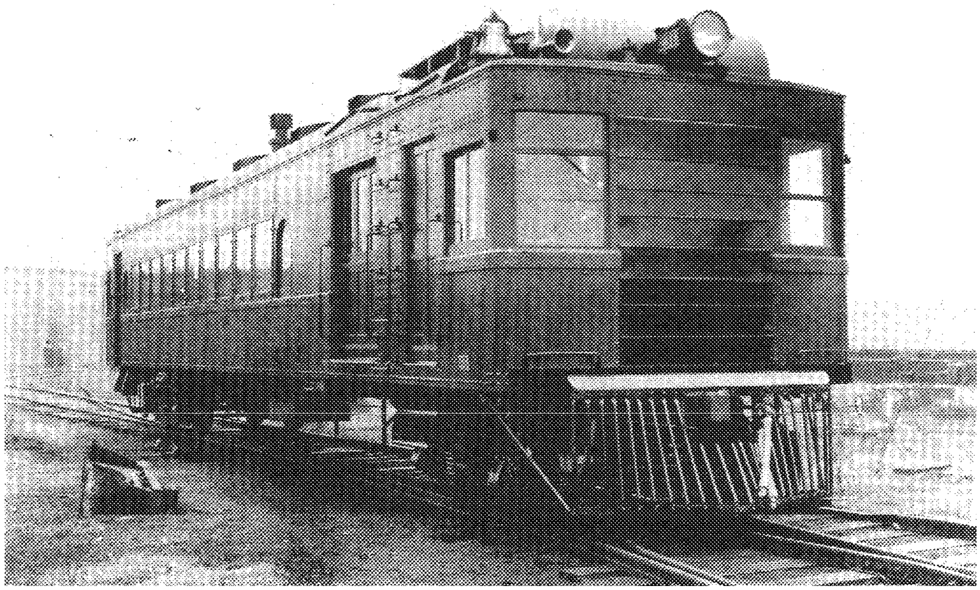
ASME International

Great Northern 2313 - Montana Western 31 Gas-Electric Rail Motorcar

An ASME Historic Mechanical Engineering Landmark

Mid-Continent Railway Historical Society
North Freedom, Wisconsin
August 16, 2003

FRONT COVER: Montana Western 31 as preserved at Mid-Continent Railway Museum, North Freedom, Wisconsin, Photo taken in October 1973 by Jeffrey Haertlein.



In October 1925, Great Northern 2313 posed for St. Louis Car Company's photographer shortly after construction. Note the original utilitarian Pullman Green paint scheme and " tube" pilot. GN later added white safety stripes to the front of the carbody. The front shutters for the radiator were controlled manually by the engineer from his cab. The original purchase price: $35,338.24. Photo from the St. Louis Car Company Collection, Washington University Archives, St. Louis, Missouri.

Dr. Hermann Lemp (1862-1954). Photo from the Franklin Institute.

Great Northern 2313, later Montana Western 31, is the oldest surviving gas-electric rail motorcar with Lemp Control. These self-propelled gas-electric motorcars played a major role in the development of modern diesel-electric locomotives.

What is a gas-electric rail motorcar? A rail motorcar is a single self-propelled vehicle containing one or more of the following areas: baggage, express, Railway Post Office (RPO), main and smoking sections of the passenger compartment. The rail motorcar, which replaces a conventional locomotive hauling one or two cars in train service, could optionally haul one or two additional freight or passenger "trailer" cars. "Gas-electric" refers to the self-propelling method. A gasoline engine drives a direct-connected generator. The electricity generated supplies traction motors directly geared to the axles of the car.

History of Rail Motorcars[1]

Railroads offered the world the first mechanized land transportation system. They began operation in America in the 1830s.

As early as the 1840s and 1850s, steam railcars[2] were built. They were introduced because a single self-propelled car could economically replace a train of a single locomotive and car. In 1860, the designer of a railcar claimed a savings of 2/3rds of the cost of the train it replaced.

By 1860, the U.S. had more railway mileage than all the European nations combined. Particularly in the western U.S., the railroad were developed through largely unsettled areas. The railroads actively promoted immigration to generate future customers. A spiderweb of branchlines served new and potential customers who required they be within about one day's horseride from the railroad.

The American railway network exceeded 250,000 miles of track by 1900. From the 1890s to 1915, a second phase of railcar development occurred. Electric motors and generators had been developed. The gasoline engine had been developed and the diesel engine had recently been introduced. This technology led to new competitors: electric interurbans—essentially high-speed intercity streetcar lines–and automobiles, tracks, and buses. The once vital branchlines became liabilities. But as ridership fell, railway operating costs remained comparatively high. Innovators at General Electric, the Electro-Motive Corporation, and other firms saw the gas-powered railcar as a technical solution to that economic problem. Some railcars had the engine mechanically connected to the wheels (such as early Brill[3] railcars), while others were gas-electrics[4] (such as those manufactured by General Electric[5]).

