THE BURLINGTON ZEPHYR STAINLESS STEEL TRAIN

This year marks the 75th Anniversary of the Burlington Zephyr stainless steel train, the train that broke all records and changed forever the way passenger trains would be built. This article is an excerpt from a new ASM book, The History of Stainless Steel, *a fascinating look at the ingenious men who built the industry. See sidebar for details.*

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In 1912, metallurgists Eduard Maurer and Benno Strauss at the Krupp Steel Work in Essen, Germany, were trying to find an improved oxidation-resistant alloy for thermocouple protection tubes. Herr Strauss, knowing that chromium was highly resistant to oxidation at elevated temperatures, made an alloy of iron containing unprecedented amounts of chromium and nickel: 20% chromium and 7% nickel. They were surprised to find that after several months on the floor of the laboratory, a bar of the metal had not rusted. They also found that the normal nitric acid etching solution for steel metallographic samples had no effect on the metal whatsoever. They were astonished to find that they had performed a bit of alchemy. They quickly filed a patent for the alloy, which was called V2A.

The discovery at Krupp was kept under wraps and not publicly revealed until August 1920, when Krupp published the news in their monthly magazine. Around that time Krupp agreed to exchange patent rights with Brown Firth in Sheffield for the chromium stainless steel that had been invented by Harry Brearley. Dr. William Hatfield at Brown Firth launched an extensive investigation that led to the discovery of 18-8 stainless steel, a somewhat better alloy than Krupp's 20-7.

The Budd company

By 1920, the Edward G. Budd Manufacturing Company in Philadelphia had become the largest manufacturer of pressed-steel, all-welded automobile bodies that were shipped to auto makers in Detroit and abroad. In 1924, the Budd Company and Michelin Cie, the French tire maker, formed the Budd-Michelin Dual Wheel Company in Detroit. The plant made the first dual wheels for trucks and buses. Budd produced the steel wheel, and Michelin supplied the pneumatic tires.

Also in 1924, the first national symposium on Corrosion- and Oxidation-Resistant Alloys was held by the American Society for Testing Materials in Atlantic City, New Jersey. Among the speakers was Benno Strauss, who came over from Krupp to deliver a paper on "Non-Rusting Chromium-Nickel Steels."

In his paper, Strauss recounted the event of their discovery of Alloy V2A. He said that the alloy was "absolutely rust-proof in damp air and completely resistant to a solution of 50% boiling nitric acid." Strauss cited the alloy as being "suitable for the manufacture of many items, including acid pumps, valves, piping, kitchen utensils, spoons, forks, beer casks, surgical and dental instruments, and metal mirrors". This was all new and very interesting to American metallurgists, many of whom, however, had become experts with the chromium cutlery type of stainless steel.

In the 1930s, in the depths of the great depression, the automobile body business at the E.G. Budd Company was slowing to a trickle, and Edward Budd had to begin layoffs from the 10,000-man factory. He lay awake nights trying to think of new products he could build to keep his company in business. Mr. Budd was intrigued with the new silvery metal cladding of the dome of the Chrysler Building in New York that had just been completed. He learned that it was a new form of stainless steel that could be cold-rolled to strengths three to four times as high as structural steel, and yet it was ductile and could be formed in presses. It was a beautiful, silvery metal that never needed painting.

Mr. Budd thought his company might just be able to build some exceptionally strong structure that would be light in weight, with this metal. He bought some sheets and had them made into airplane parts, marine hardware, and some truck trailer bodies, but none of these would lead to substantial business.

Stainless steel airplane

On an impulse, he decided to build something that would be beyond the wildest imagination – an airplane. He had not the slightest thought of getting into the airplane business. Everyone said it would just be a big waste of money. His engineers also found that this steel had never been used in its high-strength condition because it could not be welded without weakening the structure. Welding also destroyed the stainless properties adjacent to the welds by creating a phenomenon called "weld decay" or "carbide precipitation" in the heat-affected zone next to the welds.

Col. Ragsdale, Edward Budd's chief engineer,

The upcoming ASM publication *The History of Stainless Steel* tells the stories of the many stainless steel pioneers and and entrepreneurs, including Edward Budd, who used stainless steel to revolutionize passenger trains during the Great Depression. For details on *The History of Stainless Steel* and soft-cover ASM member price of $24.00, go to: www.asminternational.org/The-History-Stainless-Steel/.

