GAS TURBINES MAKE HISTORY

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GAS TURBINES MAKE HISTORY

Union Pacific Pioneers New Railroad Motive Power; Performance of Diesel and Gas Turbines Sounds Death Knell For Steamers

by C. F. A. MANN

EDITOR'S NOTE: The Union Pacific Railroad placed the largest order on record for diesel locomotives in 1952 and shortly thereafter also ordered 25 gas turbine electric engines. Now, after several years of experience in operating steam, diesel, and gas turbine locomotives, the record has been revealed to our Mr. Mann. He has dug deeply into facts and figures and gives you the first complete story on this pioneering effort in motive power. His report will appear in three successive issues of DIESEL PROGRESS. Here is the first article.

WHY did Union Pacific plunge so heavily into gas turbine power when it went all-out for diesels on the biggest scale in U. S. railroad history? (See DIESEL PROGRESS, February, 1951.) This question, and dozens more, have given rise to a terrific amount of speculation and talk in the past three years.

The cold fact remains that after the first test runs of a gas turbine locomotive in 1950, followed by trials with an improved model in 1951, the Union Pacific ordered 10 production-line identical 4500 hp. units from General Electric. They started coming on the line in early 1952. Almost coincidental with their big orders for diesels, they ordered another 15 with improvements. Why? The answer to this question covers a lot of territory.

The background that sparked this business of taking off in two directions simultaneously, unheard of in world railroad history, can first be visualized by studying the UP main line anywhere between Ogden, Utah, and Cheyenne, Wyo. Any day of the year, "normal traffic" is between 100 and 150 trains a day over this route! One of the world's great parades of motive power passes with clocklike regularity over this Bridge Route that connects three points on the Pacific Coast. Los Angeles and the Pacific Northwest are connected by the UP's own lines at Salt Lake, Ogden and Green River. The San Francisco Bay area is connected via the Southern Pacific at Ogden,—and thereby gains access to all points east at Omaha and Cheyenne. And from the latter point, traffic goes south via Denver, and east via Denver and Kansas City.

Traffic piles up at both ends of the 1000-mile UP Bridge Route. The double-tracked Ogden-Cheyenne section (482 miles long) is the bottleneck. It takes the heaviest traffic flow and crosses the main sub-ranges of the Rockies, varying in elevation up to 8013 ft. at Sherman Summit, Wyo., highest point on the line. The world's greatest fruit and vegetable movement crosses here, too. So, this 482 miles has become the laboratory for world motive power. The endless parade of surviving Big Boy, Challenger and 800 Class passenger steamers, still practically new, play tag with the giant new fleet of EMD diesels of all types. And now the gas turbine fleet of 25 is in the parade too! It takes nearly 200 of the 4500 hp. diesel and turbine plus 5000-6000-7000 hp. steamers to work this terrific railroad bottleneck route! The UP today is doing with its gas turbine fleet, worked into its older fleet, what Santa Fe did with the world's first diesel freight power in 1941. A second factor concerns historical facts peculiar alone to UP. The UP was America's first western land grant line, pioneering on a shoestring into the empty West after the Civil War. To power its locomotives, it quickly had to turn from wood to coal. It found coal in overwhelming quantities on its own land. A kindly Mother Nature put this coal largely on the roof of America in Wyoming and southeastern Idaho,—centrally located in the UP system. So Union Pacific did more to build up steam power, size, and efficiency than competitors, and, consequently, UP hung onto its steam power longer than anyone else before turning to diesels. When it did turn to diesels, finally, UP went almost overboard, as was reported by us in this magazine three years ago.

Unlike the Santa Fe, with a big load to haul and even rougher topography, Union Pacific (almost the first to nibble at diesels back in 1934) turned its back on diesel and began a period of watchful waiting. History shows that it is Union Pacific policy to buy a few of the first of everything, then generally wait a few years before doing extensive buying. It actually bought the very first modern diesel locomotive type—the historic M-10,000—with a Winton distallate engine, even before the Burlington came out with its first EMD-Winton diesel locomotives.

Another important link in the chain of events is the fact that oil in large quantities was discovered over a wide area of the land under Union Pacific ownership. So part of its management has been deeply concerned with oil, and with refining fuel to burn under boilers and in diesels. Yet UP owns not a single refinery but buys from a wide assortment of producers, many of whom do not ship a pound of freight on the UP railroad!

These, then, are the potent factors tied into the total management picture of the Union Pacific System: (a) heavy traffic; (b) a magnificent, fast, heavy-duty roadbed; (c) long experience in owning, mining, and using its own coal, and, (d) a deep financial interest in the production and marketing of petroleum products as a primary owner of oil wells. Furthermore, action based on this background is influenced by the company's thinking for the past 50 years which has been never to be satisfied with anything—just keep hunting for something bigger and better.

Because it is a wealthy railroad, and because it is pressed by the four factors that keep it forever searching for a faster way to move its endless tonnage, it is natural that the Swiss Brown-Boveri gas turbine of 1941 would have two lures for Union Pacific. It might be able to burn low-grade residual fuel oils, of which there is a tremendous quantity in Union Pacific territory. And it might someday salvage its huge unmined stockpile of costly coal in a powdered coal-fired turbine. (UP at one time burned nothing in steamers but black oil on its Northwest and California lines, now 100% converted to diesel.)

Before the English system received its Metropolitan Vickers turbine locomotive in 1952, the Brown-Boveri unit was already being tested on the Western Region railroads of England in 1949. The Union Pacific tests of the original Alco-GE gas turbine job in 1950 thus came between those of the English road models.

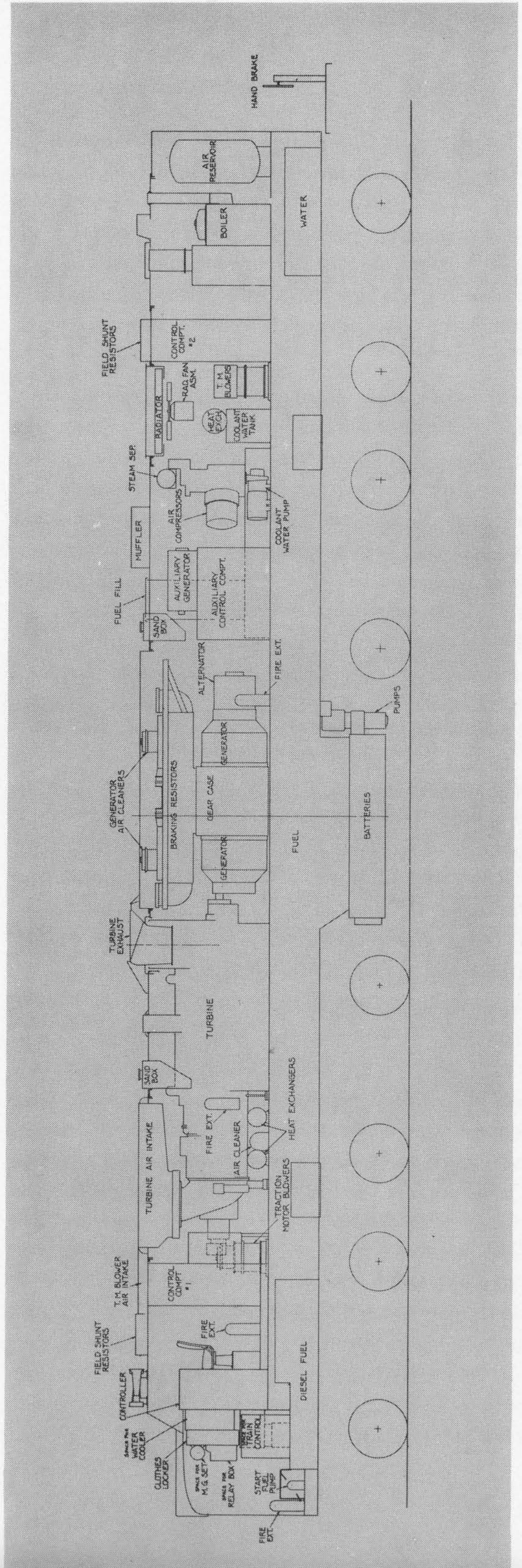
When you delve into Union Pacific's official thinking, the impetus for its sensational plunge into gas turbines appears simple. First, UP officials have always fretted under the high prices of diesel fuel, particularly when prices almost tripled right after the diesel locomotive got underway. Second, the constant heavy cost of lubricating oil for diesel locomotives that now seems to have stabilized to a relatively constant cost factor. Third, it is one of the world's few railroads ideally situated to make fullest possible use of the inherent advantages of the gas turbine yet provide a practical operating backdrop that minimizes the latent defects of operation of gas turbine locomotives at this stage.