As a GE publication noted in 1927: "Because of competition of automobiles, buses, and trucks made possible by good roads, the local and branch-line trains have been reduced to and average of two cars and a locomotive. This brings the service requirements well within the capacity of economical gas power units" for railway use. [2, p. 1]

While development was interrupted during World War 1, rail motorcars again flourished in the 1920s.[6] Serveral important post-war changes occurred. A new control system was development that allowed easier railcar operation by steam locomotive engineers. A more proactive sales and servicing policy ensured good maintenance and reliability when railcar maintenance was foreign to the steam locomotive shop forces. The Great Northern 2313 / Montana Western 31 rail motorcar is the oldest survivor from this railcar era.

The railcar era largely ended in the thirties with the Great Depression and the increasing number, horsepower, and lower fuel costs of the diesel-electric locomotives. Moreover accidents involving gas-electrics caused the ICC to recommend "convert[ing] Power units for use of a fuel less inflammable than gasoline." [7]

However, the control system developed and proven on gas-electric rail motorcar development in the 1920s, formed the basis of the control system used in diesel-electric locomotives for more than fifty years.

History of the Great Northern 2313 / Montana Western 31 Gas-Electric Rail Motorcar

On August 31, 1922 the Electro-Motive Engineering Corporation (EMC7) was incorporated in Cleveland, Ohio. EMC designed its railcars, but assembled components from other firms and had the railcars, themselves, constructed by established passenger car builders. By October 1923, construction of EMC's first rail motorcar had begun in the shops of Saint Louis Car Company. This first rail motorcar, M-300, was delivered to the Chicago Great Western Railroad in August 1942. As a demonstrator it was given serial number 100.

in August 1924. As a demonstrator it was given serial number 100.

On October 28, 1925 Great Northern 2313 was completed. Given the serial number 130, it was the 30th production rail motorcar. GN 2313 first entered service on November 27, 1925 for trains 259 and 260 between Marcus, Washington and South Nelson, British Columbia.

By 1939 Great Northern considered this rail motorcar to be too expensive to maintain. On December 28, 1939 Great Northern sold GN 2313 to the Montana Western. Montana Western merely dropped the first and last digits of the car number. MW 31 operated on the 20.13-mile railroad between its connection with the GN at Conrad, Montana and Valier, Montana.

In 1966 the Great Northern regained possession of MW31 when it traded a steel passenger/baggage combine for it. On August 12, 1966 the Great Northern donated GN 2313 / MW 31 to the Mid-Continent Railway Museum in North Freedom, Wisconsin.

GN 2313 / MW 31 was operated at the museum in the late 1960s. A four-year restoration effort was completed in 1972 when the car was featured at General Motors' Electro-Motive Division (EMD) plant for their 50th anniversary party and open house on September 9.

GN 2313 / MW 31 operated in museum service from 1972 to 1987. On October 2 and 3, 1982 the railcar ran on the Chicago & North Western Railway's mainline between North Freedom and Devil's Lake, Wisconsin. Since 1987, the railcar has been on display[8] at the museum.

Cost of GN 2313 to Great Northern, MW 31 to Montana Western

"Purchase one gas-electric motor car $34,000 June 11, 1925."[9] [3]

The Great Northern sold the rail motorcar[10] to Montana Western for $11,763.79. [4]

Significance of the Great Northern 2313 / Montana Western 31 Gas-Electric Rail Motorcar

Most rail motorcars have not survived. Many were scrapped, "de-powered" and used as trailer cars, or were "re-engined" with diesels. Gas-electric rail motorcars made useful vehicles to be modified into Sperry Rail Flaw Detector cars. As such the interiors of those cars were gutted for instrumentation. Sperry has since dieselized[11] its fleet.

- GN 2313 / MW31 is the 30th production model and is the oldest[12] surviving EMC rail motorcar. It therefore represents the earliest survivor of one of the "big two" U.S. locomotive companies: Electro-Motive (later a division of General Motors) and General Electric.

Electro-Motive Company used Winton engines modified from Winton[13] marine engines. Winton Model 106 was used in the earliest EMC rail motorcars.

- GN 2313 / MW31 currently has a model 106-A[14] engine.
- GN 2313 / MW31 currently uses General Electric model 240-A traction motors.[15]
- GN 2313 / MW31 retains most of the character of the original car. The interior arrangement of power compartment, baggage, main and smoking sections of the passenger compartment, and rear-end controls remain the same.[16]
- GN 2313 / MW31 uses the Lemp control system.

