940s, the conventional steam locomotive was under siege. Diesel-electrics had proven their superiority, and railroads were buying them as fast as they could. However, some carriers, particularly those that derived a large share of their revenue from hauling coal, which fueled the great majority of steam locomotives, were slower to embrace the diesel. A handful of the holdouts sought to develop a new generation of coal-burning motive power. The Pennsylvania Railroad, the nation's top coal-hauler, sponsored perhaps the most spectacular of these efforts.

SHIP

This was the class S2 6-8-6 steam turbine, PRR No. 6200, built in a collaborative effort by Baldwin Locomotive Works and Westinghouse Electric & Manufacturing Co. in 1944 as an attempt to prolong the dominance of the steam locomotive by adapting technology that had been widely accepted in the marine industry. The product of design and experimental work that began in 1937 and resulted in a preliminary design by 1941, it was a truly massive machine, with a total combined engine and tender weight of 992,900 lbs., and a total weight on drivers of 260,000 lbs. The 6200 was originally designed and

A few minutes out of Chicago Union Station, PRR S2 turbine 6200 bangs across the diamonds at 21st Street in March 1948. The great machine will take the train as far as Crestline, Ohio, 278 mostly flat, straight miles to the east. The S2's size and turbine propulsion invited comparisons to modern battleships, like the USS *Missouri* (inset).

Main photo, Robert Bryson; inset, National Archives patented as a 4-8-4 Northern, but it was constructed as a 6-8-6 because of the shortages of lightweight metals in World War II, and was the sole example of this wheel arrangement in North America. While its enormous size and weight alone might invite a comparison with the biggest battleships of the period, the extensive adaptation of elements of marine geared steam turbine design by Westinghouse in the development of the S2's drive system makes comparisons with marine design practice quite appropriate.

The S2 was one element of the Pennsylvania's advanced steam locomotive design program. (Another was the S1 of 1939, which also employed two six-wheel trucks and eight drivers in a rigid frame. However, the S1's drivers were divided into two sets of four, each set driven by cylinders and pistons of conventional design. The wheel arrangement of this streamlined "duplex drive" locomotive was 6-4-4-6.) Steam turbines had been used very effectively in stationary power and marine propulsion applications, and were one of the most powerful mobile propulsion systems available, with ratings of up to 55,000 h.p. per propeller shaft in some naval vessels. In comparison, the S2's main turbine was actually very small. Its 6,900 h.p. rating was similar to that of the machinery driving one propeller shaft in a WGT (Westinghouse Geared Turbine) type Destroyer Escort vessel, a relatively small and light World War II convoy escort ship.

Construction of PRR 6200 was delayed by the war and by Baldwin's resulting wartime production load. The company was involved in many war projects that got first attention from its engineering talent. The building of experimental steam locomotives was not explicitly prohibited by the War Production Board, but the construction of steam power in general required individual approval of orders for a specific type, since the railroads tended to employ customized designs. In contrast, the WPB approved construction of diesel locomotives several times a year in large lots "for stock" since they used standardized designs, and they were distributed in a need-based priority system. When a builder wanted to construct an experimental product, it was likely to encounter problems with the supply of components if other manufacturers were also strained by war production. It was in this way that the turbine's original 4-8-4 design evolved into a 6-8-6, as available materials and parts had to be adapted; the additional axles were needed to carry the locomotive's greater weight.

Following its 1944 delivery, No. 6200 was evaluated on various portions of the PRR. By mid-1945 the locomotive had been assigned to passenger service between Chicago and Crestline, Ohio, where it spent most of the next four years. This portion of the railroad was a flat, high-speed region that allowed the steam turbine to operate much of the time in its range of best efficiency.

TURBINES AND SIDE RODS

In designing the locomotive, Baldwin and Westinghouse adopted the simplest possible approach, a direct-geared reduction drive between the turbine and multiple drivers connected by side rods. This resulted a locomotive of fairly conventional appearance, with a prominent boiler atop large-diameter driving wheels connected by side rods. However, instead of steam chests, cylinders, main rods, and valve gear, there were turbine casings between the second and third drivers on either side and pipes connecting

S2 TURBINE: FROM CONCEPT TO COMPLETION

1) Patent drawing, with gearbox ahead of No. 1 drive axle. 2) Patent drawing, showing initial concept as a 4-8-4. 3) Forward (left) and reverse turbines as shipped from Westinghouse to Baldwin. 4) Bull gear mounted on drive axle, with spring cushion cups exposed. 5) Bull gear on axle, with driving wheels pressed on. 6) Top view of gear assembly for Nos. 2 and 3 drive axles. 7) Front-end view of drive-gear assembly, with forward (left) and reverse turbines in place. 8) Baldwin employee beside Nos. 2 and 3 driver sets, with gearbox in place. 9) S2 under construction. 10) Engineer at handle-type throttle.

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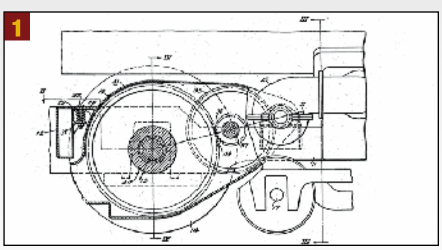

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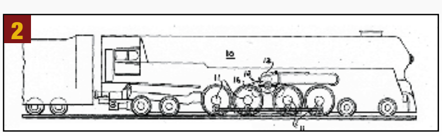

Two drawings, U.S. Patent Office

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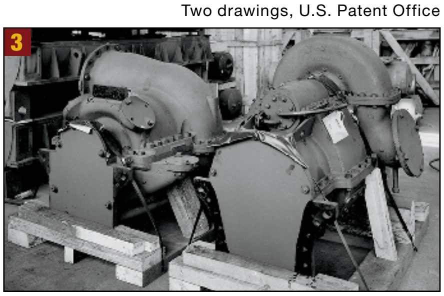

Nine photos, Classic Trains collection

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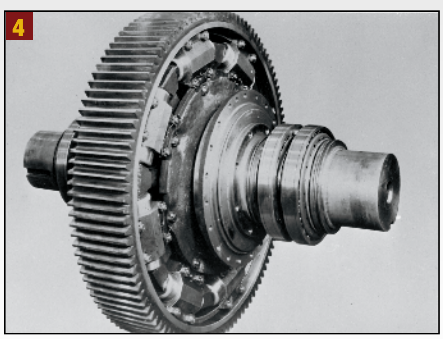