No railroad can afford a specialized type of locomotive with the restrictions governing the gas turbine if it has comparatively few daily trains and long intervals of no traffic. Idle turbine time is costly. To be economically feasible, a turbine must pull full loads at top power output as many hours a day as possible. Idling runs it straight into red ink at approximately $25 per hour. Quantities of fuel burned in the gas turbine require a minimum factor of storage and handling to make it economic.

UP officials made a long and comprehensive study of the American locomotive fuel costs. They surveyed past and future price structures in coal, heavy oil and diesel. They made a diligent search to find new uses for the great quantities of heavy residual fuel oils that are a product of many refineries on their western lines, but which find little market due to cheap natural gas competition. Only then did the company decided that the gas turbine, for its particular (and peculiar) setup, was the next logical move for it to make.

Almost simultaneously with the company's decision to go heavily into the gas turbine, it placed several large orders for all types of diesel motive power, and began a complete division by division concentration on the diesel and total elimination of steam. It literally went two ways at once: placed the largest order in U.S. diesel history for diesel locomotives at the same time it placed the largest order in world history for gas turbine power!

As 1954 ended, remaining units of its once huge fleet of steam locomotives had been pushed back to the very newest classes of the most efficient units. These largely include the Big Boy 4000 class (4-8-8-4), 3900 Challenger Class (4-6-6-4), and 800 Class passenger steamers. All less than 10 years old. They also are keeping a few of their two types of 3-cylinder Union Pacific Class. These have the largest and longest wheelbase of any steamers ever built. All except the big new steamers are generally ending their days in the flat country east of the Rockies, where water supply and fast track permit



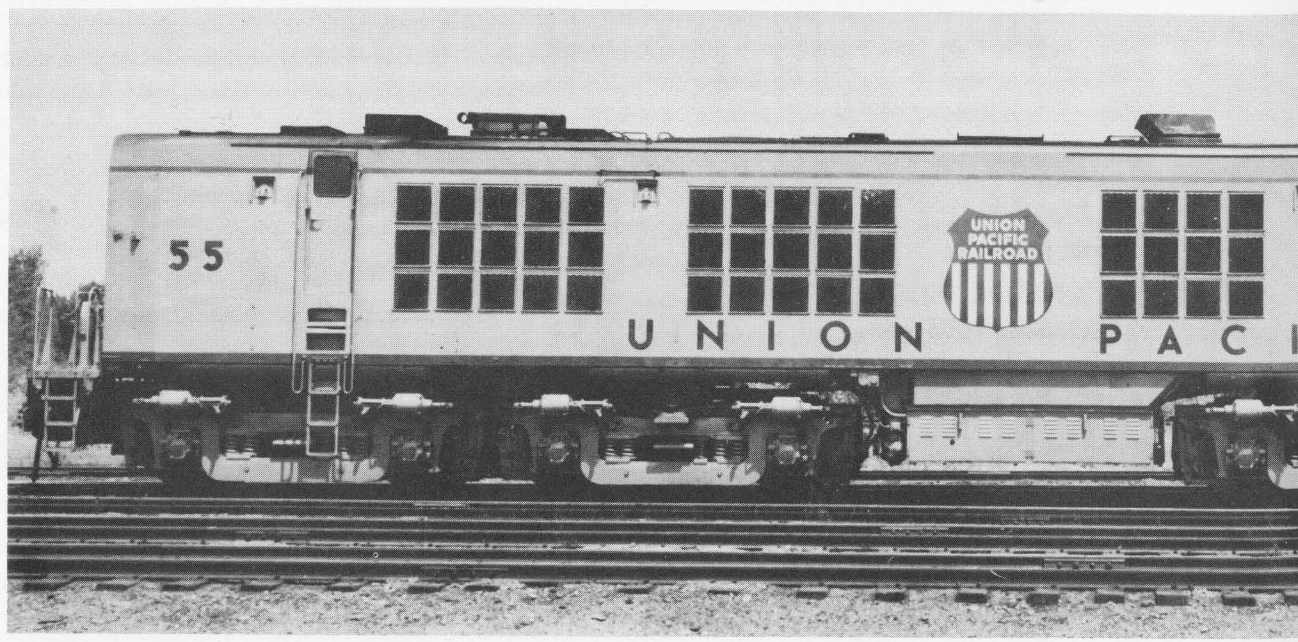
efficient usage. Heavy use of diesel is made in all regions of the system. No more steam power is being purchased and existing units may be gone within four years.

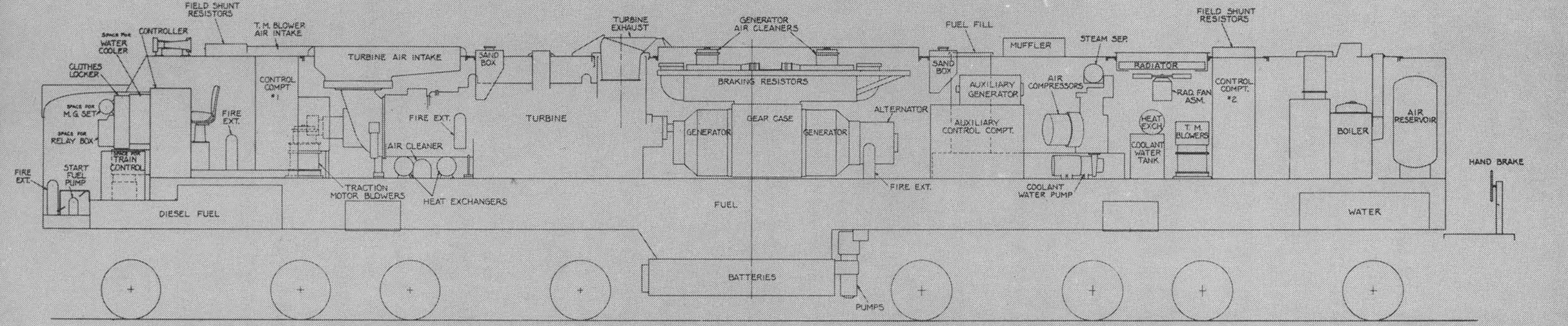
It is clearly obvious the Union Pacific intends to go as far and as fast with both gas turbine and diesel as it possibly can. Some American diesel boosters have gotten cold chills from this announcement of policy, but after you examine the total picture, it can be said that Union Pacific will remain one of the three or four largest diesel users in America for the rest of the century.

Following extensive tests with the original Alco-General Electric turbine, an initial order was placed for 10 4500 hp. units, to burn Bunker C fuel, and to deliver the same approximate output as the standard EMD 3-unit diesel used throughout the system. The first of this order went in service in February, 1952. There is a single cab 83½ ft. long. There are eight motored axles, giving 100% of the total weight of 550,000 lbs. on drivers (fully loaded with supplies). There was to be sufficient output to pull an 80-85 car, 4100-4400 ton freight train without helper over mountainous profile of the 482-mile route between Ogden, Utah, and Cheynne, Wyo. The same approximate average speeds were to be maintained as with standard UP diesel operation or with the Big Boy 4000 class articulated steamers, all of which run in a pool between these two points.

Location of equipment is shown in this schematic elevation drawing of the gas turbine locomotives built by General Electric for the UP.

One of the original 10 GE gas turbine electric freight locomotives, showing the enclosed catwalks, modified in later models.