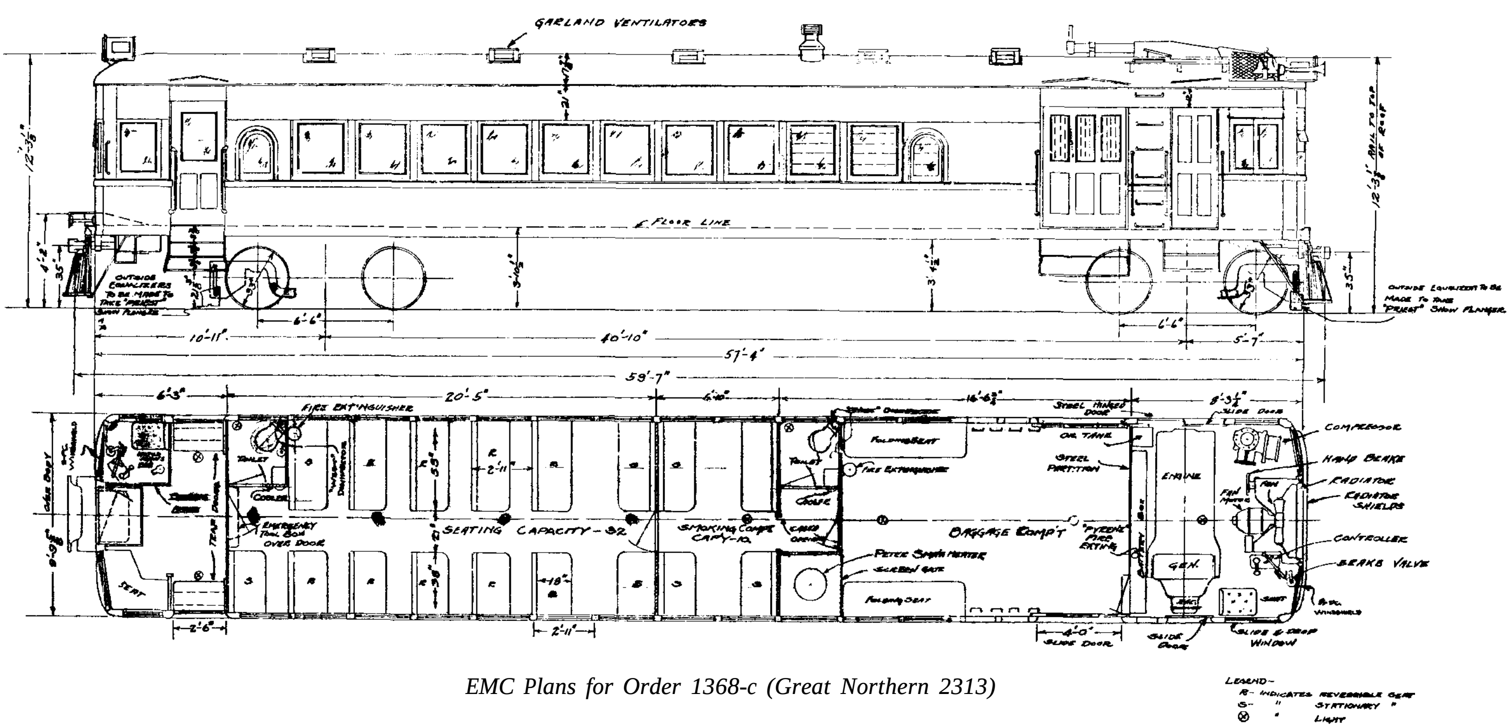
Dr. Hermann Lemp's Control System Used on the Electro-Motive Corporation Gas-Electric Rail Motorcars [6]

Electricity for streetcars and interurban equipment is supplied from generators in a power house. With no restriction on generator size, the supply produced is effectively unlimited. Therefore, large resistors were cut in to control speed.

But on-board power generation limited the size and power of generators — both because of the load gauge restrictions and the desire to minimize non-revenue space. As a result, the engineer had two different control levers—one controlling the fuel to the engine and the other controlling the electrical load. The starts and stops of railroad service and the constant changes in grades and curves make a constant load engine impractical. As a result, the engineer was often balancing these controls–too much throttle would waste fuel whereas too heavy an electrical load would stall the engine.