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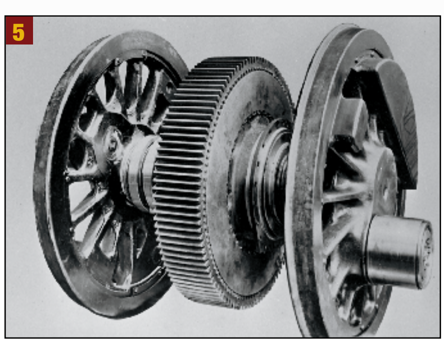

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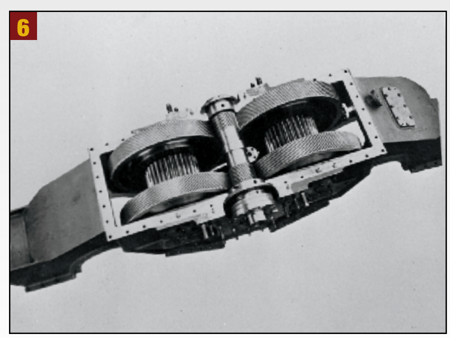

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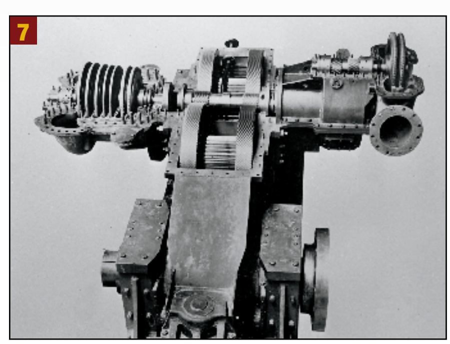


the turbines with the smokebox.

Curiously, the patent drawing for the drive train (picture No. 1 on the opposite page) shows the gearbox positioned forward of the first set of drivers, with the turbine located where the steam chest would be on a rod-driven locomotive. This was probably done for convenience or simplification of the drawings. The use of the No. 1 driver as a point for applying the force to the drivers would have resulted in a considerable shifting of the weight distribution on the drivers during periods when high tractive effort was being developed. The arrangement that was actually adopted made much better sense from an engineering point of view.

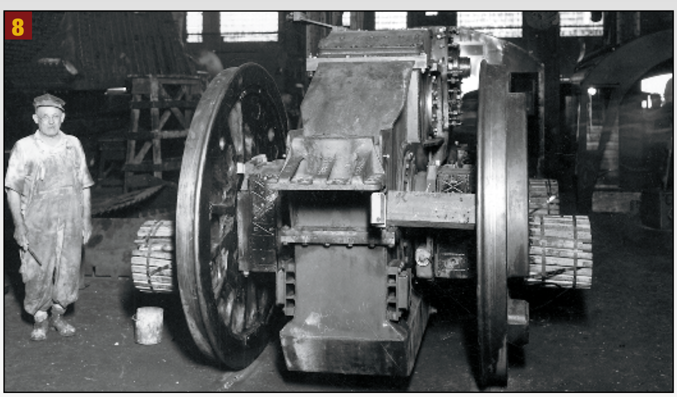
The reduction-drive gearcase on the S2 did not provide reversing capability for the main turbine, so two turbines were required. The multi-stage main turbine on the engineer's side was rated at 6,900 h.p. and was capable of driving the locomotive forward at more than 100 mph, at which speed the turbine would be turning 9,000 rpm. The reversing turbine on the fireman's side was a single-stage machine of about 1,500 h.p., and its gearing would allow the locomotive to be backed at up to 22 mph. As the S2 was designed primarily for long-distance, high-speed passenger service, backing capability was of limited importance.

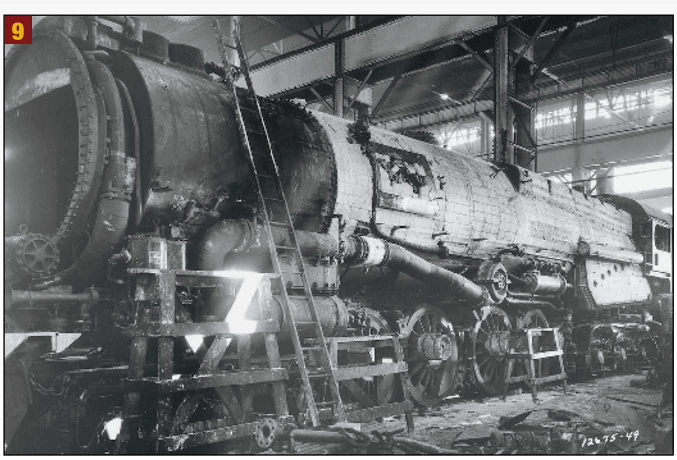
Steam supply to the two turbines was controlled by a conventional mechanically operated front-end throttle that is readily evident in photos of the engineer's side of No. 6200. The steam supply pipe ran below the center of the boiler, and each turbine was fitted with an inlet steam valve. The turbines were each designed to turn in one direction only, and just one turbine could be in use at a time.

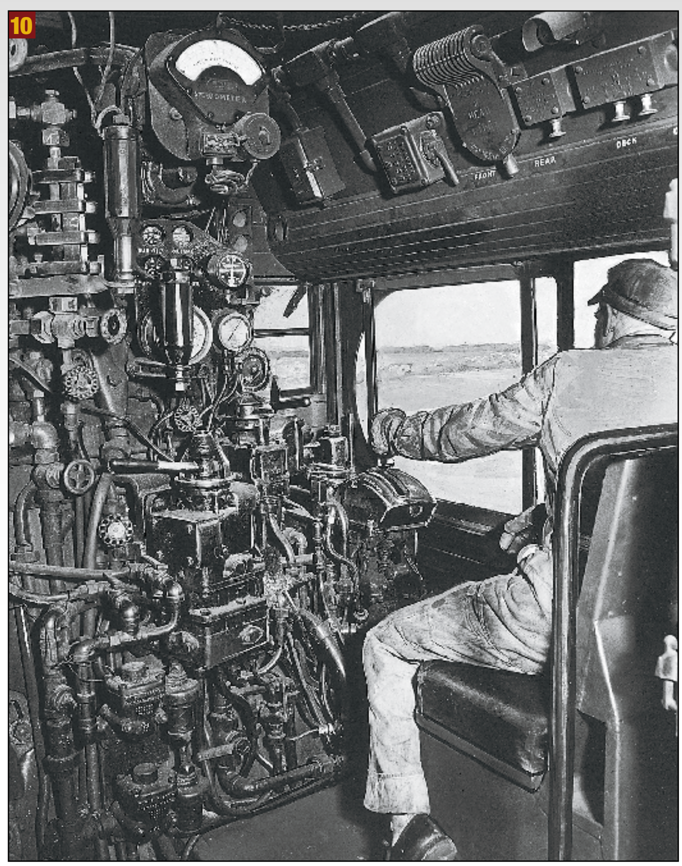
The forward turbine was always connected to the drive-gear train; when operating in reverse it was allowed to windmill backward without steam pressure. The reversing turbine was fitted with disengagement clutches that allowed it to be separated from the gear train in forward operation. In addition, the reverse turbine clutch was equipped with a locking mechanism that provided for positive disablement when it was not being used. This was to guard against the possibility of the reverse turbine being inadvertently powered through a leaking steam cutoff valve, which could result in the turbine running up to a speed where it would self-destruct.