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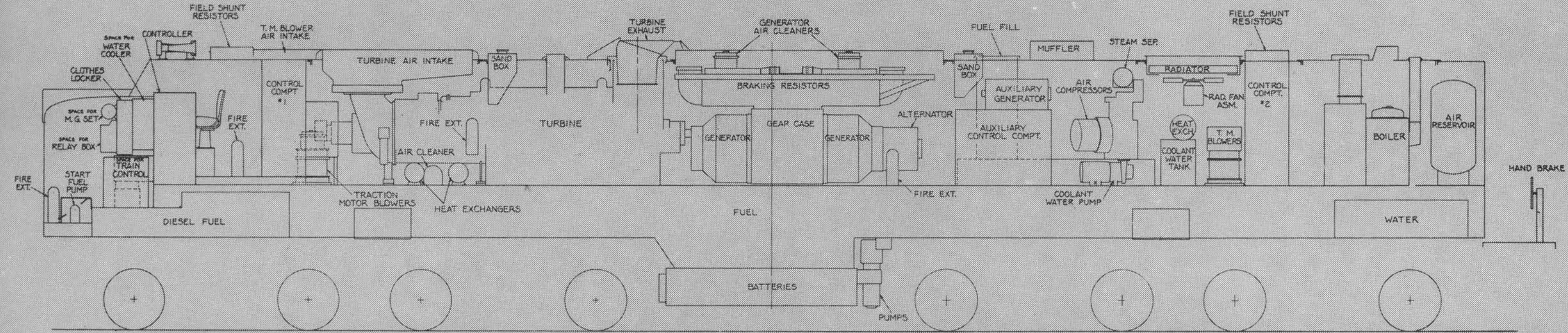
T. M. BLOWER AIR INTAKE
SPACE FOR WATER COOLER
CONTROLLER
CLOTHES LOCKER
SPACE FOR M.G. SET
SPACE FOR RELAY BOX
SPACE FOR TRAIN CONTROL
FIRE EXT.
START FUEL PUMP
CONTROL COMPT. #1
TURBINE AIR INTAKE
SAND BOX
TURBINE EXHAUST
TURBINE
FIRE EXT.
AIR CLEANER
TRACTION MOTOR BLOWERS
HEAT EXCHANGERS
DIESEL FUEL
GENERATOR AIR CLEANERS
BRAKING RESISTORS
GENERATOR
GEAR CASE
GENERATOR
ALTERNATOR
FUEL
BATTERIES
PUMPS
FIRE EXT.
FUEL FILL
SAND BOX
AUXILIARY GENERATOR
AUXILIARY CONTROL COMPT.
MUFFLER
STEAM SEP.
AIR COMPRESSORS
COOLANT WATER PUMP
RADIATOR
RAD. FAN ASM.
HEAT EXCH.
COOLANT WATER TANK
T. M. BLOWERS
FIELD SHUNT RESISTORS
CONTROL COMPT. #2
BOILER
AIR RESERVOIR
WATER
HAND BRAKE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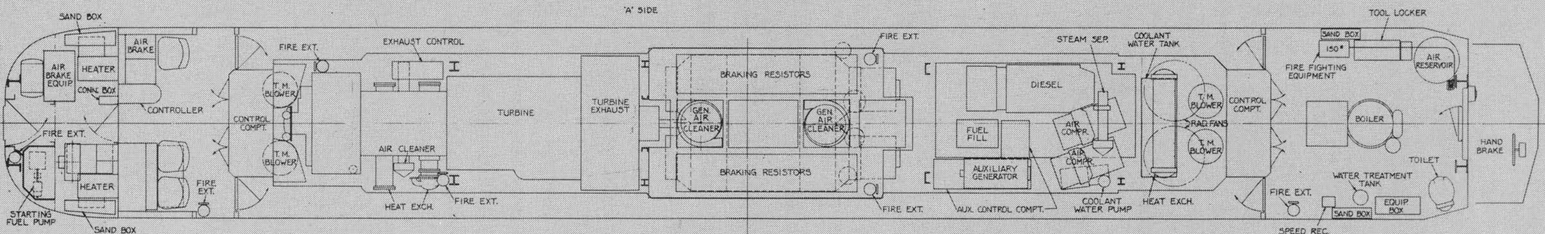
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BOILER
HAND BRAKE
TOILET
WATER TREATMENT TANK
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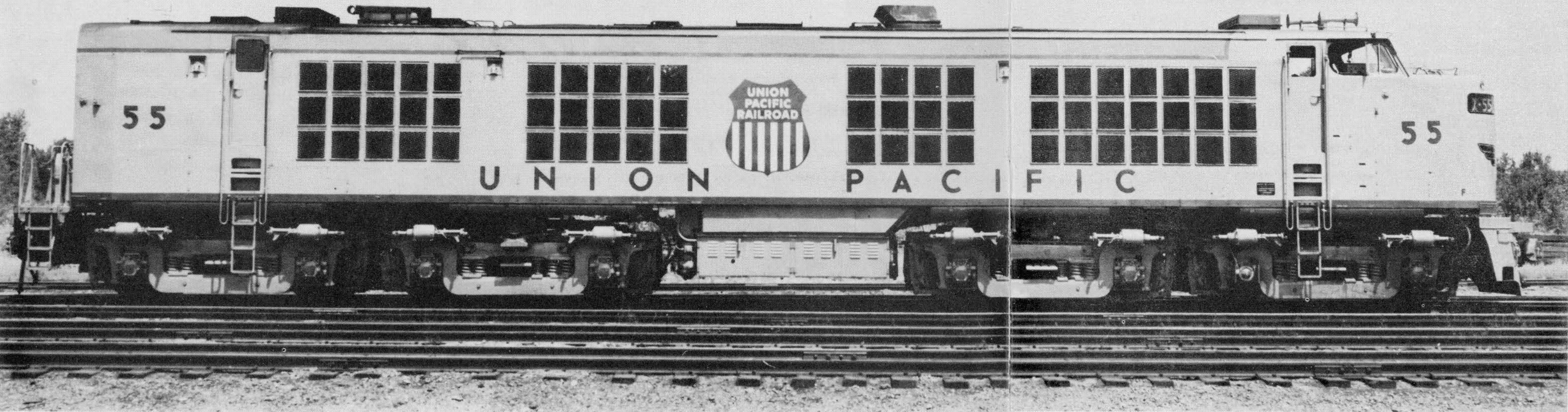
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UNION PACIFIC RAILROAD
UNION PACIFIC
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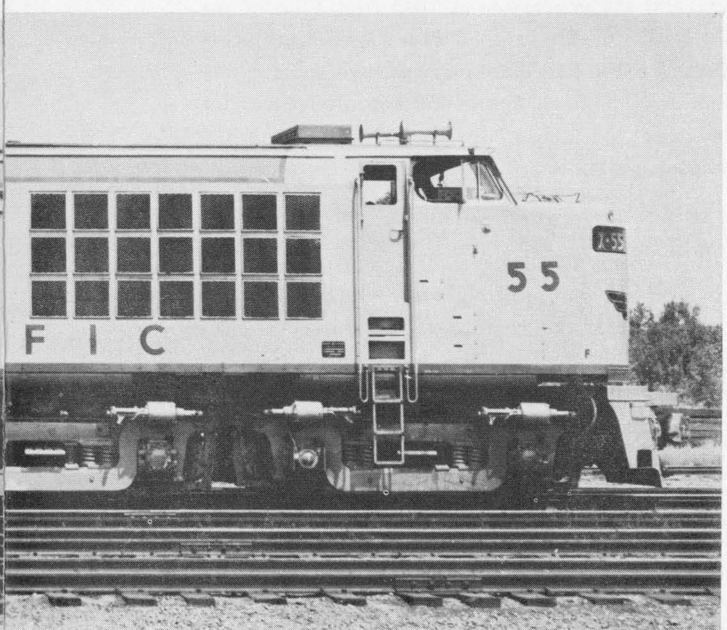
Tests on No. 50, the original model, were good enough to warrant ordering 10. While other U.S. roads feared the very high axle weights, the Union Pacific had full confidence in its magnificent road-beds, with heavy steel, rock ballast, easy curves, and practically no grades in excess of 1.25%. The only thing left to the professional U.S. motive power worriers was the fact that occasionally it gets hot in the summer and the UP locomotives constantly operate in the worst American territory from the standpoint of high altitude. The entire operation is between elevation 4300 and 8013 ft.

It was this particular point that converted this writer away from any preconceived hostilities to the gas turbine locomotive acquired as a pioneer

Schematic floor plan arrangement. Crews are comfortable and can converse in normal tones. Main turbine delivers 4500 hp. for traction.