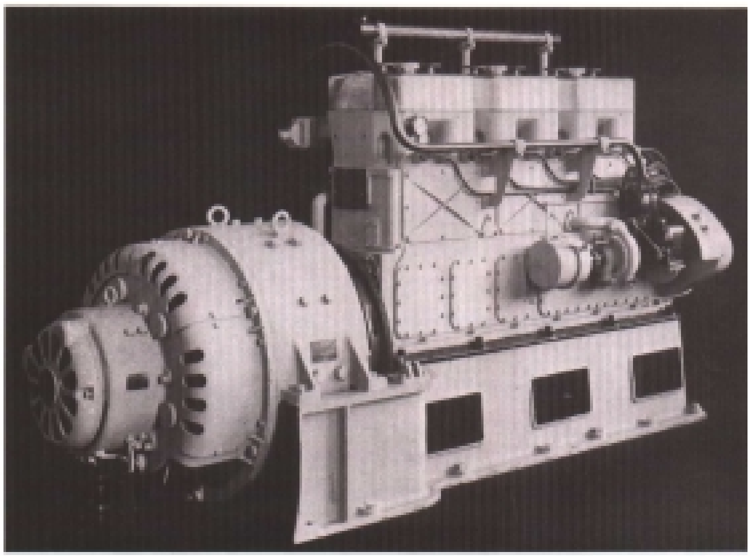
Dr. Hermann Lemp worked to find a single lever control that would make the gas-electric railcar as easy to operate as a steam locomotive. While his first patent for this problem was in 1914, it was not until his third patent for the control system (1,589,182 of June 15, 1926) that he achieved an all-electrical solution.

"I then provide in connection with...the field windings of the generator...a field winding in series with the generator load which

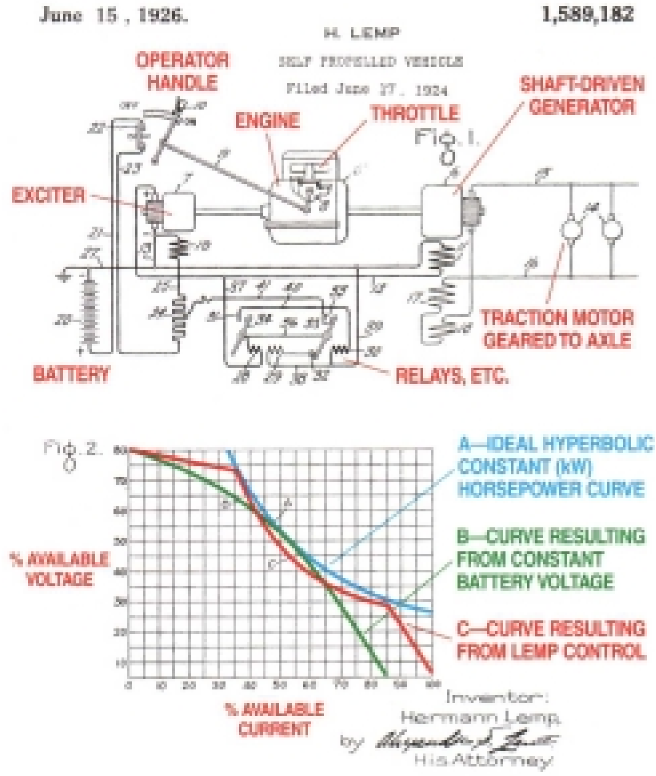


EMC Plans for Order 1368-c (Great Northern 2313)

Great Northern 2313 / Montana Western 31's interior layout has four major areas. The engine area (in front, shown at right) contains the Winton gasoline engine, the General Electric Generator, electric air compressor, and engineer's cab. Next is the baggage area with wide doors on both sides. The heating stove is a hand fired coal steam boiler. The next area is a smoking section with two sets of facing seats. The passenger area follows the smoking section. At the rear (shown at left) is the vestibule area for passenger loading. In the rear corner is the engineer's cab for reverse running.



This illustration of the Winton model 106 gasoline engine used in EMC's first motorcars appeared in EMC Bulletin 101. This view shows the magento side. The horizontal brass pipe running along the engine and curving over the top carried the spark plug wires. The engine was positioned crosswise in the engineroom. The main generator (at left), was positioned behind the engineer's seat. Mid-Continent's Montana Western 31 still retains its Winton 106A engine (similar to 106)



the generator... Thus, the load, which at any particular value of the armature current is proportional to the voltage, will fall with the decreasing engine speed faster than the power of the engine falls with the same decrease in speed the engine speed will become stable at the value where the power of the engine balances the load." [24, pp. 1-2]

In Lemp's "Fig. 2" the *horizontal* axis represents the percentage of maximum momentary armature current and the *vertical* axis represents the percentage of safe voltage. Line A is a rectangular hyperbola representing the ideal volt-amp characteristic. Line B is the characteristic from a constant potential, such as a battery. Line C, which results from Lemp control, matches the ideal Line A over a greater range than Line B.

The Lemp control system specified in his third patent[17] remained the basic control system on diesel-electric locomotives for over fifty years. The same principles are used today in the control software for diesel-electric locomotives with DC[18] traction motors.