A Baldwin magazine ad crowed that the S2 turbine was "powered like a battleship."
Preston Cook collection

The use of a geared steam turbine simplified driving-wheel and running-gear balancing considerably. A conventional rod-driven locomotive has several very complex and conflicting balancing considerations acting on the drive train







simultaneously. The quartering required for the main and side rod pin connections with the drivers in order to properly distribute the engine force application and avoid stopping the locomotive with the engines on both sides on a dead center creates a complex balance requirement, since the rods on one side of the locomotive are 90 degrees out of phase with the rods on the other side. An additional balance problem is the thrust imposed on the drive system by the weight of the reciprocating components as they reach their end of travel in each direction of movement, this forward-backward reciprocating force being applied through the main rods to the drivers. On rod-driven locomotives there is no suitable way to completely counterbalance these two forces; balance of such locomotives is very much an "art," and solutions are always a compromise.

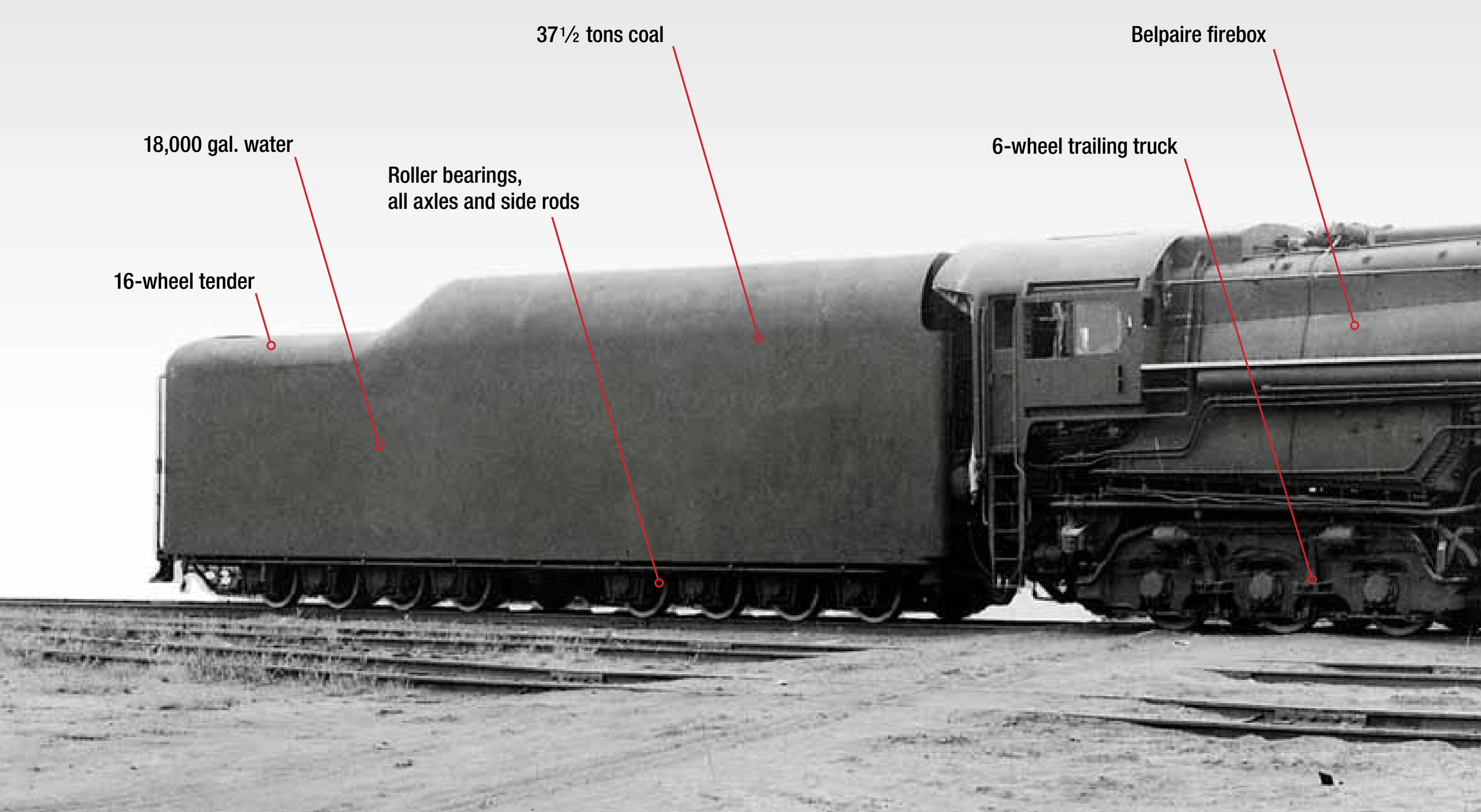
The turbine simplified the driver balance problems and considerably improved high-speed performance potential by eliminating the steam chest, piston engines, valve gear, and main rods. The S2's drive system applied the turbine power to the second and third drivers, with side rods transmitting power to the first and fourth. The side rods still had to be offset 90 degrees between left and right sides in order to avoid mechanical stalling at a dead center, but the balance problem was far less involved than on a conventional locomotive, and excellent balance could be obtained. This allowed the S2 to use relatively small 68-inch drivers that were adequate to carry the necessary counterweights while allowing sufficient room under the running boards for the turbines and steam exhaust lines. The driver diameter would result in a rotating speed of 296 rpm at a locomotive speed of 60 mph, and 493 rpm at 100 mph.

MARINE TURBINE SIMILARITIES

Westinghouse brought a wealth of steam-turbine experience to the S2 project. At the time, the firm was one of the leading U.S. manufacturers involved in transportation applications of geared steam turbines, thanks primarily to its marine business activity. Westinghouse turbines were the predominant propulsion power plant in many classes of U.S. Navy vessels at the time, in applications of more than 50,000 h.p. per propeller shaft. A number of features of the 6200's forward and reverse turbines and their power transmission system had notable similarities to marine practice.

