BALDWIN -
Westinghouse

Geared Steam
Turbine Locomotive
for the
Pennsylvania Railroad

BALDWIN

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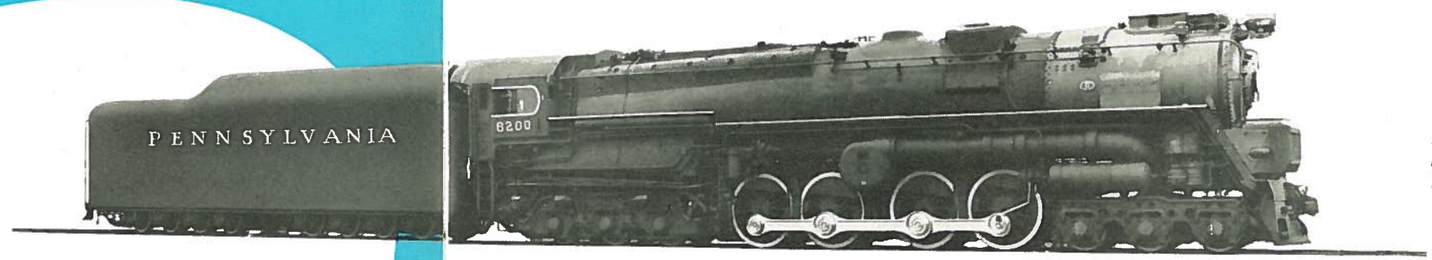
Westinghouse

STEAM TURBINE LOCOMOTIVE

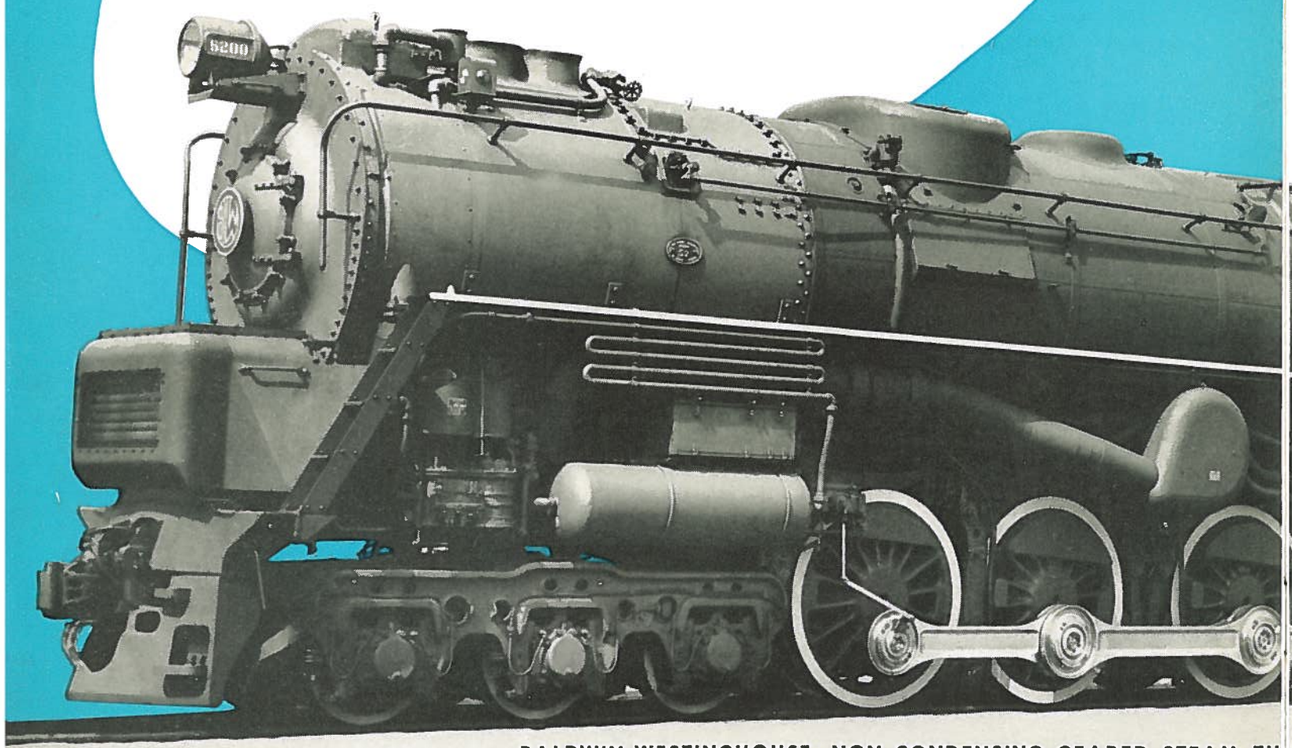
THE BALDWIN LOCOMOTIVE WORKS

PHILADELPHIA, PA.



Right side of Pennsylvania Railroad Class S-2 locomotive showing the forward drive turbine.

STEAM TURBINE LOCOMOTIVE

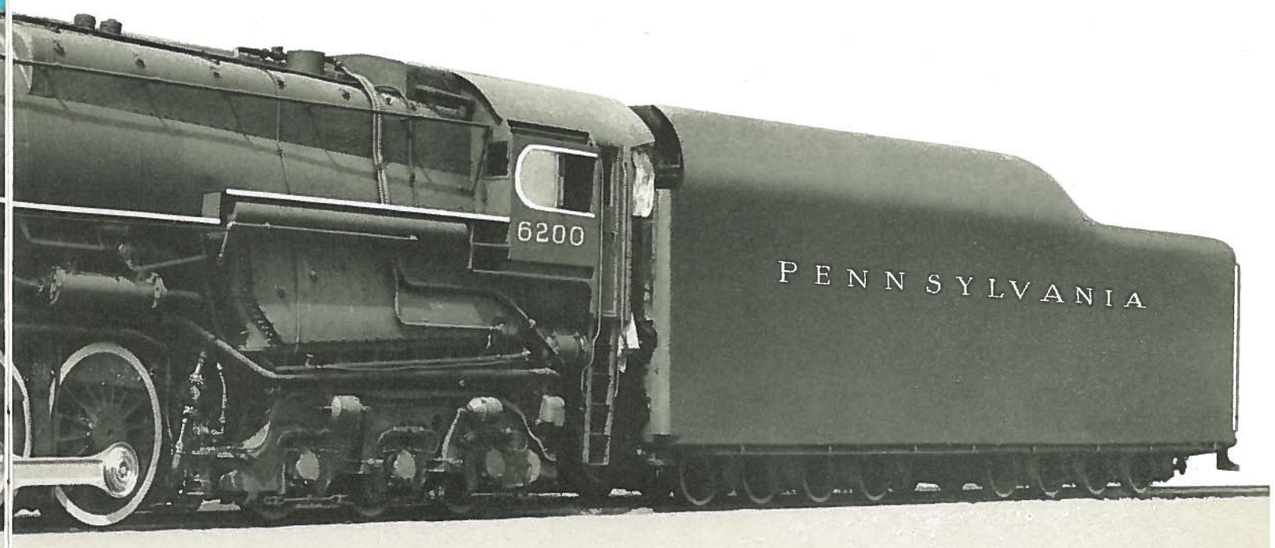


A HIGH-SPEED locomotive powered by a steam turbine, like those that drive the nation's new giant battleships and swift destroyers, has been built to speed wartime and peacetime traffic on the Pennsylvania Railroad.