General Specifications, Great Northern 2313/ Montana Western 31

GN 2313/MW31 is a standard gauge, self-propelled, gas-electric rail motorcar that weighs 32 tons. It is approximately 60 feet long and 10 feet wide. The St. Louis Car Co.[19] was contracted to build the car itself and assigned it job number 1368-C

Gasoline Engine Specifications

The model designation DE-106 refers to a double-ended control system with the Winton model 106 or 106 A engine. A double-ended control has a cab at each end that does not require the car to be turned for reverse running.

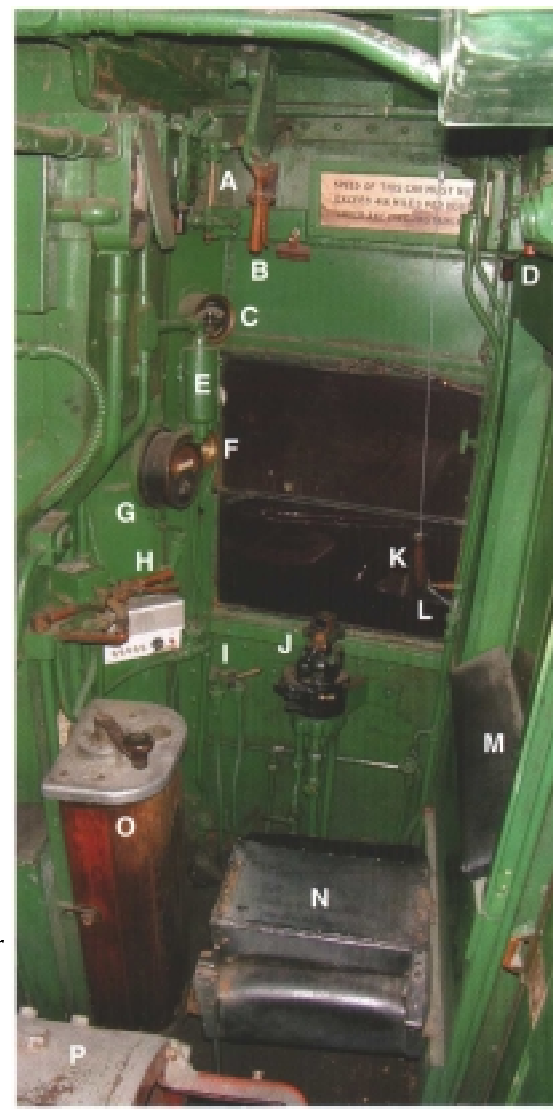
The Winton engine model 106 had 6 cylinders with a 7-inch bore and an 8-inch stroke. It ran at 1,000 rpm with a nominal horsepower of 175. It weighed 4,270 pounds or 24.4 pounds per hp. The 106A had the same stroke, but a 71/4-inch bore. At the same weight, its 220 hp yielded 19.4 pounds per hp. [2]

Two General Electric model 240A 600-volt 110-hp motors power the two front axles. Early in 1925, Electro-Motive discovered that the basic design of their 240 traction motor was wrong. It was redesigned and put into service in the spring of 1927. ""The two-forty motor,' Hamilton recalls. 'nearly put us under. Before it was replaced with the new model it cost us a quarter million in addition to an untold amount of

Composite photo of engineer's compartment looking forward. Photo by David Mattoon.

KEY:

A. Radiator Water Level Sight Glass
B. Radiator Shutter Lever
C. Ammeter
D. Headlight Control
E. Light for Gauges
F. Lubricating Oil Pressure Gauge
G. Voltmeter
H. Throttle Lever
I. Sander Valve
J. Air Brake Valve
K. Horn Pull
L. Windshield Wiper Air Valve
M. Arm Rest
N. Engineer's Seat (back folded down)
O. Reverser Controller
P. Main Generator



lost business. In those days we weren't prepared for a reverse of those dimensions'" [summarized from [19]. pp. 55-56, quote on p. 56][20]

Gas-electric rail motorcars initially used traction motors designed for streetcars and interurban service. However, gas-electric cars operated differently. Because they were used for longer distance service and often on rough track, they required a vibration-absorbing motor. A 1927 GE publication stated: "The GE-292 motor [a later model than the 240A] has a spring-nose suspension similar to that on electric locomotives [because] it was found that the solid nose suspension of the earlier equipment causes excessive vibration in the motor." [2, p. 9]

Economy of GN 2313 Compared to the Steam-Locomotive Train It Replaced

Railcars were introduced to reduce costs. The Great Northern Railroad performed an actual cost comparison during the last full month of steam operation and the first full month of rail motorcar operation.

The steam-locomotive train during October 1927 made 27 round trips and traveled 5,348 miles. It cost $115.34 per trip, $3,114.28 per month, and $.5823 per mile.