The use of separate forward and reverse turbines was common on ships, which usually had separate ahead and astern turbines in order to provide the greatest propulsive efficiency and make the drive gearbox as simple as possible. The S2's forward turbine used a Curtis impulse stage and five Rateau stages, with the turbine design optimized for 70 mph operation. It delivered power to a dual pinion gear set, also a common feature on marine geared turbine drives. This divided the power input of the highest speed shaft to two gear paths, one running down either side of the axle-mounted bull gear. The input shaft powered a secondary idler shaft that provided the first step of speed reduction. The idler shaft received power through two driven gears on either side of another pinion that delivered power to the bull gear in a second step of speed reduction. The bull gear was carried in an assembly fitted with spring cushion cups, similar to the arrangement used on electric locomotives of the time, to apply the power to the drive axle. Conversely, the spring

S2 COMPONENTS: CONVENTIONAL AND EXOTIC



cushion cups would also tend to absorb some of the track-related forces being transmitted back up the driveline and reduce their impact on the turbine.

To further divide the drive forces, two identical power transmission routes were provided by having the pinion shaft drive two idler shafts, one transmitting power to the No. 2 driver, the other powering the No. 3 driver. All four drivers on each side were connected by side rods, so they acted as a single unit, even though the center two were the only ones that were gear-driven. The drive machinery for both the No. 2 and No. 3 axles was housed in a grease-lubricated gearcase that was supported by the axles, again similar to electric locomotive practice.

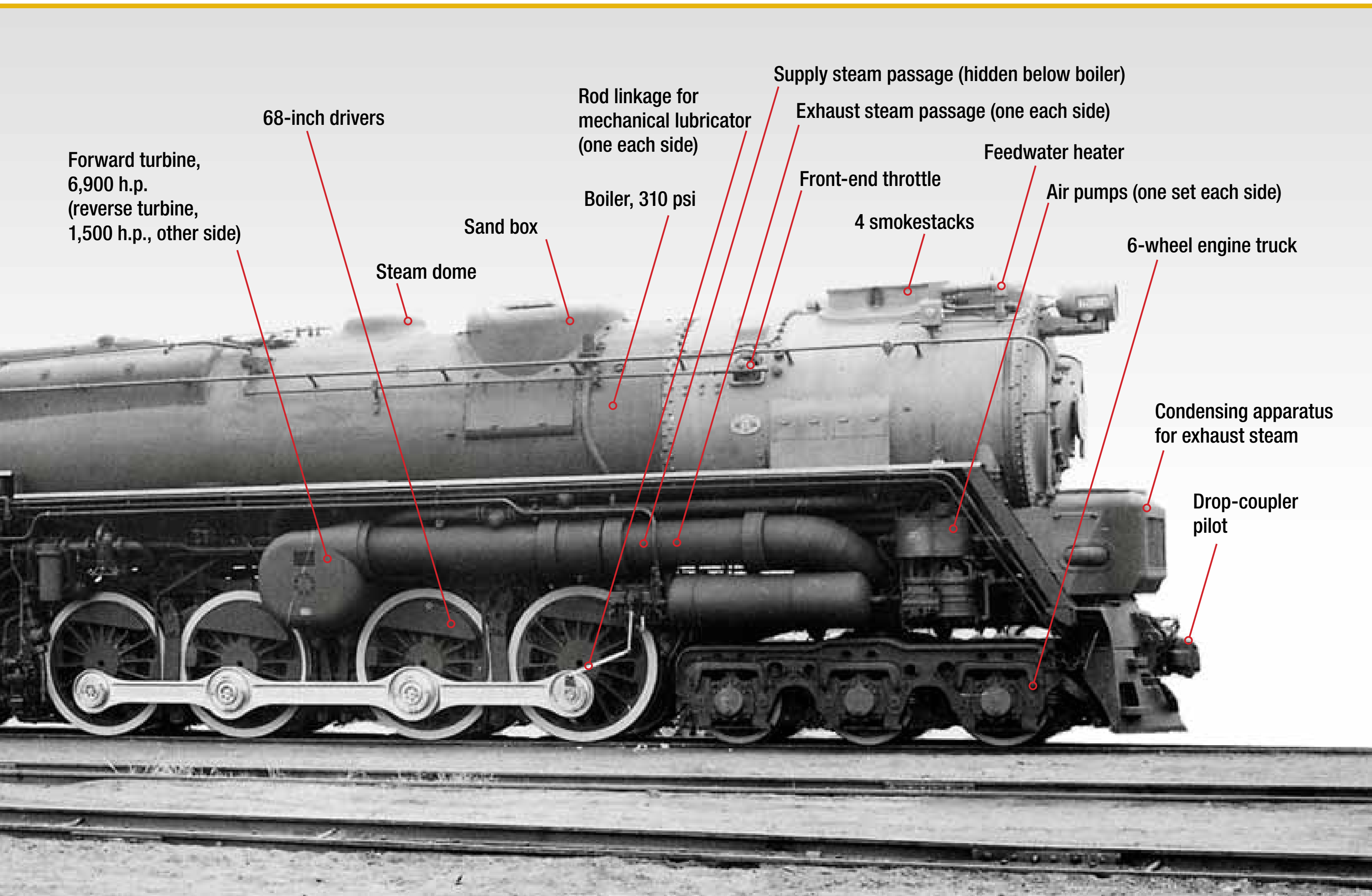
Turbine 6200, a test car tucked behind its tender, stops at Englewood, Ill., with PRR's New York–Chicago *Golden Arrow*. The small, curved smoke deflectors were an early addition.