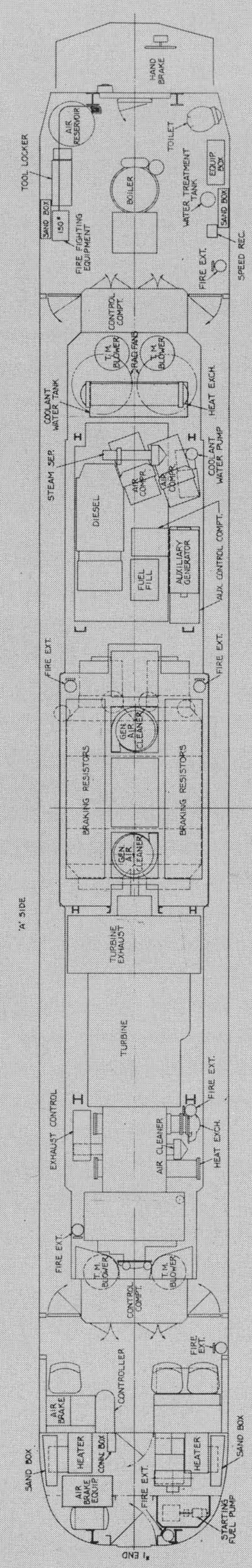


Table I
General Specifications
Union Pacific Gas Turbine Locomotives
Wheel Arrangement B-B-B-B

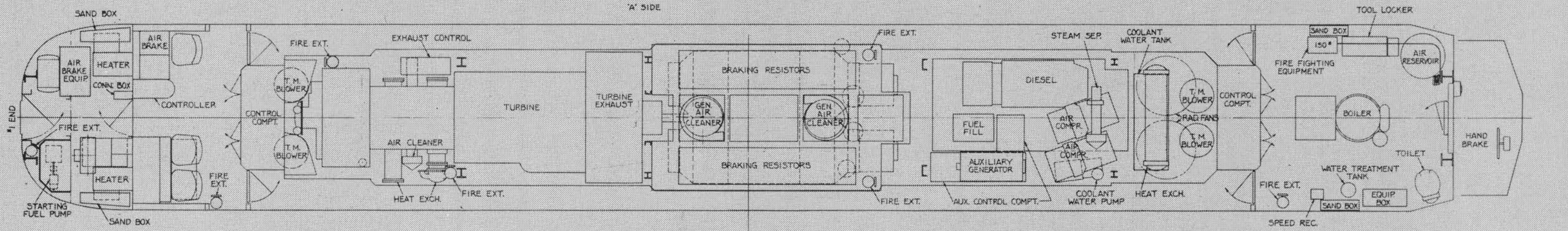
Weights
- On drivers (approx. 2/3 supplies) –520,000 lbs.
- Per driving axle (approx. 2/3 supplies) –65,000 lbs.
- Per driving axle (maximum) –71,800 lbs.

Dimensions
- Track gauge–4 ft. 8½ in.
- Length, inside coupler knuckles–83 ft. 6½ in.
- Height, roof sheets–14 ft. 5½ in.
- Height, maximum–15 ft. 7 in.
- Width, maximum–10 ft. 3/8 in.
- Rigid wheel base, trucks–9 ft. 4 in.
- Wheelbase, total–68 ft. 1 in.
- Wheel diameter–40 in.
- Clearance under gear case–4½ in. above railtop.
- Track curvature (min. rad.) –274 ft. 21°.

Ratings
- Total turbine input to generators for traction–4500 hp. (80°f. at 1500 ft. altitude.)
- Continuous tractive effort–105,000 lbs. at 12.9 mph.
- Maximum tractive effort at 25% adhesion–130,000 lbs.
- Maximum speed–65 mph.
- Gearing–74/18.

Supplies capacity:
- Bunker C fuel oil–7200 gallons.
- Diesel fuel oil–1000 gallons.
- Lubricating oil–300 gallons.
- Water:
  - Cooling–145 gal. diesel radiator system.
  - Boiler–700 gal. boiler heating system.
- Sand–37 cu. ft.
- Braking air–100,000 cu. in.

NOTE: Gas turbine locomotives provide 53 hp. per foot of length against 30 hp per foot for diesel; 17.5 hp. per ton on drivers vs. 12.5 hp. per ton on drivers in the diesels.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diesel man from World War I days up on the Puget Sound waterfront. Later on in this story we shall give a brief account of a trip aboard two of the turbine jobs. The very first hill we climbed was wet and greasy-rail all the way. A rare rainstorm was just ahead. The turbine seemed awfully slippery and too little weight on the rail for the total turbine power output, at full throttle. Actually this is a tremendous advantage because the turbine normally can spin the wheels at starting or on wet track on a hill. Its excess capacity compensates for the handicaps against it due to dry air, high altitude, high summer temperatures, and not quite enough weight for total horsepower. There is exceptional reserve turbine power to offset the adverse factors at every point. Actually, with the optimum output and efficiency from a turbine arising when the air is dense and cold, and operated as near sea level as possible, the region through which the Union Pacific fleet operates has its seasonal compensations to boost the yearly average performance perhaps higher than in almost any part of North America. The reason is simply that while the region does get sunshine and hot spells, it also has terrific winds, bitter cold and heavy blizzards, bringing the longest periods of absolutely dry rail to be found on the continent. The typical Wyoming blizzard is so fine and sharp grained that the dry powdery crystals on frozen steel rail form the most perfect of winter traction.

The engineer's operating station is the same on all 25 of the Union Pacific's pioneer fleet of gas turbine freight engines.

It is these and innumerable other factors dug up by the research department of Union Pacific, backed by their able management staff in Omaha and shrewd financial staff in New York, that led Union Pacific to pioneer the gas turbine on a large scale with every promise of success. For details on the gas turbine locomotives themselves, see Table I which gives general specifications. A List of Equipment, which accompanies the concluding article in this series, gives more details about specific major equipment in the cab. The running gear consists of four 2-axle, swing-bolster swivel trucks, with a span bolster applied to each two trucks. All axles carry 4-pole series motors rated at 550 hp. 1085 amps. and operating at 900 volts. The motors are forced-air ventilated by four axial flow vertical fans mounted in the cab. Gear ratio is 18-to-74, giving a maximum speed of 65 mph.

The entire frame, which rides on the two pairs of trucks and the two-span (connecting) bolsters, is actually a double bottom tank, with flat platform on top for carrying the entire equipment and turbine load. The hollow tank spaces are for fuel, turbine residual fuel and water. They are piped with steamlines, bolted to the floor, to permit constant temperature of about 175° and supplied from the small heating boiler in the rear compartment. Heating of the residual fuel oil is constant and carefully regulated by bulb thermostats throughout the tank area. A depressed center area of the tank, and an elevated portion above it, midpoint between the two pairs of driving axles, permits complete draining and filling from the center of the long, thin double-bottom type tank. Battery boxes extend below the bottom.

The cab, mounted on top, at first glance seems more crowded with equipment, auxiliaries and accessories, than a submarine. In the nose is the usual brake control equipment, starting fuel pump and other minor accessories. Next back is the operating compartment, then the main traction motor control and contactor cabinet.

The main turbine is a General Electric locomotive type, dual-fuel, two-stage axial-flow gas turbine, with 15-stage axial-flow compressor delivering 4500 hp. for traction to four 1125 hp. 900 volt dc generators through a central single reduction gear. The turbine operates at a rated speed of 6900 rpm. and the generators at 1645 rpm. One of the four generators is equipped with a special motoring winding for use in cranking, and two shaft extensions drive 3-phase, 6-pole 150 kva alternators for operating the major auxiliaries during normal turbine operation.

Air for combustion, at the rate of 80,000 cu. ft. per minute, enters the compressor at outside air pressure, and leaves at approximately 80 lbs. per sq. in. at 500°f. From the compressor, air enters a series of six combustion chambers arranged around the perimeter of the first stage nozzle blading. The combustion chambers are of special alloy steel, the inner layer being perforated to receive the combustion air, which both cools the burner shells and dilutes the high temperature of the burned fuel flame. Fuel is fed through a 16-cylinder, wobble plate Sundstrand pump. Complex controls interlock with the throttle and feed at a pressure of 400 lbs. per sq. in.

Extra No. 52 at Green River Bridge, Wyo. All UP freights run as extras, bearing locomotive number as designator. No. 52 was one of first gas turbine locomotives delivered to UP.

GAS TURBINES MAKE HISTORY

(Second of three articles from DIESEL PROGRESS, *Feb. 1955)*

Locomotives and Fuels Are Under Constant Examination of Union Pacific Management With Dual Goals of Simplicity in Power Plant and Lower Costs

By CHARLES F. A. MANN

THE Union Pacific Railroad began testing gas turbine electric freight locomotives back in 1950. Today, the UP is operating 25 of these 4500 hp engines alongside some 200 diesels and the newest and largest of the company's steamers. In our first article, printed last month in DIESEL PROGRESS, we reported some of the history and background for Union Pacific's two-way plunge—into pioneering the gas turbines at the same time it was building up the greatest fleet of railroad diesels. In this, the second of three articles, we want to present construction and operating details pertaining to the gas turbine locomotives.

One of the most discussed and misunderstood features of the gas turbine is the exhaust and the noise it makes. Actually, at full speed, the noise is that of a giant steam boiler blowing the safety valve, and at close range is less annoying than that of a 16-cylinder diesel engine, because of its unpitched quality, a sort of gigantic, feathery swoosh. Inside the engineer's control cab, there is absolutely no vibration or secondary noise, and the air intake seems to make more noise than the exhaust. The entire turbine power plant is only 20 ft. long and weighs but 15 tons, mounted.