The new coal-burning locomotive is propelled by jets of steam spinning a precision-made "windmill" encased in steel. With a rating of 6,500 horsepower, the new "iron horse" will be able to maintain the schedules of the largest and heaviest passenger trains.

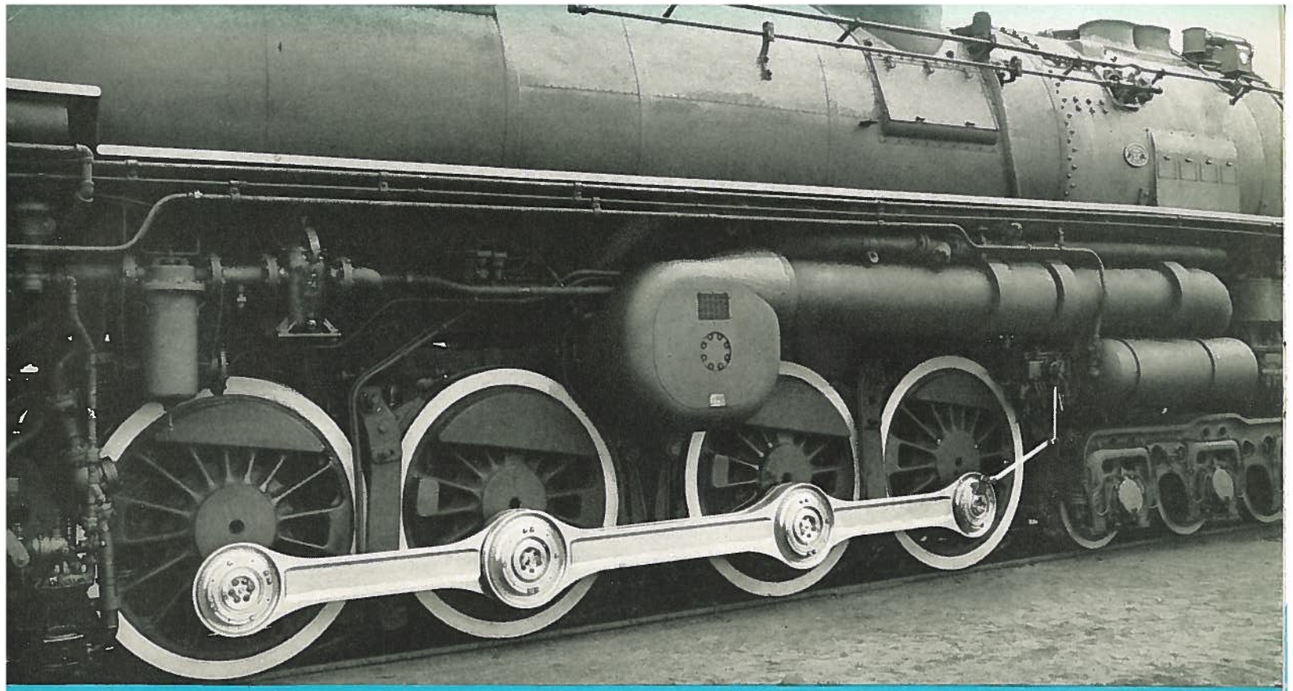
A Baldwin-Westinghouse Product

Two pioneers in the railroad equipment field pooled their experience and facilities in the building of this turbine locomotive, first of its type to be produced in the United States. The locomotive was built at the Eddystone Plant of The Baldwin Locomotive Works and the turbines and gears were manufactured by Westinghouse Electric and Manufacturing Company which has had wide experience in building marine turbines

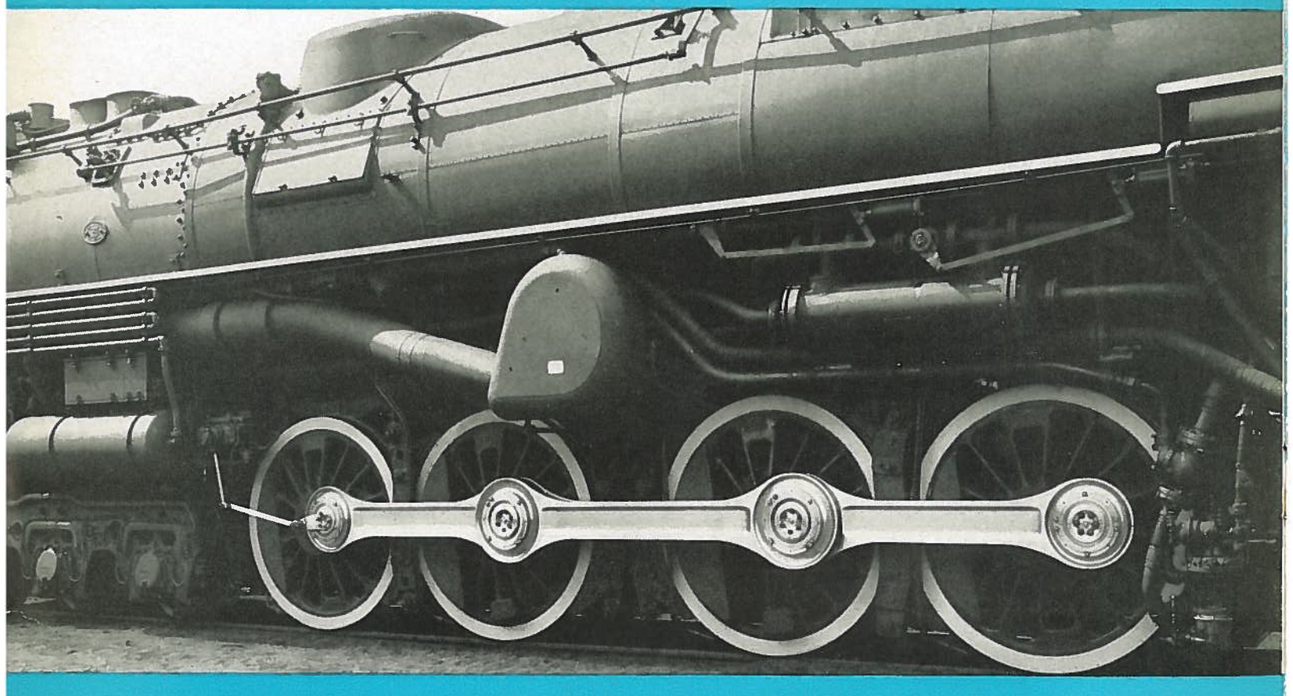


BALDWIN-WESTINGHOUSE, NON-CONDENSING GEARED STEAM TURBINE LOCOMOTIVE BUILT FOR THE PENNSYLVANIA RAILROAD

Gauge	4′ 8½″
Drive, Non-condensing, geared steam turbine.	
Forward Turbine	
Nominal rated capacity	6,900 hp
Maximum operating speed	9,000 rpm
Reverse Turbine	
Nominal rated capacity	1,500 hp
Maximum operating speed	8,300 rpm
Boiler diameter: F. 93″; B. 102″	
Working steam pressure	310 lb
Fuel, Bituminous Coal	
Heating surface	5,002 sq ft
Superheating surface	2,050 sq ft
Grate area	120 sq ft
Driving wheels, diameter	68″
Wheel base, driving	19′ 6″
Wheel base, rigid	13′ 6″
Wheel base, total engine	53′ 0″
Wheel base, engine and tender	107′ 10½″
Weight on driving wheels	260,000 lb
Weight, total engine	580,000 lb
Weight, tender (⅔ coal and water)	347,000 lb
Tender water capacity	18,000 gal
Tender fuel capacity	75,000 lb
Tractive force, forward	70,500 lb
Tractive force, reverse	65,000 lb



Close-up of right hand side of the locomotive showing the location of the forward motion turbine.