Above, Paul Eilenberger; below, Classic Trains collection

DRAFTING AND OTHER ISSUES

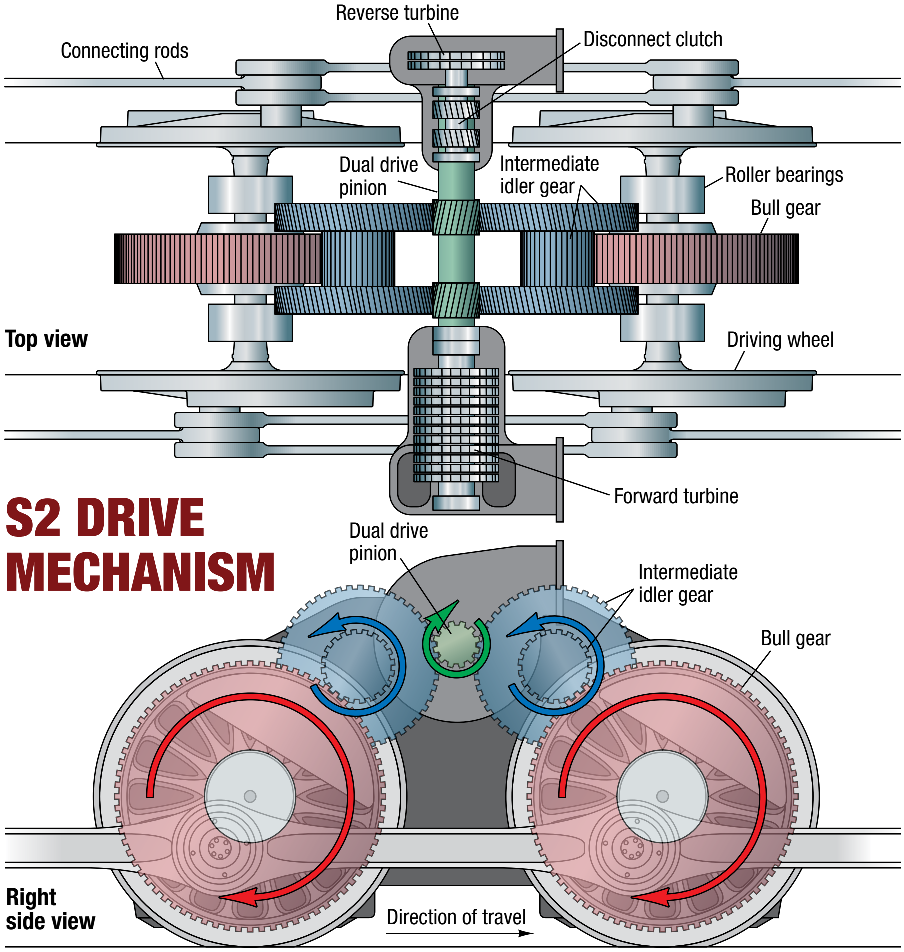
One of the problems encountered with PRR 6200 was how to control the turbine exhaust in such a way that it would provide adequate draft to the firebox and sufficient smoke-lifting at the stack. In conventional rod-driven locomotives, there is still a substantial amount of energy available in the exhaust from the cylinders, which provides a pulsed, high-velocity drafting effect when directed through the exhaust nozzle (producing the characteristic *chuff-chuff* sound). In a steam turbine, the exhaust steam exits the turbine with minimal remaining energy. When exhaust at lower throttle settings was directed through a single stack of adequate size to handle the exhaust flow at full throttle, this did not provide sufficient velocity for draft and smoke-lifting at all speeds.

The solution to the draft problem was provided by Charles Kerr Jr., who devised a grouping of four exhaust stacks, their use controlled by throttle-operated butterfly valves. For starting and low-speed operation, the S2 used a single stack, which was not fitted with a control valve; the other three stacks were opened sequentially as speed and load increased. The linkage that operated the stacks was a relatively simple arrangement of mechanical rods and bell cranks. Located



A famous August 1945 photo shows the S2 doing what it did best: racing a mile west of Warsaw, Ind., with the eastbound *Broadway Limited*.

Ira H. Eigsti photo



on the exhaust side of the steam circuit, where the steam energy was already expended, the mechanism had no significant effect on the throttling of the turbine. In service it was found that the series of sequentially opening stacks was still not adequate to lift the smoke clear of the locomotive, and during its lifespan, PRR 6200 was fitted with two types of smoke deflectors, the second installation being similar to that used on New York Central's 4-8-4 Niagaras.

CONTROLLING THE TURBINE

If all the control functions for the turbines and throttle on PRR 6200 had been operated directly by the engineer, he would have been a very busy man. Changing direction and getting the locomotive moving would require closing and opening the appropriate turbine inlet valves, possibly disengaging and locking the reverse turbine, adjusting the throttle setting, and operating the valves controlling the three additional smoke stacks as they were needed with increasing speed and load. Of course, all this needed to be done simultaneously with the engineer's normal operating and safety duties, and this was simply too much for one man. Assigning some of the tasks to the fireman in a locomotive where the cab would already be loud with the sound of turbine exhaust was also impractical. Consequently, Westinghouse engineer Harry C. May designed a "Fluid Pressure Control System for Multiple Turbine Installations" that managed all these functions through a system of relays and servo motors (U.S. Patent 2,515,962, filed August 23, 1944).

The scope of this system was to control starting, running, reversing, power output, and speed, and to limit speed in both directions of operation. The system also was designed to prevent reversing direction of movement until the locomotive came to a complete stop, to control the pressure-lubricating system for engine components and running gear, and to alarm and cut off the application of power in the locomotive if lubrication was lost. In order to achieve all of these functions, the system had to interface with the S2's air system, steam-delivery and exhaust systems, the lubrication system, and its own internal hydraulic and pneumatic control circuits.

The combined control system was a masterpiece of mechanical technology, combining all functions in a single lever control that moved in a crooked slot from neutral to full throttle forward and full throttle reverse. The "jog" in the controller path avoided the possibility of the engineer going directly from forward to reverse movement in the dark or by snagging the control handle with his coat. Through the use of relay valves and servo motors, the system was adapted to operate conventional hardware with the appropriate linear or rotary control movements, allowing the use of common steam locomotive auxiliary equipment rather than requiring the design of new components. It was designed in such a way that it could be adapted to two turbines with individual throttle valves, or two turbines using a common front-end throttle valve and individual cutoff valves, as was used on PRR 6200.

HOW THE S2 PERFORMED

Testing of PRR 6200 revealed that the locomotive achieved many of the objectives its designers had envisioned for it. The S2 was more than adequate for high-speed passenger service, proving itself a very impressive performer at speeds above 60 mph. It could easily attain and maintain speeds in excess of 100 mph with a heavy train. The S2 was not only more efficient than conventional steam locomotives, it was also smoother running because of the lack of main rods and heavy reciprocating components. But PRR 6200 also revealed significant problems, and exposed the limitations of geared steam turbines on a locomotive.

The limited range of best operating efficiency of a geared steam turbine proved to be one of the most significant technical problems faced by the locomotive. Many high-horsepower marine applications of steam turbines combined the use of a cruising turbine with high- and low-pressure turbines, to allow selective operation in the range of greatest efficiency. Unfortunately, such a complex plant was impractical in the limited space available on a locomotive.

Consequently, PRR 6200 had been designed for best performance in a rather limited high-speed range that would correspond with anticipated passenger-service needs, and its performance at lower speeds was sacrificed in the belief that it would spend relatively little time at those speeds. There was not sufficient flexibility for effective dual-service (freight and passenger) use of such a locomotive unless the drive-gear ratio could be changed to optimize the turbine performance in different speed ranges.