The turbine is started by the following sequence: First: the heating boiler is left in operating status continually to keep the residual fuel warm. It derives current for the burner motor, water pump, and controls from the storage battery set. Second: when starting up, the operating crew switch on the diesel auxiliary generator set. This consists of a 270 hp. Cummins diesel engine and a 150 kw. generator (210 hp. at 2100 rpm.) 180-310 volts, and a 16.5 kva alternator. Third: at the turn of the turbine control switch, cold diesel fuel oil is fed to the burners after the motoring winding on one of the main generators gets the turbine up to approximately 5800 rpm. from current supplied by the diesel. After approximately 4½ minutes, the fuel control system automatically switches to the hot residual fuel oil when all burners are firing properly and the predetermined temperatures in the control system are reached. The diesel automatically shuts off.

The auxiliary diesel performs a series of unique functions in that it energizes the entire locomotive up to the requirement of providing motor blower cooling air. It supplies dc power to operate the cooling water pump motor, dc lube pump motor, a battery charger set, steam boiler motors and controls, and for excitation of the traction motors during regenerative braking going downhill. When the turbine is completely shut down, the diesel supplies enough dc current to two of the traction motors for hostling in the yards and even setting out a boxcar or two on the road. Also it operates the two air compressors when the main turbine is shut down. Coupled to the dc generator on the auxiliary diesel, is a 16.5 kva alternator driven by a shaft extension to supply ac current for starting fuel pump motor (diesel starting fuel for the turbine), diesel radiator cooling fan motors, and water booster pump motor when the gas turbine is shut down.

When shutting down, the engineer's control switch is turned first to one position which provides switching back to cold diesel fuel, to replace black hot oil in the control circuit and main fuel pump. Then, after the burners are shut off, the diesel auxiliary starts up and remains in operation until manually shut off to leave the locomotive totally shut down. Then it goes back to only the heating boiler which remains in operation as long as the batteries are sufficiently charged, to keep the fuel warm and water pipes from freezing.

While the turbine itself is very light, the bulk and weight of the auxiliaries and accessories and complex control systems make up sufficient added weight, with supplies, to hold the locomotive to the rails. Directly over the four gear-driven traction generators, and the two auxiliary turbine-driven generators on the shaft extensions, is the dynamic brake resistors. Because of long mountain grades, dynamic braking is vitally important and a factor in reducing the turbine hours and air braking load. The dynamic brake will hold as much as the locomotive will pull at any given speed, but its effectiveness drops sharply to near zero in two stages at low speeds, and is most effective at speeds of from 15 to 35 mph. The cooling fans operate only during braking.

Beyond this section is the auxiliary control cabinet, center sand boxes, coolant water pumps, diesel auxiliary engine, coolant water heat exchanger for turbine lube oil cooler (gear box oil cooled in same circuit), compressor jackets, diesel engine jacket water and lube oil cooler, two air compressors, and two traction motor blowers. The control compartment for the auxiliaries and accessories is on the bulkhead between the main machinery space and the after compartment. The after compartment contains the small heating boiler, main compressed air reservoir, sand and equipment boxes, fire extinguishers and crew's toilet.

The original ten turbine locomotives were equipped with an elaborate system of steam-cleaned fuel oil filters. At first these were believed necessary for handling Bunker C fuel. Experience showed that the fuel could be more cheaply and easily cleaned before being put on the locomotive, and all filters were eliminated. The original 1600 lb. Vapor-Clarkson heating boiler has been cut to a 800 lb. boiler which gives adequate heat.

The turbine rotor is supported at each end and in the middle, at the outlet of the compressor, on bearings supplied by high pressure, cooled, continuously filtered lubricating oil, which also is by-passed to the gear box. Oil is drawn from a sump tank by either the ac or dc lube oil pump. The dc pump is used to flood the turbine bearings before starting and after shutdown. As the turbine comes up to speed, the ac pump (powered from the turbine alternator) comes up to speed and the dc pump is automatically shut down. Oil passes through a water-cooled heat exchanger and is divided between the turbine and reduction gear. Turbine lube oil is again divided between turbine bearings and accessories and the whole system interlocked with safety and warning switches which shut down the turbine in event of failure.

The compressor casting is in four sections carrying the stationary blades and the compressor wheels. The latter, 15 in all, are bolted together in line. The design permits only the minimum area of steel to be exposed to high temperatures. The rim is

This semi-permanent tanker indicates extent to which Union Pacific is carrying its fuel research. Richfield Oil collaborated in testing propane.

welded to the wheel core approximately 2 in. inside the bucket seats.

Combustion chamber assemblies require inspection after each 100 hrs. of turbine operation. Cracked, burnt or distorted liners are renewed. Fuel nozzles are replaced and cleaned after each 50 hrs. of operation. The retractable spark plugs used to fire the cold diesel fuel are checked at the same time the nozzles are changed. The first stage nozzle, where the 1300°f. hot gases first leave the combustion chambers, are designed for 8000 hrs. of operation. They are drilled for cooling air to pass through their entire length.

Turbine fuel regulation is an electro-hydraulic governor which automatically controls load and speed. It is interlocked to protect the turbine from excessive exhaust temperatures, and speeds, and for controlling output relative to the throttle position for current input to the traction motors. Turbine speed under load varies from 4800 to 6900 rpm. which indicates a very high rate of fuel consumption at the lower or idling speed. Actually the turbine burns 60% as much fuel at idling as it does under full load. Yet the overall full load thermal efficiency is given at 17%. General estimates indicated a fuel consumption of 350 g p h. of Bunker C fuel under average road conditions. However, the consumption of 24 of the 25 UP turbines for the months of August and September 1954, both Bunker C and diesel fuel, averaged 359.8 gallons per turbine hour.

With extensive heating requirements for heating fuel tanks and by small tracer piping on all water, lube and fuel lines, for both heating fuel and preventing freezing in cold weather; the extensive use of the diesel auxiliary in starting, yarding and to excite the regenerative brake system going downhill, the great fuel-saving steps possible in the future, under continuous operation, lies in shutting the turbine down at every chance. So far, starting

Table II

Miles and Turbine Hours
UP Gas Turbine Locomotives
October 31, 1954

Locomotive Road No.	Placed in Service	Accumulated Miles	Accumulated Turbine Hrs.
51	1-31-52	291,046	12,311
52	4- 9-52	259,803	10,951
53	5- 7-52	251,853	10,489
54	6- 4-52	259,328	10,892
55	7- 9-52	253,861	10,723
56	8-13-52	226,016	9,426
57**	5-20-53	89,752	3,482
58	7 -3-53	133,452	5,674
59	8-12-53	134,237	5,636
60	8-26-53	127,966	5,043
61	4- 1-54	68,940	2,832
62	4-14-54	65,772	2,435
63	5-18-54	55,689	2,102
64	5- 8-54	60,017	2,293
65	6-11-54	48,845	1,856
66	6-23-54	37,162	1,414
67	6-30-54	46,095	1,752
68	7-10-54	35,914	1,402
69	7-28-54	30,865	1,227
70	7-31-54	33,100	1,256
71	8-19-54	21,851	872
72	8-24-54	21,923	831
73	9-25-54	12,849	512
74	10- 2-54	7,780	340
Total, all gas turbine locomotives		2,574,096	105,751

**Locomotive 57 on propane fuel from May 31, 1953 to January 4, 1954, 69,600 miles, 2961 turbine hours, converted to Bunker C fuel January, 1954.