Close-up of left hand side of the locomotive showing the reverse or back-up turbine.

and gears to propel United States warships and cargo vessels.

This new step in railroading was undertaken with the immediate aim of trying out the turbine principle in practical operation, to determine its adaptability in opening the way to higher speeds and greater operating efficiency for the steam locomotive.

The boiler, frame, trucks and driving wheels are of the conventional type, the most notable difference being the absence of cylinders, valve motion and their accompanying parts.

The use of a turbine drive eliminates piston rods and other reciprocating parts and, therefore, the driving wheels can be perfectly balanced. This permits operating the wheels at higher speeds than would be practical with a locomotive of the conventional type. Driving wheels can be made materially smaller, leaving more space for fire-box and boiler.

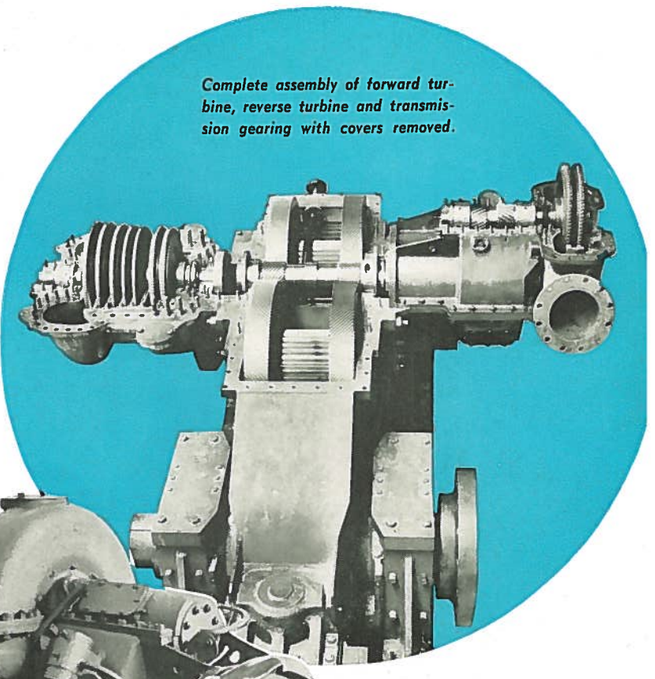
Forward Turbine

The 6,900-horsepower, non-condensing steam turbine which imparts forward motion to the locomotive is located on the right-hand side and is supported by the main locomotive frame. It drives on the middle axles through double reduction gears and a flexible-cup drive which is interposed between each of the final gears and the corresponding driving axle.

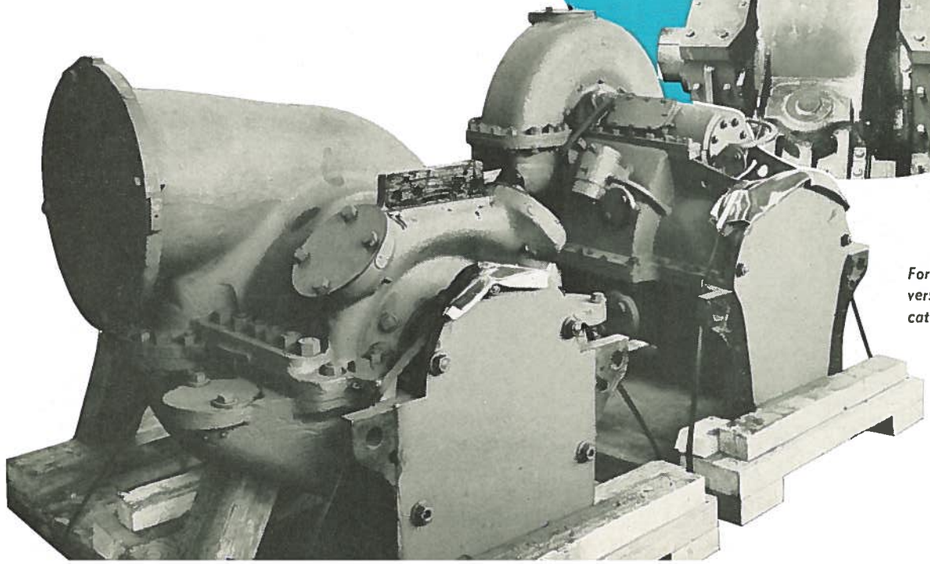
This forward turbine is of the impulse type and consists of a Curtis Stage followed by five Rateau Stages. In order to obtain favorable tractive effort when starting at low speeds, the turbine is overbladed and the maximum efficiency and horsepower are attained at a locomotive speed of about 70 miles per hour.

The forward turbine is no larger than an ordinary easy chair and accounts for less than one per cent of the total locomotive weight of 290 tons.