The low-speed loading scenario for a locomotive also differed significantly from the performance of a geared turbine plant in a ship. Marine turbines started the propeller shaft in motion smoothly, and frictional resistance was minimal since shaft bearings were pressure-lubricated. The resistance of the propeller in the water was also very low at the beginning of rotation, and departures of vessels large enough to be powered by geared steam turbines were usually started with a backing movement out of a berth, assisted by tugs.

The situation was quite different for a

PENNSY'S BATTLESHIP

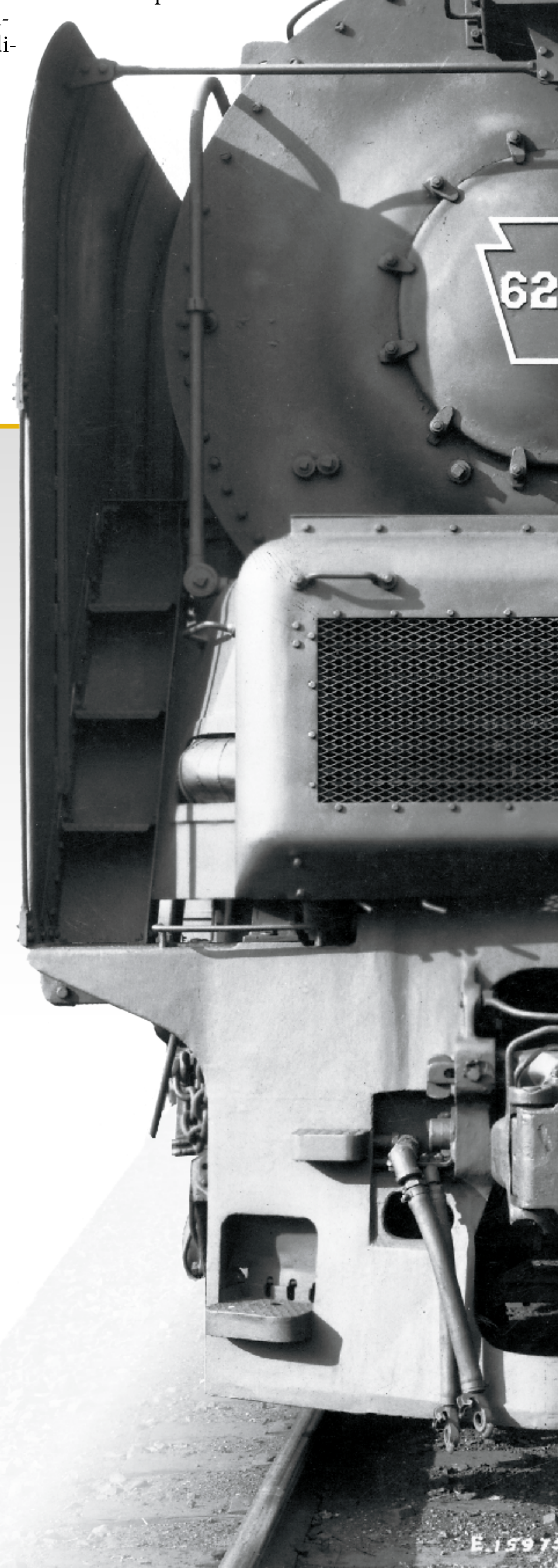
Wheel arrangement	6-8-6
Class	S2
Road number	6200
Builder	Baldwin-Westinghouse
Year	1944
Driver diameter	68 in.
Turbines	
Steam pressure at inlets	285 psi
Steam temperature at inlets	750 deg. F
Back pressure at outlets	15 psi
Forward	
Nominal horsepower	6,900
Max. operating speed	9,000 rpm
Reverse	
Nominal horsepower	1,500
Max. operating speed	8,300 rpm
Boiler	
Pressure	310 psi
Max. outside diameter	102 in.
Grate area	120 sq. ft.
Fuel	Bituminous
Combustion chamber	120 in.
Tube length	18 ft. 0 in.
Circulators	6
Heating surfaces	
Evaporative	4,992 sq. ft.
Superheater	2,050 sq. ft.
Weights, working order	
On drivers	260,000 lbs.
Total engine	580,000 lbs.
Tender	449,400 lbs.
Rated tractive force	
Forward	70,500 lbs.
Reverse	65,000 lbs.
Factor of adhesion	
Forward	3.69
Reverse	4.00
Tender capacity	
Coal	37 1/2 tons
Water	18,000 gal.

Like Baldwin, PRR linked the S2 to naval ships. From a 1945 ad: "the same kind of power that sends big battleships forward—*turbine drive*!"
Preston Cook collection

geared steam turbine locomotive. The standing friction of a train could be considerable, especially in cold weather or if it was sitting on uneven track structure. Generating the tractive effort to overcome starting friction could require the use of relatively high throttle settings, and when movement did start, it was often with some slipping. A wheel slip in a steam turbine locomotive was magnified by the gear reduction drive and could result in the turbine going suddenly from very low speed to several thousand revolutions per minute, putting immense force on the input drive shaft and pinions.

At the beginning of motion, the turbine had virtually no flow resistance through the stationary nozzles and the blades—it behaved more like an open pipe. As a result, PRR 6200 had a legendary tendency to take its boiler from 310 psi steam pressure down to less than 100 psi while starting a train, and this put tremendous stresses on the boiler and firebox. The locomotive went through its short life with numerous staybolt failures, and spent a great deal of time undergoing repair. Fortunately, this locomotive was a coal-burner, which tends to make the thermal gradient across the firebox less severe. In comparison, oil-burners run a very high thermal gradient between the burner area and the flues, further stressing the firebox, and an oil-burning steam turbine would have had much more serious problems.

The technical issues with firebox stress and staybolt failures on the S2 were never fully resolved. It was later determined that the locomotive's boiler in fact had a design deficiency that contributed to the staybolt failures—that is, they were not solely attributable to the rapid pressure changes with throttle movement. Baldwin began the work to design a revised boiler for the locomotive, but the rapid onset of dieselization removed the urgency to reach a design solution before new hardware could be developed.



S2 TURBINE VS. E7 DIESEL

How did PRR 6200 stack up against Electro-Motive's E7 passenger diesel? The S2 cost $255,000; a three-unit set of E7's was $500,000. The tractive effort of PRR 6200 at high speeds was greater than that of three E7's, an advantage when the S2 was tackling short grades or accelerating to a higher speed. But, if the diesels were sufficient to maintain a balance speed that could hold the schedule, additional high-speed tractive effort would be of little benefit.