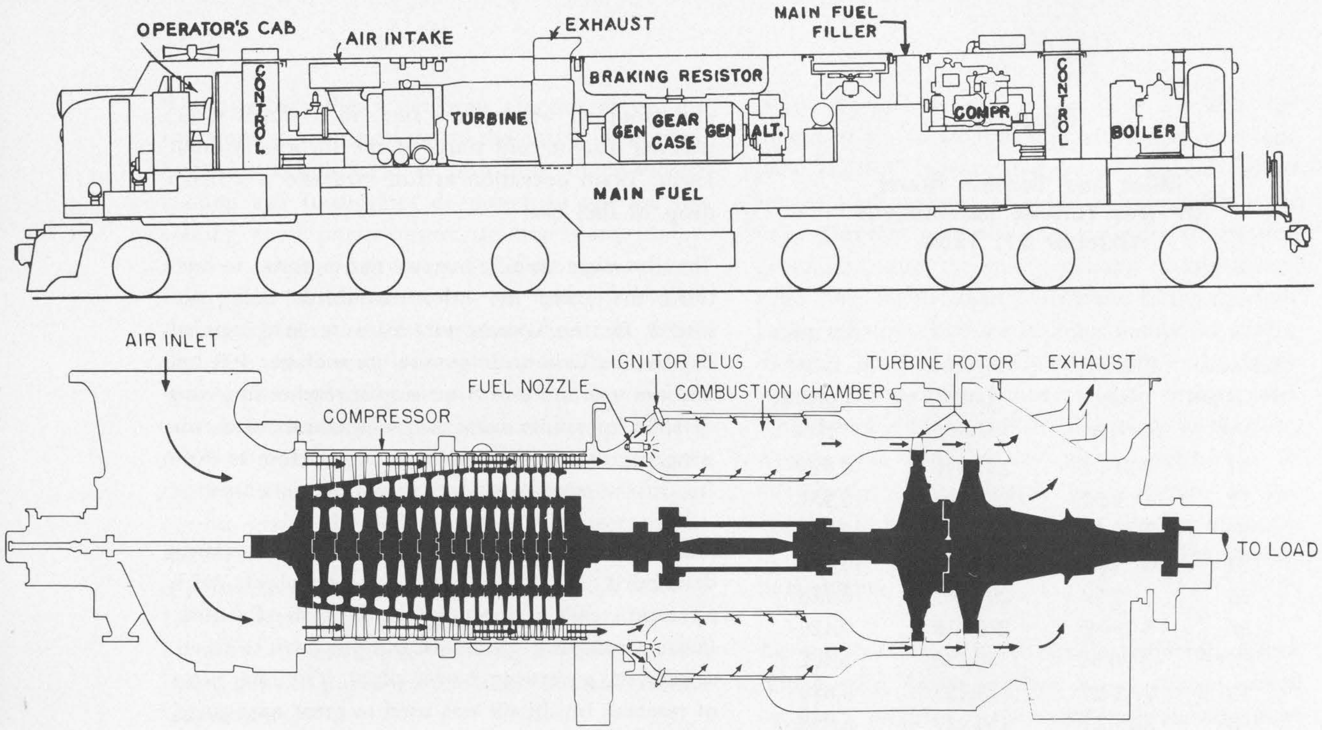
NOTE: Locomotives averaged 107,254 miles, 4406 turbine hours.

and stopping with diesel fuel, in a timed cycle, permits instant cold starts of the turbine without harm. Train operation at full load effects a sharp drop in fuel use.

Total average turbine output, net, is equal to one-third the gross, the other two-thirds being absorbed by the compressor. Parasite load carried by the auxiliary ac-dc generators averages 400 hp. and the maximum turbine output reaches in excess of 5500 hp. under favorable temperature and running conditions. This gives a net of close to 5000 hp. to the traction motors at maximum output.

The Union Pacific management has constantly demanded simplicity in its power plants with operation that is foolproof and practically automatic. Great effort therefore was put forth to create a fully self-governing power plant. The long years of research on diesels was used to great advantage.

From the beginning, the heavy fuel consumption has been the chief development target by both UP and General Electric. It was realized that costly diesel fuel was out, but the door was open to everything else. Locomotive No. 57 was set up May 31, 1953 to run tests on using propane gas, and arrangements were made with Richfield Oil Co. to share in this development work. The long fuel research by Union Pacific pointed toward using surplus residues from natural gas on one end and Bunker C and powdered coal on the other. The propane experiment required a 12,500 gallon special car to carry the gas under pressure. The car was semi-permanently coupled behind the locomotive. Steam from the heating boiler liquefied the propane and delivered it at 150 psi. to the burner. After 69,600 miles and 2961 turbine hours, the experiment proved that propane was a perfect fuel from standpoint of perfect combustion and trouble free turbine operation, but handling problems were severe and the cost way too high. No. 57 was converted to Bunker C fuel.



Side view of gas turbine locomotive shows machinery layout. Bottom diagram shows air flow of gas turbine for locomotive drive as installed by General Electric for Union Pacific.

Presence of vanadium pentoxide and sodium sulphate in the fuel ash resulting from combustion of the residual fuel oils reacted with alloy steels in the blading to produce surface and depth corrosion. A trouble-free residual fuel could thus be identified as one of low vanadium and sodium ash content. Cooperative research by General Electric, Union Pacific and Richfield Oil involved a specification establishing controls as follows: 1. The ratio of sodium to vanadium in the ash was not to exceed 0.3. 2. The ratio of calcium to vanadium in the ash was to be not less than 5.0. 3. Magnesium, barium and nickel in the ash were a benefit and could be substituted for calcium on a 2-to-1 basis. 4. The total ash in the compounded residual fuel oil should not exceed 2%.

It was realized that deposits would form on the first stage nozzle and first stage rotor buckets, but this was considered less harmful than the corrosion. Last year it was learned that magnesium gave promise of being more effective than calcium in limiting corrosion and deposits at the operating temperatures existing in these turbines.

The entire gas turbine fleet has now been set up to receive pre-treated residual Bunker C fuel oil from wayside tanks at Green River, Ogden, and Cheyenne. Normally, fueling is done at Cheyenne and Ogden. During a recent 30 months, this fuel ranged in price from $1.40 to $1.65 per 42-gallon barrel. The filtering and pre-heating is largely done by the refineries at a cost of about 11¢ per barrel for treatment. It is again filtered at the wayside stations before going to the locomotive tanks. Continuing cooperative research is being carried on to further standardize turbine fuel, and the specifications are readily met by a combination of widely scattered producers of surplus Bunker C fuel ranging from Los Angeles to southern Wyoming.

Diesel fuel ranges from 9 to 10 cents. The UP gas turbine locomotives burn about 4.28 gallons of Bunker C per 1,000 gross ton miles and their diesels burn diesel oil at the rate of about two gallons per 1000 gross ton miles. Therefore, it would seem that when the cost, consumption and efficiency factors (thermal) for gas turbine and diesel on the Union Pacific are compared, total fuel costs are so close as to startle a lot of persons.

The great question remains as to how far into the future will low Bunker C prices prevail? Will prices start climbing as diesel fuel costs did once the railroads began demanding it by the millions of gallons? Will refinery practice keep on cutting down the output of Bunker C fuel, or will many southwestern refineries keep on with up to 37% of their yield as heavy residual fuel oil? And will the coal turbine people ever get a powdering, portable ball-mill sufficiently compact and efficient to permit blowing powdered coal instead of oil into a gas turbine locomotive? Nobody can say. But Union Pacific has the operating stage set; the know-how; the research facilities. And UP is strong enough financially to weather the thing through to its end—just as it has big steam power right up to today, when the funeral dirge is being played and 110 years of Steam nears finish.

As it will be seen from Table II, the UP is rolling up heavy daily mileage with its fleet of turbines. The last of the 25 went into service in late October. Together, the fleet averages over 8,000 locomotive miles per month, considered excellent for this difficult, mountainous territory. They are hitting close to 110,000 gross ton miles per freight train hour, a figure which may drop as the operations merge into the complete movement in the area. Turbine hours average close to 400 per month and over all availability from 78 to 80%. This is not too significant at the moment in view of the relative newness of the entire fleet.

GAS TURBINES MAKE HISTORY

(Last of Three Articles from DIESEL PROGRESS, *March, 1955)*

Author Sees Place in U.S. Railroad Operations for Both Diesel and Gas Turbine Locomotives