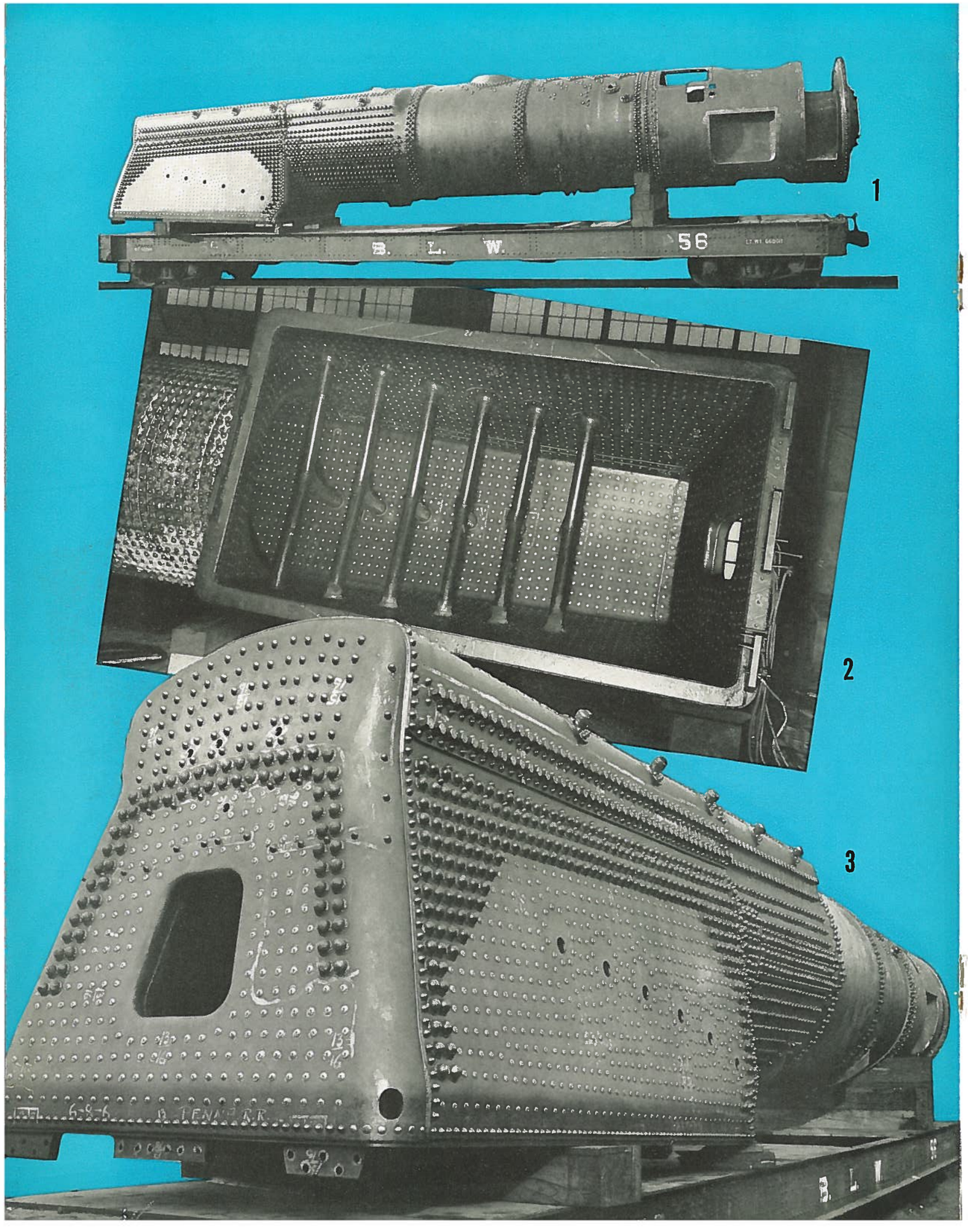
Steam is shot into the turbine through dozens of stainless steel nozzles and the jets strike the first row of turbine blades at a speed of 2,000 miles per hour. The chromium steel blades—more than 1,000 of them, some less than an inch long and the largest somewhat shorter than an average index finger—are mounted in grooves running around a steel spindle inside the turbine. These blades catch the high velocity steam to make the steel spindle revolve, just as a wheel turns when



Complete assembly of forward turbine, reverse turbine and transmission gearing with covers removed.



Forward turbine and reverse turbine before application to the locomotive.



a stream of water is played on its spokes. Rows of stationary blades, fastened to the turbine casing, "bend" or deflect the steam leaving one set of blades and direct it into the next set at the proper angle.

When the locomotive is traveling forward at a speed of 100 miles per hour the tips of the largest turbine blades will be going nearly 700 miles per hour.

Wrings Energy from Steam

In a hundredth of a second the turbine wrings heat and pressure out of the steam, converting them into mechanical power. In a four-foot journey through the turbine blades, the steam loses all but about 15 pounds of pressure and so much heat that it would scarcely boil a potato at the exhaust end. But even this small amount of remaining energy is put to work, sucking burned coal gas up through exhaust stacks to create a continuous, non-pulsing draft through the fire-box and boiler tubes.

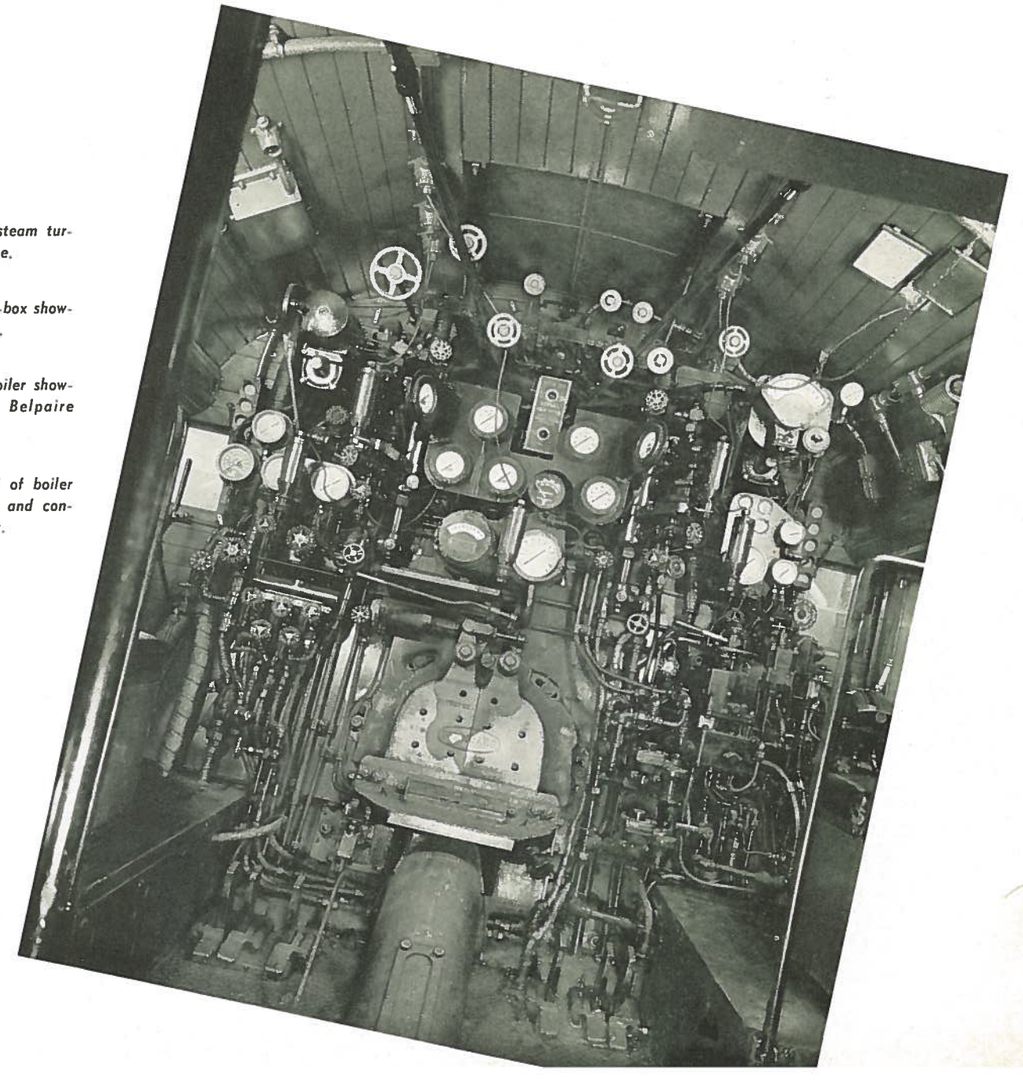
Very little power is lost in the gears, as they are bathed in hundreds of gallons of lubricating oil each minute. This oil is sprayed over the contacting gear teeth and is forced into the bearings by fan-like centrifugal pumps driven by two small steam turbines which circulate and recirculate the entire oil supply. The oil is pumped from the gear case sump through a strainer and a filter, to a lubricating oil cooler which is cooled by boiler feed water. The gear teeth mesh with so little