The disadvantages of PRR 6200 were its diminished performance and high steam use at low speeds, and its relatively poor total efficiency, a trait shared with other steam locomotives regardless of drive system. The S2 pushed total efficiency higher than the 7 percent of rod-driven, non-condensing steam locomotives, but nowhere near the 30 percent efficiency of 1940s diesels.

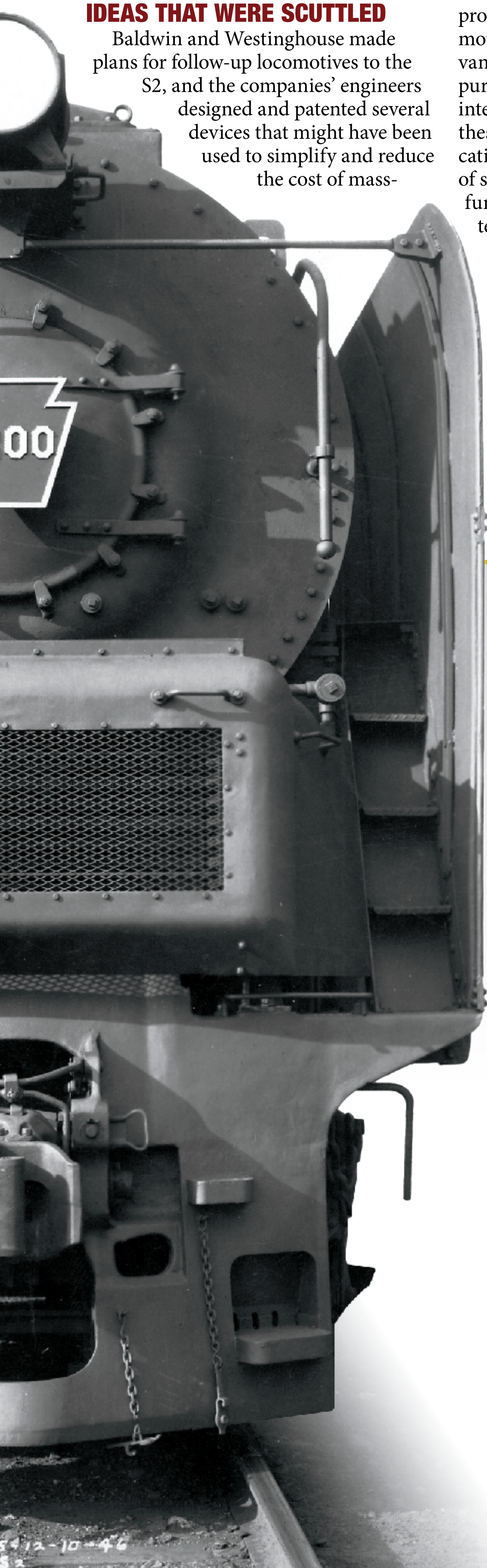
If the S2 and diesel were both burning fuel with equal heating value, the turbine would have required about 4½ times the fuel of the diesels. However, coal has only about one-half the heating value per unit weight of diesel fuel, so the coal-burning steam turbine would in fact need 9 times the weight of fuel required by the diesels. This was an improvement over rod-driven steamers, where the ratio was typically 11 or 12 to 1, but a fleet of turbine locomotives would still require a large portion of a railroad's freight-hauling resources to be tied up transporting locomotive fuel. These economics of fuel consumption, combined with the need to maintain steam support facilities, plus the greater expense of tending and maintaining steam power and its lower availability, were central in the decision of the railroads to dieselize. While the turbine had some advantages over conventional steam, it still could not compete economically with diesels.

In the table below, the S2's higher proportion of prime mover horsepower usable as rail horsepower is due to the 97 percent efficiency of the turbine locomotive's gearbox drive compared with the efficiency losses through the generators, traction motors, and gearboxes of the diesel-electric that result in a transmission efficiency of 85 percent.—*Preston Cook*

EMD

	S2	3-unit E7
Total weight (lbs.)	992,900	945,000
Weight on drivers (lbs.)	260,000	630,000
Total wheelbase (ft.)	108	198
Starting tractive effort (lbs.)	70,500	155,925
Tractive effort, min. cont. (lbs.)	n/a	79,200
Prime mover h.p. for traction	6,900	6,000
Actual rail horsepower	6,550	5,100
Locomotive weight (lbs. per h.p.)	143	157½

Source (S2 data): Westinghouse Engineer Magazine, Sept. 1947



IDEAS THAT WERE SCUTTLED

Baldwin and Westinghouse made plans for follow-up locomotives to the S2, and the companies' engineers designed and patented several devices that might have been used to simplify and reduce the cost of mass-produced gear-drive steam-turbine locomotives. Of course, these became irrelevant as the PRR and other railroads pursued wholesale dieselization, but it is interesting to take a look at the direction these developments were headed as indications of how a subsequent generation of steam-turbine locomotives might have functioned. All of these proposed systems related to the transmission of power between the turbine and the driving wheels, some of them providing multiple gear drive ratios, and some providing for a reversing function that would have allowed the locomotive to be built with a single turbine.

One of the problems experienced with the S2 involved difficulty engaging the reverse turbine, since the drive and clutch mechanism required the locomotive to be at a complete stop for this to be done. This problem was given some priority in subsequent design projects, in order to find a more reliable way of reversing the locomotive. A patent application for a "Locomotive Drive" was filed by Frank J. Alben on June 10, 1943, and resulted in the granting of U.S. Patent 2,411,350. The drive system included a reversing gear set built into the transmission gear case that would have engaged and disengaged an additional reversing gear shaft to change the direction of movement.

This was a direct adaptation of common marine-drive technology used in reversing gearboxes. It would have allowed a steam turbine locomotive to be built with one turbine, but would provide only a single gear-reduction ratio in each direction of movement. Later, Thomas J. Putz designed a reversing arrangement with the patent application

TURBINE TYPES: PRR S2 VS. C&O M-1

In 1947, Baldwin and Westinghouse built three immense steam-turbine-electric locomotives for Chesapeake & Ohio, class M-1. The designers attempted to address the most difficult problem of steam turbine application, the limited efficiency range of the turbine. To this end, the M-1's used the essential elements of the transmission system of the diesel-electric locomotive. This provided advantages in control flexibility as well as the high starting tractive effort of traction motors. The M-1's had a single turbine prime mover, similar to the one used in the S2, driving multiple generators, with the electrical output powering conventional axle-hung motors. Speed and load control was provided to keep the turbine operating at no less than 60 percent of its maximum speed in all operating situations; this allowed the system to avoid the "open pipe" low-speed performance problems of PRR 6200 and provide an acceptable rate of steam usage at low speeds.