By CHAS. F. A. MANN

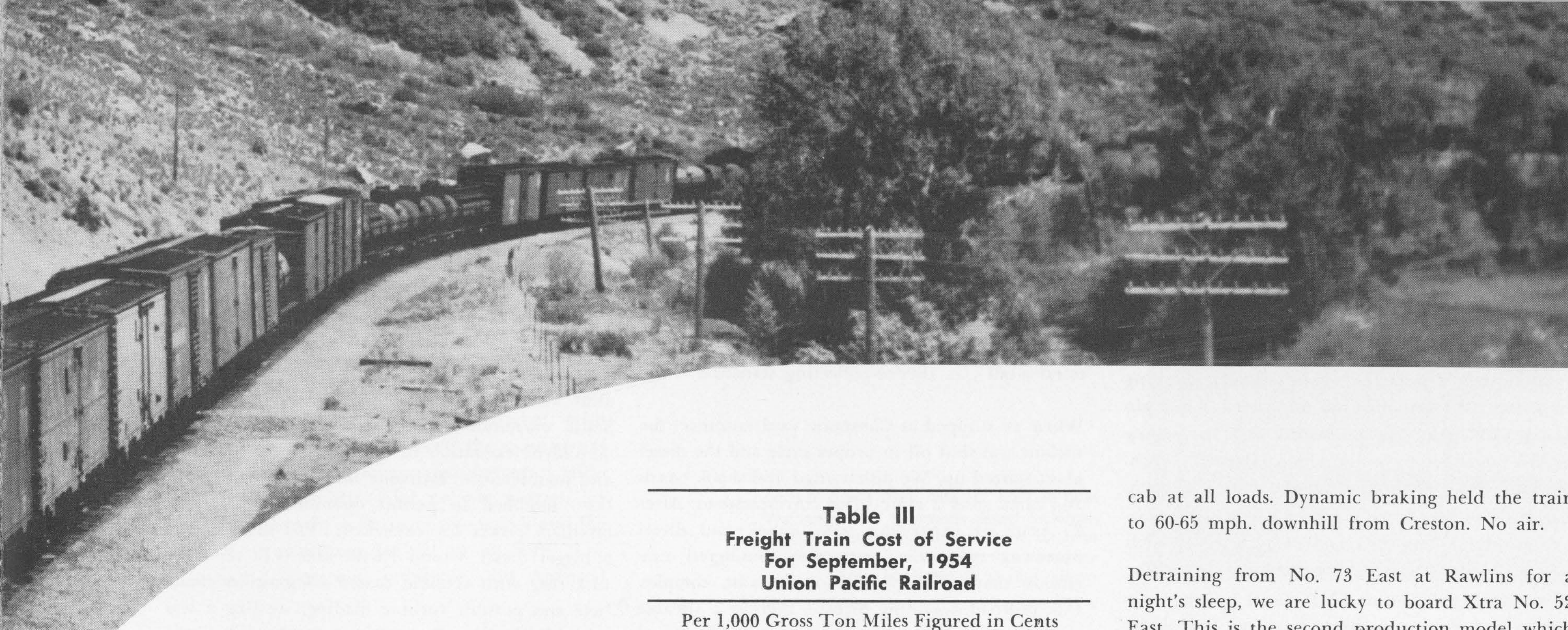
As a part of this study of gas turbines on the Union Pacific, we were given special permission from the President's office to ride through three divisions to see at first hand both the typical operating problems and how turbines function. It is a far cry from the theoretical approach in the drafting room and in the engineering offices, to the cab ahead of 85 cars of freight that some trainmaster wants moved in a hurry. The location of a drinking water cooler next to an excessively hot cab heater is more important than vanadium in the residual ash. The fact that the high, steady tractive effort against slippery rail on a hill overtaxes the capacity of the pneumatic sanders to keep the rails hard, reminds the engineer that the turbine generates more power than can be used on a heavy pull without spinning the wheels. The automatic transition sometimes, on bad rail, works in and out so fast, between wheel slips, as to drive the engineer nuts. And way back in the builders specifications it suggests some 3700 lbs. of ballast can be applied to the two front trucks to hold it down tighter. Tonight, as we climb the hill east of Green River, we could use it, despite the fact that axle weights are 12,000 lbs. heavier than on the diesels.

The first series of General Electric's gas turbine locomotives delivered to the UP had enclosed catwalks.

The last 15 of the locomotives delivered have open catwalks. Filters in the side panels were eliminated.

Extra # 73 East, with Ted Brosen, engineer, in charge, leaves the Green River yard at 5:15 p.m. with 86 cars and 5300 trailing tons, bound for Rawlins, 134 miles away. The unseasonal rain, plus the fact that a streamlined diesel passenger went out ahead, creates bad rail. There is a peculiar, recurring operating headache noted everywhere that whenever a streamliner goes uphill ahead of a freight, the rail is slippery and coated with a fine film of oil. Diner and toilet drainage and exhaust from propane generator sets under the coaches is blamed. At the top of the 1% grade we are doing 36 mph. and on level or very light adverse grades we reach 45-55 mph. with one or two spots a bit faster. The absence of excessive noise and almost total absense of rumble or vibration dispels much of the misunderstanding and rumor drifting around about gas turbines. Obviously many of the comforts and control facilities have been borrowed outright from the diesels. It was remarkably noticeable that neither the head brakeman nor the fireman made a single trip back through the locomotive on the run. No. 73 is one of the new units with open catwalks instead of a full width cab and had only 512 turbine hours and 12,849 miles on it as of October 31, 1954, 10 days prior to our trip. Arriving at Rawlins at 8:45 p.m., we had a short stop and crew change and departed for Laramie at 9 p.m. While the mileage is shorter, there is one bad hill at Creston, the true Continental Divide. It took three hours and 30 minutes to go the 134 miles from Green River to Rawlins, and slightly less from Rawlins to Laramie. Engineer Willard Rucker is a gas turbine fan and apparently is surprising his supervisors by keeping up on turbine technology. It must be remembered these engine crews have to be skilled. They run gas turbine, diesel and Big Boy steam interchangeably, every month. An engine crew never knows which type of locomotive it will be assigned from one run to the other. In some ways, these Union Pacific engine crews have to be

One of the original gas turbine locomotives delivered to Union Pacific is shown pulling a heavy freight train through Wasatch Canyon.



smarter and more open-minded than other railroad crews. The eastward ranging bad weather dumps rain on the Big Hill at Creston, and we slipped badly and dropped back to 11 mph. With heavy sanding all the way. The remarkable 20-notch traction motor control is superior to previous types in that it is smooth, very responsive, and power is varied without jerks or fuss. The fully automatic transition is the smoothest yet put into a locomotive. Some engineers say it is too sensitive.

The impressive thing about the road operation of a gas turbine is that the power plant seems to run at top speed from the moment of starting to shutback to idling when entering a terminal or going down a long hill. What variations there are in rate of fuel feed do not register in the speed of the turbine. The midget heating boiler causes more fuss in the operating cab than all the rest of the gadgets put together. The steam pressure varies from 90 to 240 lbs. with great rapidity. Sometimes the lights flash and bells ring but everything keeps going. The immediate problem in all turbines appears to be further simplification of controls and housecleaning some gadgets off the instrument panels. Diesels were the same way when they began hauling freight in 1941, as this writer reported from the pioneer Santa Fe experiment. And later on the Western Pacific.

Table III
Freight Train Cost of Service
For September, 1954
Union Pacific Railroad

Per 1,000 Gross Ton Miles Figured in Cents

	Steam	*Diesel*	*Turbine*
Repairs	27.44	16.56	14.45
Engine house expense	14.89	3.66	2.24
Fuel	54.99	20.12	22.23
Lubricants	1.47	1.40	.47
Other supplies	5.65	.16	.04
Enginemen	18.28	18.79	14.22
Trainmen	22.42	23.34	15.54
Total	145.14	84.03	69.19
Same for Year 1953	130.67	85.78	87.32

Exhaust and intake noises remain so constant that after the first hour, you become oblivious to them. Normal conversation is possible at all times in the cab at all loads. Dynamic braking held the train to 60-65 mph. downhill from Creston. No air.

Detraining from No. 73 East at Rawlins for a night's sleep, we are lucky to board Xtra No. 52 East. This is the second production model which came on line in April, 1952 and had already passed 260,000 miles of operation by November 1, 1954. By contrast, its wide cab and 126 filter panels (since removed) make it seem bulky and formidable. Again, Engineer John Deleplaine turned out to be a student and philosopher. He stated flatly there's no difference between running the gas turbine over the big Sherman Hill, highest point on the System, and running a diesel. He is a Union Pacific veteran with a West Virginian eye to thrift. Every chance he gets he shuts off the turbine to save the company money! He says the younger engineers seem afraid to start the turbine up and are afraid to shut it down. He advocates a bigger diesel auxiliary power plant out in the back compartment, so the turbine can be shut off completely when maneuvering in yards (on level track), doing light switching, coasting downhill in regenerative braking, and all the rest. Why waste fuel in the gas turbine when it is a machine designed to run full power, full speed, full load, when the business of running a freight locomotive calls for highly variable operating conditions?

It was a rough trip up the Big Hill out of Laramie. At one point we completely stalled to a dead stop because of slippery rail. It took an hour and a half to go 14 miles. Coming out of Laramie, we left the long ice dock at 4:45 p.m. Part of the load of 85 cars (71 loads and 14 empties, a total of 4300 tons), had to be re-iced. Laramie is a big re-icing point on the Union Pacific for West Coast perishable freight. A couple of miles east, on main track No. 1, we began to slip badly due to wet rail. Nothing would hold the wheels. Finally, grinding to a stop, the locomotive was uncoupled. The train was braked tight. We proceeded with the engine uphill for about six miles with sanders full open. Backing down, the sanders were still left open. Coupling up again, we managed to start the train and grind uphill on the triple-sanded rails at speeds below 10 mph. It is here that everybody agreed the 12-motor, 12-axle, 3-unit EMD diesel freighter was superior to the gas turbine. Engineer Deleplaine says he regularly takes 4500 tons up the same hill, faster, with a 4500 hp. EMD diesel, than he does with the gas turbine that would pull 5000 tons on dry rail. The cold fact remains that in periods of bad rail, the load behind the gas turbine must be reduced to bring it up to normal operating speed. The 12-motored diesel has advantages on heavy pulls at slow speeds.