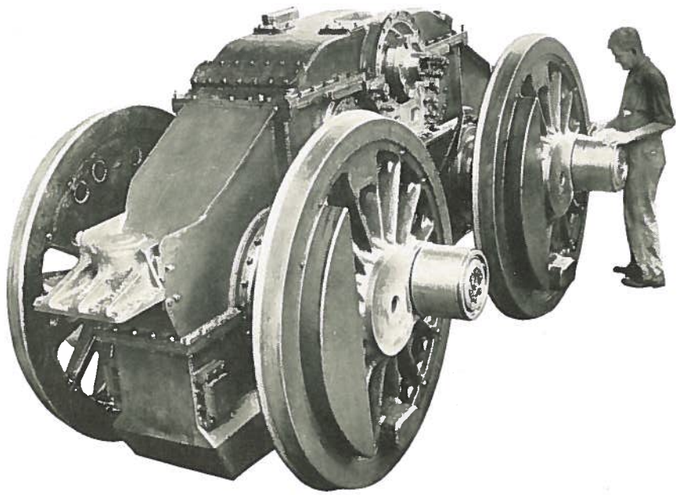
1—*Boiler of the steam turbine locomotive.*

2—*Interior of fire-box showing circulators.*

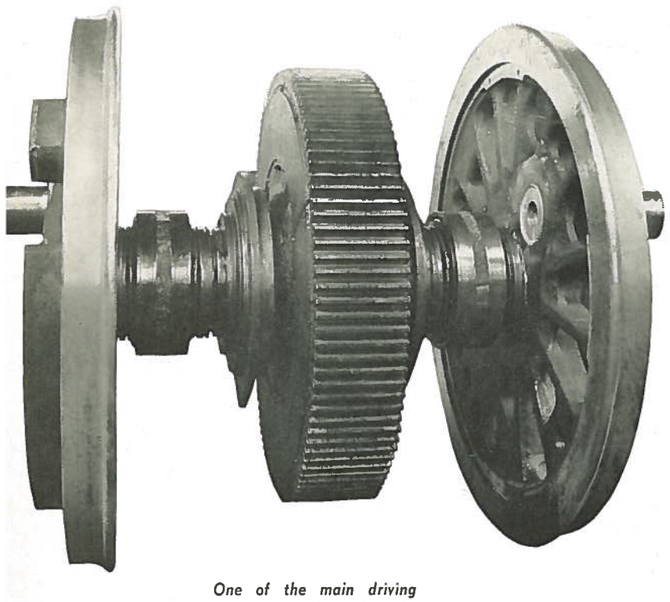
3—*Close-up of boiler showing modified Belpaire type fire-box.*

Right—*Back head of boiler showing gages and control equipment.*





Transmission unit, without turbines, mounted on two center pairs of driving wheels.



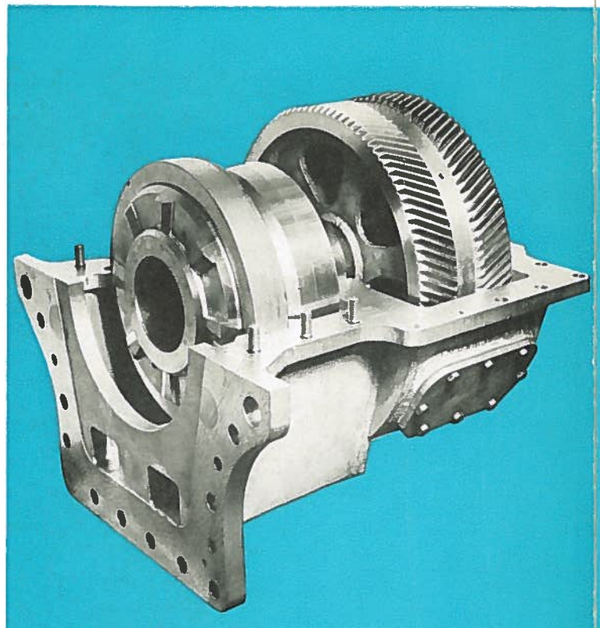
One of the main driving gears mounted on the axle.

friction that 97 per cent of the turbine's power reaches the axles.

Reversing Turbine

Backward motion of the locomotive is accomplished by means of a 1,500-horsepower reversing turbine mounted on the left side of the locomotive. It is supported by the same gear case to which the forward turbine is attached, therefore, the entire power unit becomes a complete self-contained assembly supported from the main frame of the locomotive at three points, an arrangement which allows considerable flexibility in the system.

The reversing turbine, designed to operate the locomotive backward at a speed of 22 miles per hour, consists of a single Curtis impulse element.



Reversing gear and clutch which engages the turbine when the locomotive backs up.

The rotor disc is mounted on the end of the pinion shaft and carries two moving rows of blades. Inlet nozzle blocks and a single stationary row of guide blades are mounted in the turbine casing, providing admission of steam over approximately 50 per cent of the periphery of the rotor.

When steam is entering the main turbine which drives the locomotive forward, the reversing turbine is entirely disengaged from the transmission. When backward motion of the locomotive is desired, the reversing turbine is engaged with the transmission by means of a clutch before steam is admitted to the reversing turbine.

The forward turbine is never disengaged and must therefore operate in a direction of rotation opposite to normal when the locomotive is moving in reverse.

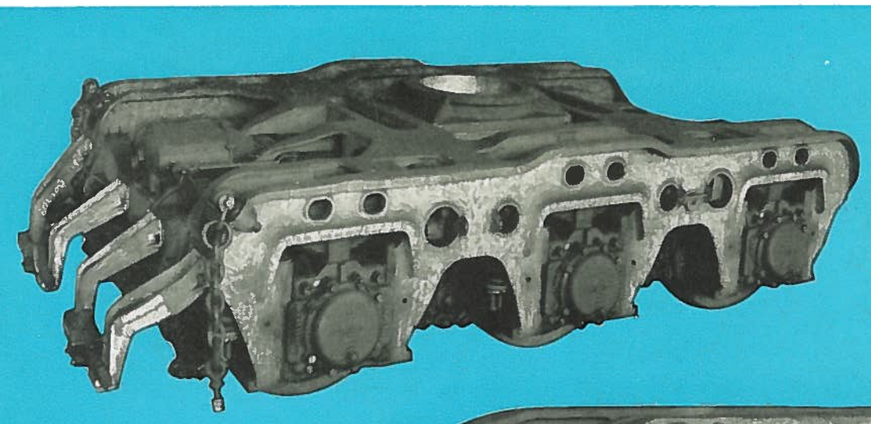
Control

The locomotive is controlled from the cab by means of a single lever, the position of which determines the flow of steam to both forward and reversing turbines. A protective device makes it impossible to operate the clutch engaging the reversing turbine with the transmission unless the locomotive is at rest. Overspeed protection is provided for both turbines to prevent damage from slipping wheels or overspeeding from any other cause.

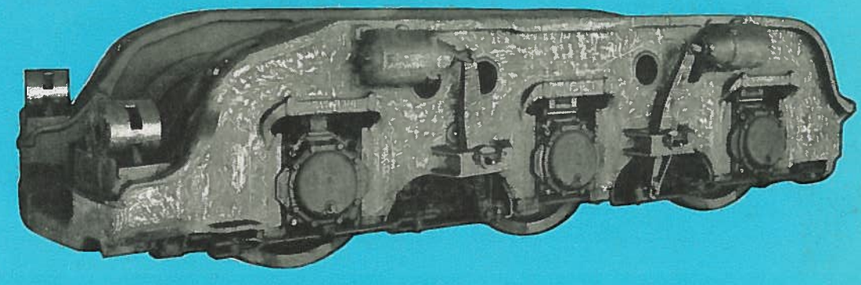
The throttle control of the locomotive utilizes a pneumatic system and the overspeed protection is provided by a hydraulic system.