The cost of the rail motorcar in December 1925. when extrapolated for 27 round trips, was $1,380.24. It cost $51.12 per trip and $.2880 per mile. [14]

Thus, when compared to the steam-locomotive train, the rail motorcar reduced cost per mile by 50 percent, costs per trip by 56 percent, and costs per month by 56 percent.[21]

Another benefit of railcars was their faster schedules. "On tests in its first days of operation, Mountain Station to Apex, 9 miles, was covered in 21 minutes whereas 32 minutes [were] required for the steam train it replaced." [13]

Dr. Hermann Lemp (1862-1954) [11]

Dr. Lemp was born in Berne, Switzerland. "The Franklin Institute awarded [October 17, 1951] the George R. Henderson Medal in Hermann Lemp, of Ridgeway, NJ. for his contributions to the development of the diesel-electric locomotive... He came to this country to work in the laboratories of Thomas Edison in Menlo Park, NJ and New York. After six years as an electrical engineer with the Schnyler Electric Company, he was chief engineer of the Thomson Electrical Welding Company in 1889-1895. He was for many years affiliated with the General Electric Company in Massachusetts and Erie, Pa., where he developed the electric transmission for diesel-electric locomotives. He later became chief engineer of the Erie Steam Shovel Company and then consulting engineer to the locomotive department of the Ingersoll-Rand Company. From 1938 to 1940 he was engaged in railroad building for the New York World's Fair." [17, p. 61]

"[Richard Dilworth] was working closely at this time with Dr. Hermann Lemp, an electrical genius in the class of Steinmetz and Pupin....

"'I learned a lot from Lemp,' Dilworth recalls.'Lemp always worked from the positive side. When a problem came up that seemed insoluble, Lemp would look around and see what we had to work with. Instead of looking for the difficulties. he'd take an inventory of the favorable factors, and go on from there. If one way wouldn't work, he'd try another. He was one of those men who literally never gave up..

"'Maybe something happened years ago. Dilworth explains, 'when

MW 31's main passenger compartment presently seats 26, but the original floor plan shown earlier indicated an off-center aisle, thereby accommodating 32. The seats apparently changed after 1931; they now are the same width on both sides of the aisle. Air vents in the ceiling were connected to ten "Garland" ventilators mounted on the roof to promote fresh air ventilation. Paul Swanson photo, August 26, 2002.

Lemp was trying to develop the first X-ray machines. Later on, if that same thing happened when he was trying to build a Diesel, he'd recognize it, even though the circumstances were entirely different. Lemp looked way below the surface of things. He'd recognize a basic idea wherever he saw it, and he'd remember what happened to it the first time. I think I had the same faculty to a lesser extent."' [20, pp. 28-29]

Richard McLean Dilworth (1885-1968)

Dilworth was a machinist for an outside contractor at General Electric when, in 1910, they hired him to work on their gas-electric cars. Dilworth was assigned to delivering railcars and then became supervisor of the people delivering them. In 1912, Dilworth went to G.E, in Erie to work on experimental railcars. When G.E. stopped developing gas-electric cars, Dilworth worked on diesel engines, steam turbines, and marine reduction gears. In 1923 Dilworth again worked on gas-electric cars at G.E. and began contracting with other companies building them. Work with Harold Hamilton's EMC led to Dilworth being hired as EMC's Chief Engineer on January 1, 1926.

Richard Dilworth, as Chief Engineer, later worked on the development of locomotive truck mounted brakes, the Union Pacific's M-10000 distillate engine, and the Pioneer Zephyr [1], the FT freight locomotive [16], and the GP road switcher. He retired in 1952. [20, pp. 103-105]

Harold Lee Hamilton (1890-1969) [19] and [24]

Harold L. Hamilton formed the Electro-Motive Corporation with the idea of marketing an improved gas-electric rail motorcar. Hamilton worked as a locomotive engineer on several railroads. He began working in the sales and service department of the White Company motor trucks in 1916. Hamilton's rail experience, the state of the existing railcar[22] field, and Hamilton's automobile sales and servicing[23] policy all convinced him a market existed for an improved railcar.

Hamilton believed a mechanical transmission was not feasible for a railcar. The vibrations induced from the roadbed would be directly transmitted to the engine and the heavy masses involved would make mechanical gear shifting impractical. On the other hand, previous gas-electric railcars had not been widely used because the railroads considered them unreliable and the engineers found them difficult to run.

As a result, in 1920 Hamilton drew up a plan for an engine and an electrical transmission. But surveying the field he found that GE had built railcars with a similar design. Hamilton resigned from White in July 1922. Hamilton persuaded General Electric to design the control system of his railcar, but GE required that Hamilton provide the engine. Hamilton contacted the president of the Winton Engine Company who agreed to build and finance an engine for Hamilton.