This section of the Union Pacific mainline is a classic example of the astuteness and wealth of the company. To cut down the adverse westbound grade from Cheyenne to about .7%, from 1.50%, the company has just spent $10,000,000 building a low grade line from Cheyenne to Dale, just west of Sherman Hill summit. It is nine miles longer and is the costliest section of railroad track ever built on earth. The old divided 2-track line and the new line are operated as Tracks 1,2,3, from an elaborate centralized traffic control setup in Cheyenne, so that any track can be used in either direction for anything that comes along.

At the Sherman Summit, Engineer Deleplaine put the train into regenerative braking with the turbine idling for traction motor excitation. He grumbled because he couldn't use the diesel. We rolled down at 40 mph., then dropped back to 25-30, and coasted to a stop at Cheyenne yard west entrance at 7:45 p.m.—three hours for the 56 miles. Most of the time was spent in the first 13 miles. Train crews blame the company for deliberately overloading the turbine. The company doesn't seem to mind a-tall . . . they're collecting statistics!

When we stopped at Cheyenne yard entrance, the turbine was shut off in proper cycle and the diesel plant started up. We dismounted and shook hands and came away a more sober correspondent. After 25 years of experience with diesel, and diesel operating economies, it is our considered conclusion that in the middle of the vast, complex U.S. railroad operating picture, there is a sizeable spot for the gas turbine locomotive. The diesel made this economically possible; and the diesel will continue to do 75-80% of the work on U.S. railroads for the next century. Furthermore, we believe the delicate balance of fuel costs and availability will set the pace in both directions and that the turbine will spur the diesel to bigger and better things. And it would not surprise us if Union Pacific, when their warranty period ends, will gingerly lift a conventional 600 hp. General Motors-EMD switcher unit out of a yard switcher and put it into a General Electric gas turbine locomotive and do just what loyal, wise old Engineer John Deleplaine suggests: give the turbine a helper big enough to permit it being shut down for everything except full speed operation on the road. The Union Pacific is just that smart!

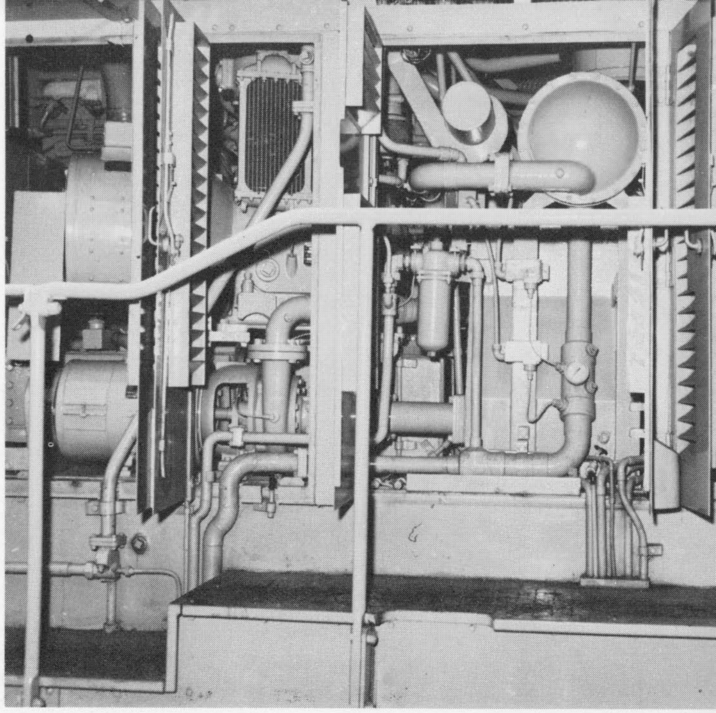
As indicated, development work is going ahead constantly. Elimination of the complex, hard-to-clean-and-maintain 126 side air filters has worked wonders. The turbine runs better then ever. This permitted the last 15 GE turbines to have catwalks and a narrow housing moved inboard to the line of the equipment items, making it easier and faster to service and repair the units in the shops. The roof overhang has been left so the train crew can gain sheltered access at all times. Combustion chambers have been lengthened 12 in. to improve combustion characteristics. The first stage nozzle diaphragm, heretofore a solid ring, has been split to facilitate removal. Piping and wiring has been improved and simplified. As stated, the steam-cleaned filters for turbine fuel have been done away with, and the heating boiler size cut in half. Static excitation has replaced the complicated amplidyne excitation in the interests of simplicity and maintenance. Dynamic braking controls have been modified to permit operation with diesel auxiliary power for excitation. The next step is a bigger diesel. Union Pacific and G.E. are both tinkering with ceramic coated combustion chambers and possibly turbine blading, stealing a leaf from the jet aircraft practices already under test.

Back in the Omaha office, performance figures, in the chilled form, supercede opinions and sandhouse chatter out on the road. Perry Lynch, the able Executive Vice President of Operations, whose entire staff cooperated generously with this writer, is all smiles these days. As figures pile up, he is certain that Union Pacific has again pioneered the way for world railroading with its big new fleet of gas turbine electrics.

Read Table III for the answer. The overall statistics on diesels, of course, are a composite from the entire fleet. Many units operate in train limit territories, in full crew law states, and where train crew pay is based on weight on drivers. This raises diesel engine crew labor costs above the average. The smaller and newer gas turbine fleet operates under more optimum conditions and heavy repairs have not yet begun on most of the units. By placing them solely in high-tonnage, high mileage service—like diesels were placed against steam 13 years ago—

they can make a top showing from the start.

Union Pacific will shortly undertake research into utilizing the vast waste heat going out through the roof in a jet-like roar with billions of calories or btus warming the blue sky each minute. Some of the UP staffers have dreamed of a bigger exhaust port in the roof, lined with steam tubing. Others have dreamed of a by-pass to a waste heat boiler, with complete rearrangement of the "furniture" inside the cab. Diesels went through this rearrangement process, too, if you will remember, with excellent results. Nobody expects the existing gas turbines to last much longer than five years without becoming obsolete. And nobody worries, for American ingenuity is again on the march and the railroads of tomorrow are yet to be born. The mechanical, operating, economic and financial aspects of the whole Union Pacific gas turbine program have aroused the world. There is no other development like it anywhere on earth at the present time. America and the Union Pacific are leading the way.



Service doors from catwalk lead to heat exchanger on Cummins diesel auxiliary engine, compressor jackets, lube oil heat exchanger, and cooling water storage tank. Radiator is in roof, above.

List of Equipment

Turbine—1 G.E. locomotive-type, oil-burning 2-stage gas turbine with a 15-stage axial flow compressor. Rated 6900 rpm. and 4500 hp. for traction at 1500 ft. elevation and 80°f. ambient temperature.

Gear box—1 G.E. type ST 216B, single reduction double helical gearing with one pinion and two driving gears, reduction from 6900 rpm. to 1645 rpm.

Traction generators—4 G.E. type GT 576, shunt wound, 6-pole dc machines, driven in pairs from each end of the two larger gears in the gear box.

Traction motors—8 G.E. type GE 752, series wound, 4-pole, forced ventilated dc.

Traction motor blowers—8 G.E. type GYA-18, axial flow, ac. motor driven with vortex cleaners.

Turbine auxiliary alternators—2 G.E. type ATB-954, 3-phase, 6-pole alternators rated 150 kva.

Diesel alternator and dc. generator set—1 G.E. type GMG-161, consisting of alternator and dc. generator directly connected to diesel engine.

Air brake—New York Air Brake Co. 24RL.

Battery charging motor generator set—1 G.E. type GMG-160 consisting of 3-phase, 4-pole induction motor driving a 4-pole dc. generator rated 35 kw. at 75 volts.

Generator and auxiliary air cleaner blowers—2 G.E. type GYA-19 axial flow ac. motor driven with vortex cleaners.

Diesel engine—1 Cummins NHRBIS-600 rated 270 hp. at 2100 rpm.

Air compressors—2 Gardner-Denver type ABO, 2-Stage, 3-cylinder water cooled.

Fuel heating steam generator—1 Vapor Heating Corp. type OK 4608, rated 800 lbs. per hour at 200 lbs. pressure.

Radiator—1 Perfex, seamless tube, 4-core, 2-pass unit with two induction motor-driven propeller type fans.

Miscellaneous accessories—Pyle National oscillating headlight; Chicago Pneumatic speed recorder; Solex glass windshields; Kysor steam cab heaters with fans; Calrod electric emergency cab heaters; 6 Ansul-Dugas dry chemical 30 lb. fire extinguishers; 2 Prime rear vision mirrors; Williams-grip traction motor connectors.

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