Mechanical Parts

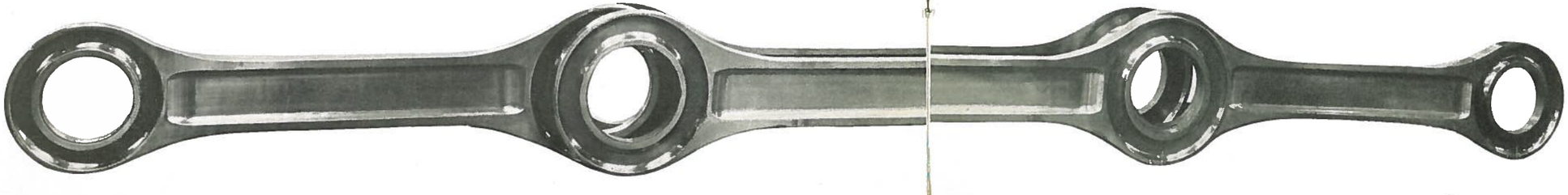
The main frame of the locomotive is a cast steel



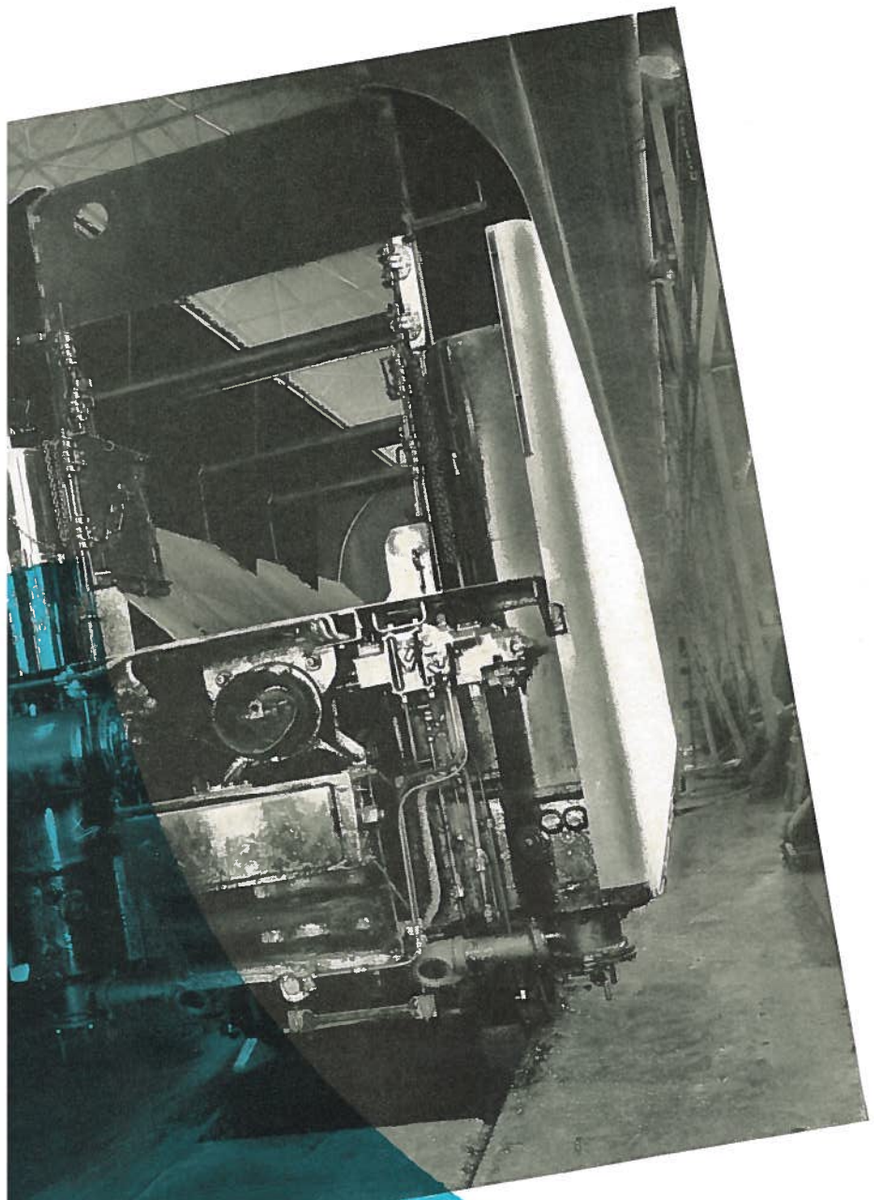
Six-wheel front engine truck.



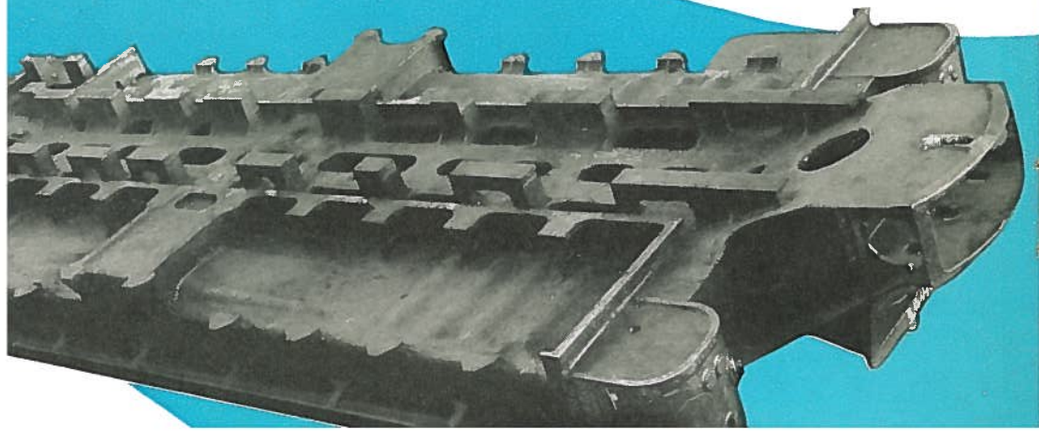
Six-wheel Delta type trailing truck.



Roller-bearing connecting rods for one side of the locomotive.



Front view of tender before it was coupled to the locomotive.



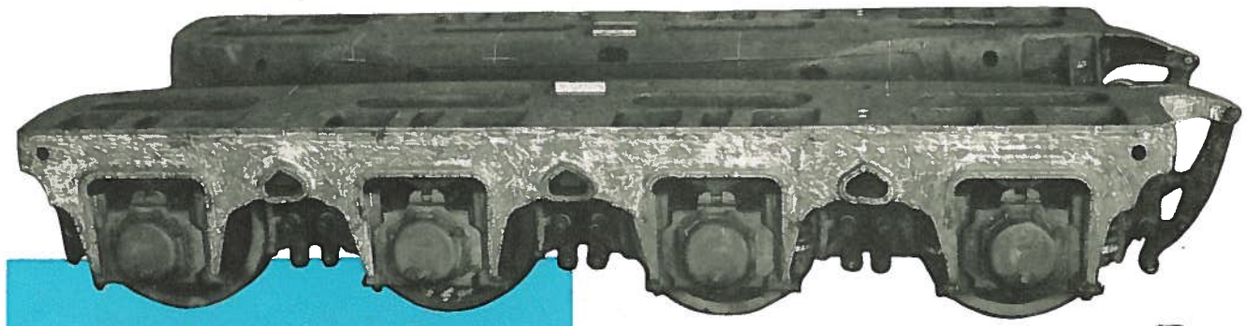
bed with boiler saddle, crossties, brake hangers and other parts cast integral with it.