Like the S2, the M-1's eliminated the balance problems posed by the main rods and reciprocating weight of conventional steam locomotives. Like a diesel-electric, their turbine, generator, and traction motor drive was smooth and balanced in high-speed operation and put no rotating loads on the track. The steam-turbine-electric provided one advantage that no diesel could match: It could burn coal directly, an attractive capability for C&O and other coal-haulers.

However, the C&O M-1 locomotives abandoned the cost advantage of geared drive by adopting the complexity and expense of an electric transmission, and they could not overcome the low total thermal efficiency inherent in steam power. The steam-turbine-electrics in fact made the situation worse by routing the mechanical output through an electric transmission system. This took the total efficiency of the machine a step backward from PRR 6200.—*Preston Cook*

	PRR S2	C&O M-1
Total weight (lbs.)	992,900	1,194,800
Weight on drivers (lbs.)	260,000	508,000
Total wheelbase (feet)	108	140
Starting tractive effort (lbs.)	70,500	98,000
Tractive effort, min. cont. (lbs.)	n/a	48,000
Prime mover h.p. for traction	6,900	6,000
Actual rail horsepower	6,550	5,100
Loco. weight (lbs. per h.p.)	143	199

Source: Westinghouse Engineer Magazine, September 1947

Main photo, PRR; above, C. P. Fox

SUCCESS AT LAST—AS A TOY

Unlike its prototype, Lionel's version of the S2 was a popular, outstanding performer.

Despite the failure of the Pennsylvania's turbine locomotive to generate any repeat sales for Baldwin and Westinghouse, a greatly scaled-down version of it was central in a major marketing success by the Lionel Corporation.

In 1946 Lionel was looking for distinctive prototypes for its postwar toy train product line, and selected PRR 6200 as being one of the outstanding designs for reproduction as a "selectively compressed" model. The toy S2 was introduced in 1946 in two visually identical versions: the Lionel 2020 in O-27 sets and the 671 in the company's O gauge sets. The 671 was also produced in a rare "electronic" set that had the capability of uncoupling cars anywhere on the layout. The turbine was again made available in the later Lionel 681 locomotive.

Over the years, all three of these models proved to be outstanding and durable performers, and are still sought by collectors. The production run of the 681 turbine and its detailed successor, the 682 (above), did not end until after 1955, some time after the real Pennsylvania 6200 had been retired and scrapped.

In recent years Lionel, Bachmann, and MTH have produced selectively compressed O gauge reproductions of the 1940s and '50s Lionel turbines, and Lionel also produced a scale model of the 6200 in the 1990s that required O-72 track. This distinctive locomotive has also been produced in HO and O two-rail scale brass versions by several importers. In the world of scale and semi-scale model railroading, the Pennsy turbine realized a level of success and visibility that the prototype never achieved.—*Preston Cook*

filed on June 28, 1946. This was for a "Locomotive Reversing Gearing Apparatus" that was located outside the gearbox, once again allowing the use of a single drive turbine but with a single reduction gear ratio in each direction of movement. U.S. Patent 2,447,136 was assigned to this invention.

Several designs were submitted for gearbox drives that would provide multiple reduction ratios, which could allow the turbine to perform at its best efficiency over a wider range of track speeds. A design by John S. Newton for a "Two Speed Transmission For Turbine Locomotives" was submitted on June 18, 1946, and was granted U.S. Patent 2,435,633. This design provided two different drive gear ratios using a clutch and brake arrangement in a manner similar to an automotive automatic transmission. The theory of operation was quite similar to two-speed automatic transmissions for automobiles, but the system was intended to be a means of matching the peak turbine efficiency to one of two separate speed points, a high speed setting for passenger service, and a lower speed setting for fast freight. Unlike an automotive gasoline or diesel engine, the steam turbine could generate torque right from a start, so it did not require any torque converter in the drive line. An alternate design for a "Synchronized Planetary Reversing Gearing" providing multiple drive ratios as well as a reversing function was developed by Edwin E. Arnolt, Thomas J. Putz, and John S. Newton. It was submitted on August 30, 1946 and granted U.S. Patent 2,463,012.

DECLINE AND DISPOSITION

Throughout its operating career, PRR 6200 continued to suffer from failed staybolts in the firebox. It was initially thought that the rapid changes in boiler pressure when accelerating a train with the turbine were the major contributing factor to these failures. However, observation and testing disclosed that a boiler design defect was in fact the most significant contributor. While this might seem unlikely in the case of an experienced steam locomotive builder like Baldwin, its engineers determined that there was an area of high thermal gradient caused by flow problems around the circulators in the firebox.

More on our website
See some of the patent drawings covering elements of the Pennsy's S2 turbine locomotive at www.ClassicTrainsMag.com

PRR 6200 brings the *Manhattan Limited* into Chicago on June 13, 1947; the S2 sports its second, larger set of smoke lifters. Working the coachyard are three B6sb 0-6-0's, sisters to the last active PRR steamer [see page 72].
W. H. N. Rossiter photo

As the end of the 1940s approached and the Pennsylvania Railroad worked its way toward total dieselization, the S2 spent increasing amounts of time out of service. By 1949, No. 6200 was generally inactive, its forward turbine having been damaged and the blades removed from the last expansion stage, reducing its efficiency. The locomotive was stored at Crestline, Ohio, until about 1952, and then was cut up for scrap.

In its four-year service life, the S2 ran just 103,000 miles. In comparison, the Pennsy's E7 diesels were racking up as much as 24,000 miles *per month*. For most of its career, No. 6200 was available for service less than 40 percent of the time, while the E7's typically posted availability figures of more than 90 percent. With such low availability, the turbine was no bargain despite its much smaller price tag.

An additional factor that contributed to the demise of experimental steam programs was the widespread belief in early postwar research that the technology would soon be developed to extract diesel fuel and gasoline economically from coal through hydrogenation, gas synthesis, or other processes. If coal could continue to be a major energy source through refining into petroleum products that could be burned in diesel locomotives, it was reasoned that there would be much less need to solve the technical problems in the development of new steam locomotives that were still much less efficient than diesels.

The Baldwin-Westinghouse vision of a fleet of mighty gear-drive steam turbine locomotives that could delay or defeat the diesel onslaught proved to be beyond their reach. The technical problems with PRR 6200 were never adequately resolved, while the performance and economy of the railroad's E7's and the diesel power that followed them effectively closed the door on further steam development. In the article "PRR Ventures in Locomotives" published in the October 1949 issue of TRAINS magazine, the anonymous author provided a comment that proved to be the locomotive's epitaph: "No. 6200 seemed to spend more time in the shops than in service."