Hamilton persuaded Edwin B. Meissner, president of the St. Louis Car Company, to build his first cars. Meissner invested considerable money of his own. [26, pp. 145, 148] Hamilton incorporated the Electro-Motive Engineering Corporation on August 31, 1922. In 1923 the company was changed to Electro-Motive Company.

EMC was, therefore, a "store-front" design company in Cleveland with major subsystem design and manufacturing being contracted out.

General Motors bought out the company in 1930, but Hamilton remained president until 1935. The company then became the Electro-Motive Corporation. Production facilities at La Grange, Illinois, were begun in that year. In 1942, the corporation was dissolved and it became the Electro-Motive Division of General Motors. Hamilton retired (as a GM vice-president) in 1957. [24] In 1957 Harold L. Hamilton, Richard M. Dilworth, Eugene W. Kettering, and "citation to their associates" won the 1957 Elmer A. Sperry Award.[24] ■

NOTES

[1] Using the categories and summarized from [8] with additional information.

[2] In 1905, for example, George J. Kobusch, president of the St. Louis Car Company, formed the Kobusch-Wagenhals company to market the steam motorcars invented by W. G. Wagenhals. Although a catalog was produced [10], only one car was ever produced [15, p. 6.]. The catalog stated that railroads had been trying on their own to produce steam railcars for the past 25 years. In 1925, Baldwin Locomotive Company delivered two steam railcars to the American Railroad of Porto [sic] Rico and three more were under construction [18].

[3] Mechanically connected railcars tended to shake apart since track vibration was transferred to the engine's pistons.

[4] These gas-electric railcars adopted streetcar technology. However, streetcars were powered by an unlimited stationary power plant. Reducing the size to put the generator on-board led to a more complicated control system for the locomotive engineer. This control system, and its replacement, will be described later.

[5] "The main reason for [General Electric] discontinuing the gas-electric car business was due to the war [WWI], the anticipated heavy rise in the cost of gasoline, and also the tremendous improvements in design of the modern gasoline engines which would have required the development of a new line of engines." [2, p. 16] See [12] for more early GE history.

[6] Even Brill switched over to manufacturing gas-electric rail motorcars.

[7] In 1923, "Engineering" was dropped from the corporate name. [24, p. 537]

[8] GN 2313/MW31, as it is now displayed, has elements from both its Great Northern and Montana Western heritage. A restoration plan is being developed to restore it to a consistent era.

[9] "The operation of this car will permit discontinuing operation of trains 259 and 260 between Marcus and Nelson, BC and the payment to the C.P.R. [Canadian Pacific Railway] of trackage charges [charges for one company to operate over another line] between Troup Junction and Nelson. In the aggregate, it is expected that the placing of this car in operation will make a saving of about $15,000.00 per annum." [9]

[10] AFE (Authorization for Expenditures) 57994.

[11] This is not completely negative. Sperry bought Winton parts from EMD to support their fleet before Sperry dieselized. Sperry donated a Winton engine, manuals, and spare parts to Mid-Continent Railway Museum.

[12] [8] provides the list and disposition when known of EMC [and all other rail motorcar manufacturers.] Investigations supporting this claim, though not presented here, were presented in the original nomination application form to the national History and Heritage committee.

[13] Since the 1920s, E. W. Kettering at General Motors Research had been developing a 2-cycle diesel engine. GM bought Winton Engine Company in June, 1930 as an entry into the diesel field and had the Winton people commercialize this engine. GM purchased Winton's largest customer, EMC, in September 1930.

[14] The differences between 106 and 106-A will be described with the technical specifications. There is conflicting evidence whether GN 2313 was built with 106 or 106-A, but both appear to have been obsolete within two years after the car was built.

[15] It was built with either 240 or 240 A traction motors. The suffix A probably indicates minor design changes.

[16] The most obvious change is that the aisle is no longer off-center. Therefore, the seats have been modified or replaced. This aisle change was probably made after 1931 based on the [5] diagram.

[17] Lemp's first patent for this problem was Number 1,216,237 of June 24, 1914. [21] Lemp's second patent was Number 1,313,097 of August 12, 1919. [22]. Both these methods used rocking arms, air or hydraulic cylinders or friction wheels. Lemp's third patent, in contrast, provided an all-electric solution to the problem.

[18] For more information on direct current traction motor systems, see [25].

[19] St Louis Car Company has gone out of business, but its archives are preserved at the Washington University Libraries in St Louis.

[20] In October 1927 General Electric published The Gas-Electric Car [2]. It lists equipment for 42-, 50-, 65-ton gas-electric rail motorcars from EMC and 50- and 75-ton motorcars from American Car and Foundry Co. All use the later GE-292-A traction motor.