The front engine truck is a six-wheel, constant resistance type with cast steel frame and outside roller bearings on each axle. The back engine truck is a six-wheel Delta trailing truck with cast steel frame. It, likewise, has outside roller bearings on each of the three axles. Rolled steel wheels, manufactured by Standard Steel Works Division of Baldwin, are used on both front and back trucks.

All four driving axles are fitted with roller bearing boxes similar to those used in many conventional steam locomotives. The driving wheels are 68 inches in outside diameter with cast-steel, spoke type centers. All driving wheels have flanged tires.

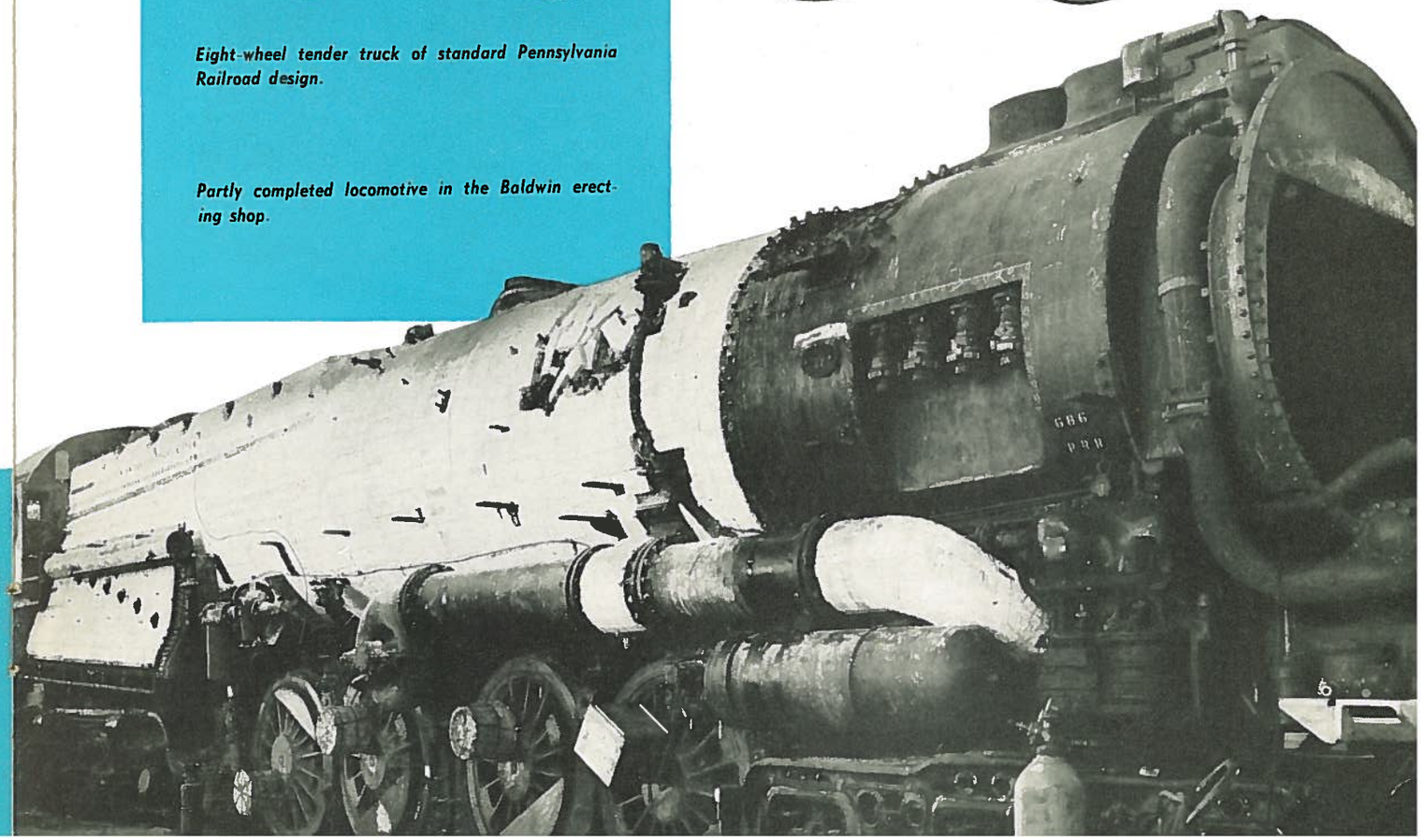
All four pairs of driving wheels are connected by side rods with roller bearings at the crankpins. No main rods, crossheads or valve motion work are required because of the turbine drive.

Westinghouse-American combined automatic and straight air brake equipment is provided, having clasp brakes on the driving wheels and



Eight-wheel tender truck of standard Pennsylvania Railroad design.

Partly completed locomotive in the Baldwin erecting shop.



on all engine truck and tender truck wheels.

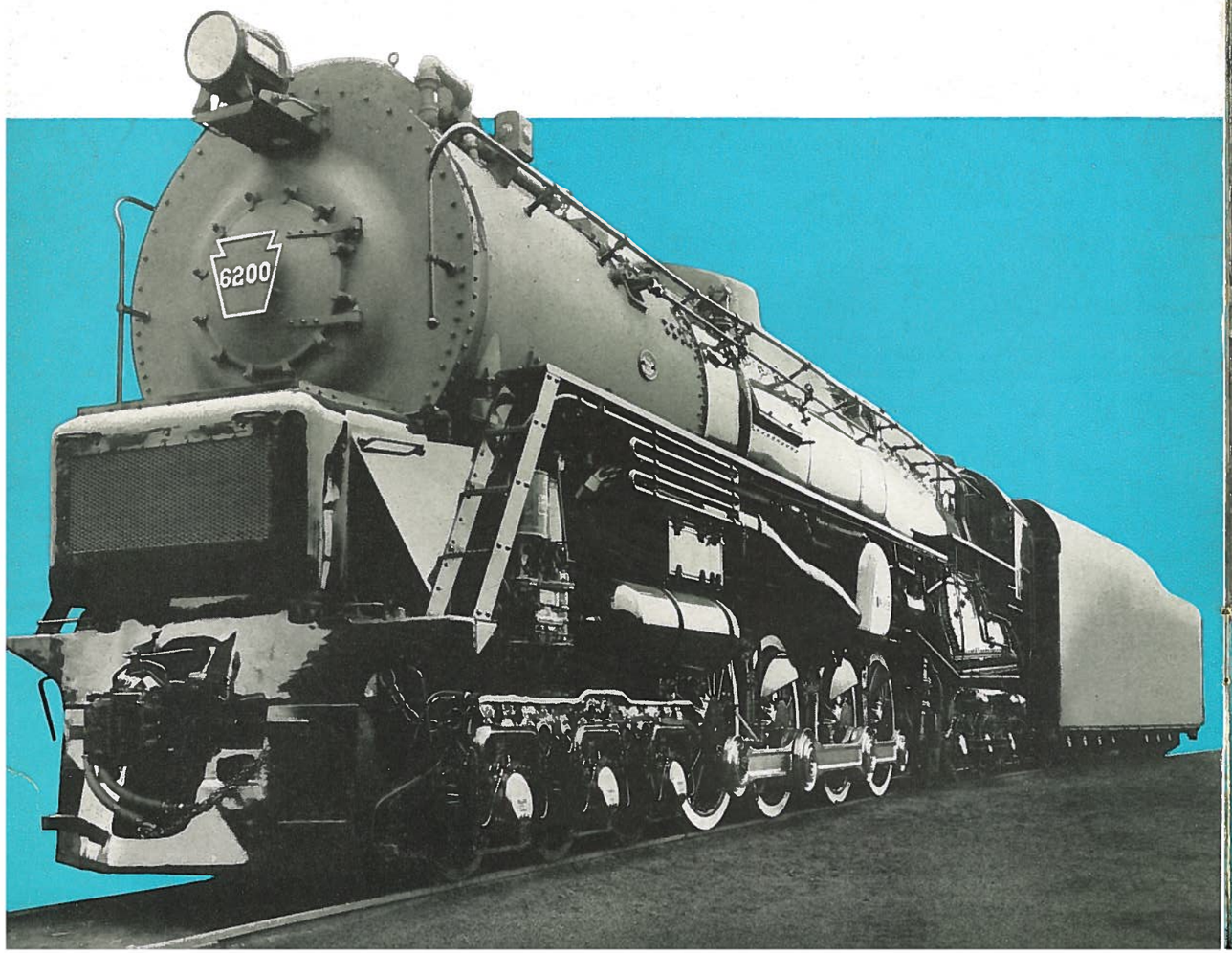
The boiler is a modified Belpaire type, 93 inches diameter outside the first course, designed for a working steam pressure of 310 pounds per square inch. It is equipped with a Type "E" single-loop superheater, feed water heater and stoker. The fire-box has six circulators supporting the fire-brick arch, and a combustion chamber which extends 120 inches into the barrel of the boiler.

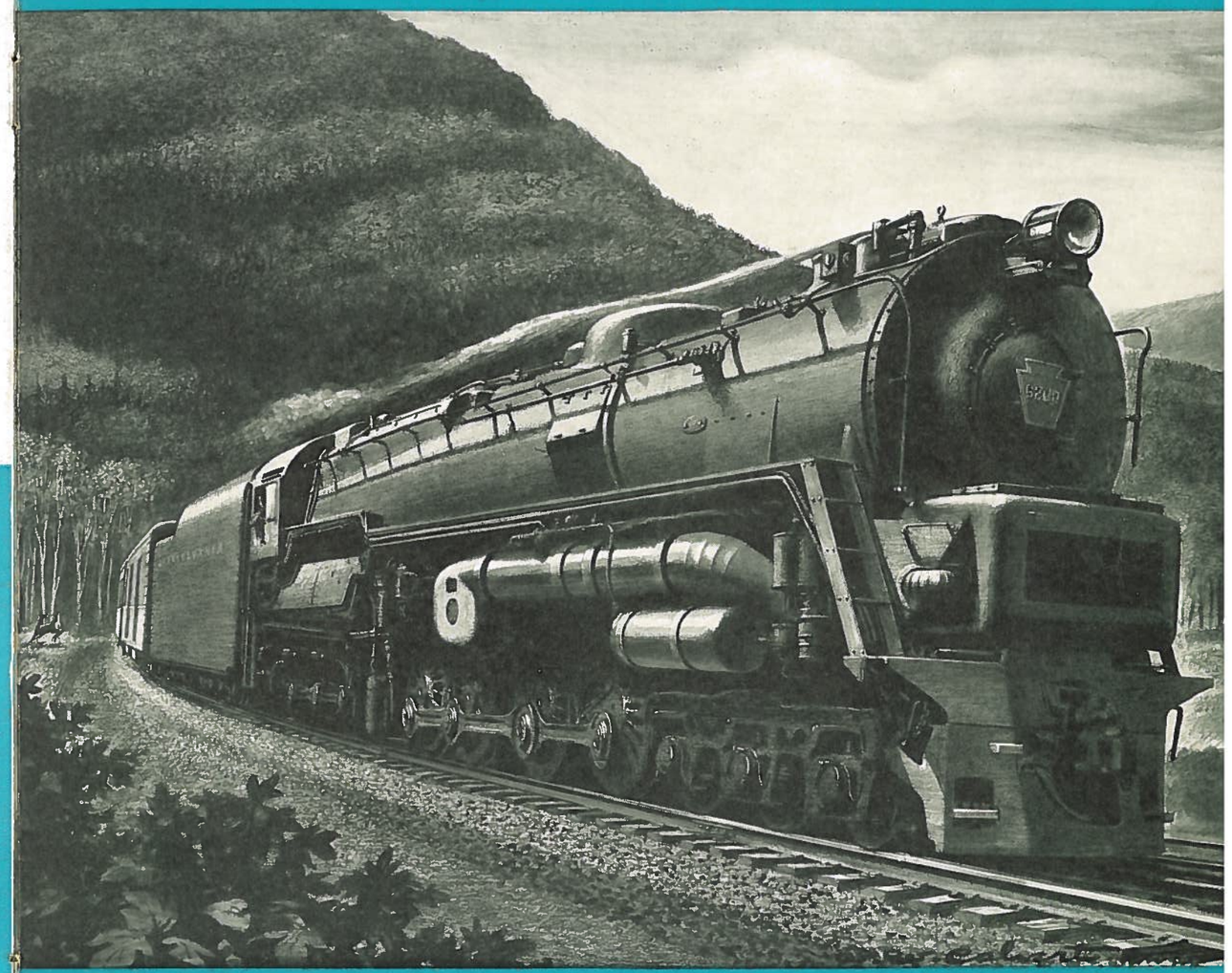
The tender, having a capacity of 18,000 gallons of water and 75,000 pounds of bituminous coal, is built up on a cast-steel, water-bottom frame. It is carried on two eight-wheel trucks of standard Pennsylvania Railroad design.

Performance Characteristics

Due to its turbine drive, the locomotive has uniform torque at all speeds, similar to that of electric and diesel-electric locomotives. The tractive power of the turbine locomotive, exerted at the rail, exceeds at practically all speeds that of a conventional steam locomotive having equal boiler capacity and weight on drivers. It also exceeds the tractive force of a 6,000-hp diesel-electric locomotive at speeds above 40 miles per hour, with a considerable advantage at speeds above 50 miles per hour.

At speeds above 30 miles per hour the steam consumption of the turbine locomotive per horsepower at the rail is considerably less than that of a comparable reciprocating steam locomotive. At starting and at very low speeds the steam consumption of the turbine is relatively high, but with modern high-speed, main-line schedules, with few stops and very little operation at low speeds, this is more than compensated for by the advantages of the turbine at high speeds.





BULLETIN 222
PRINTED IN U. S. A.
TRIM-PRINT, YORK