[21] Calculations done on the basis of (rail motorcar–steam) / steam.

[22] Although White did sell a line of railcars, Hamilton refused to sell them knowing that they were not reliable.

[23] While at White, Hamilton had twice as many servicemen as salesmen. When challenged, he merely labeled some of his servicemen as salesmen.

[24] Given in recognition of "a distinguished engineering contribution which, through application proved in actual service, has advanced the art of transportation whether by land, sea, or air. " The medal is administered jointly by the American Institute of Aeronautics and Astronautics, the Institute of Electrical and Electronic Engineers, the Society of Automotive Engineers, the American Society of Mechanical Engineers, and the Society of Naval Architects and Marine Engineers. <http://www.nasm.edu/nasm/aero/trophy/sperry.htm> [National Air and Space Museum], downloaded April 12, 2003.

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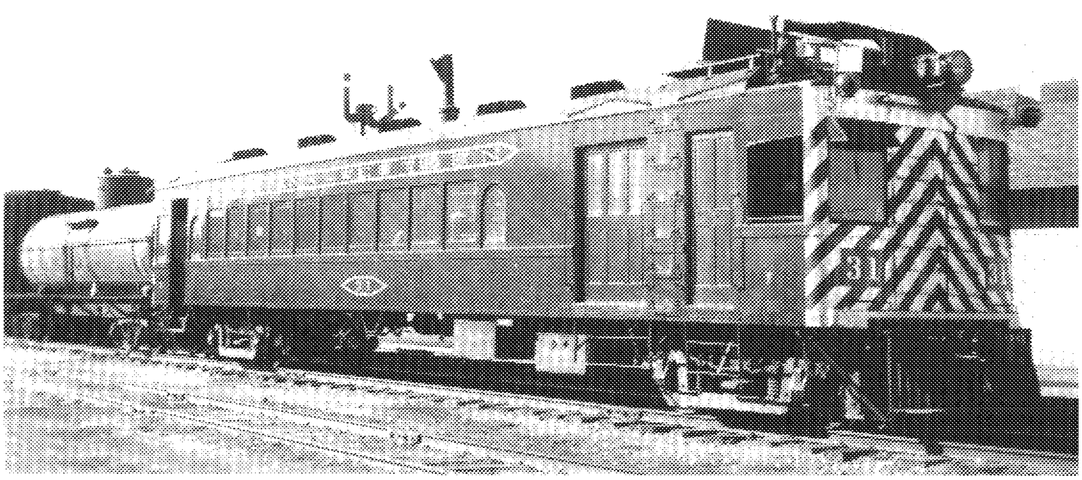

This Photo documents Montana Western 31's use as a freight locomotive. It possessed enough power to pull one or two extra cars, thereby saving the cost of operating a separate freight train with an expensive steam locomotive. This service was well suited for the tiny 21-mile Montana Western which moved smaller amounts of freight. Great Northern also had used the car in this fashion judging from existing photos. W.R. McGee made this view at Conrad, Montana, on October 18, 1941. Bill Buhnnaster collection.

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The History and Heritage Landmarks Program of ASME International (the American Society of Mechanical Engineers) began in 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee initially composed of mechanical engineers, historians of technology, and the curator (now emeritus) of mechanical engineering at the Smithsonian Institution, Washington, D.C. The History and Heritage Committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements of particular significance. This Committee is part of ASME's Council on Public Affairs and Board on Public Information. For further information, please contact Public Information at ASME International, Three Park Avenue, New York, NY 10016-5990, 1-212-591-7740.

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HISTORIC MECHANICAL ENGINEERING LANDMARK
GREAT NORTHERN 2313 (MONTANA WESTERN 31)
GAS-ELECTRIC RAIL MOTORCAR
1925

GREAT NORTHERN 2313, LATER MONTANA WESTERN 31, IS THE OLDEST SURVIVING ELECTRO-MOTIVE CO. (EMC) GAS-ELECTRIC RAIL MOTORCAR. THIS 32-TON CAR FEATURES A WINTON GASOLINE ENGINE AND GENERAL ELECTRIC GENERATOR AND TRACTION MOTORS, IT CONTAINS BAGGAGE AND PASSENGER SECTIONS AND REDUCED OPERATING COSTS BY 50 PERCENT OVER THE STEAM-LOCOMOTIVE TRAINS IT REPLACED.

THE EARLY EMC CARS MADE THE FIRST MAJOR USE OF HERMANN LEMP'S CONTROL SYSTEM,WHICH SAW WIDESPREAD USE IN DIESEL-ELECTRIC LOCOMOTIVES FOR OVER 50 YEARS.

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