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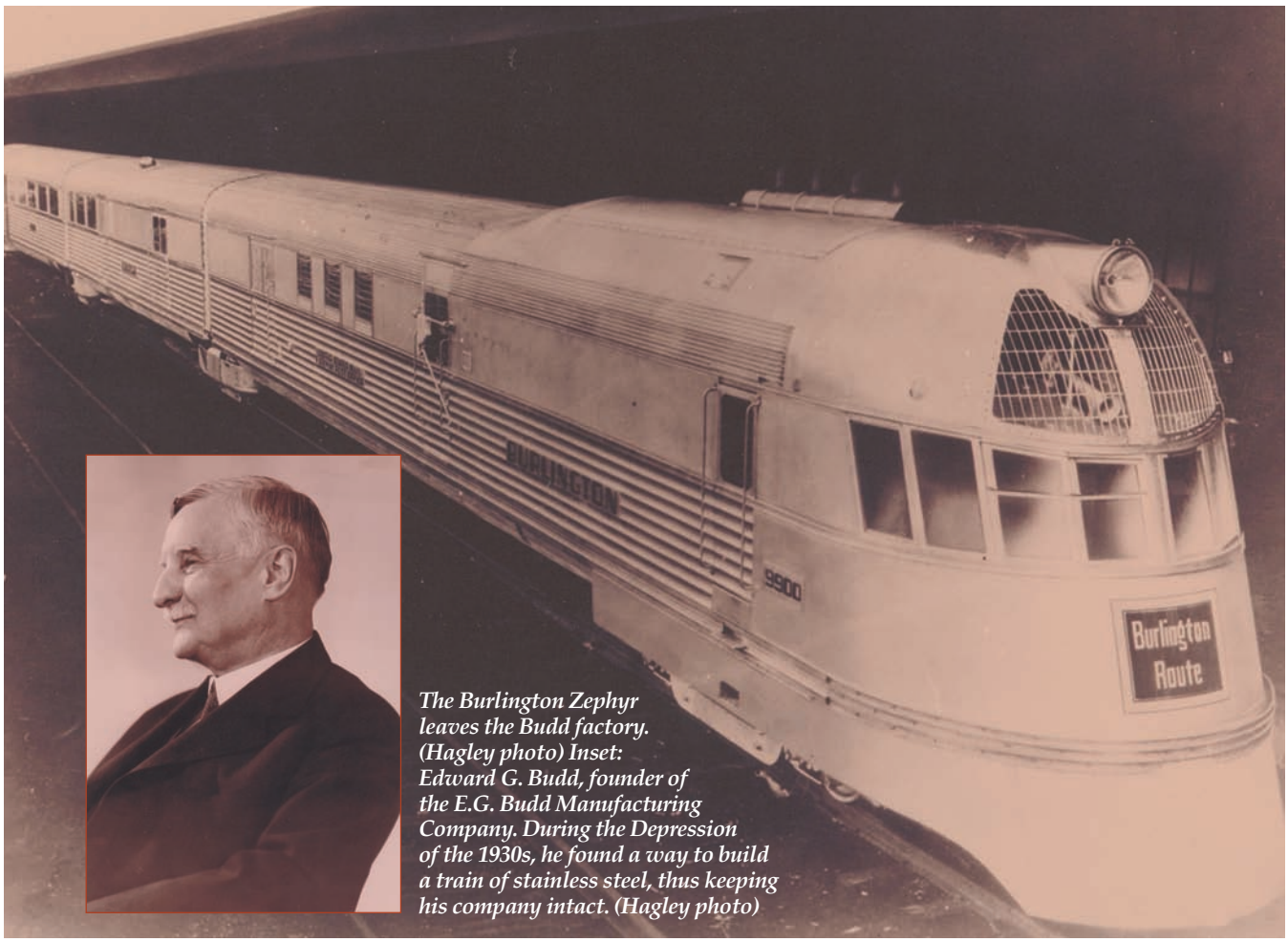


The Burlington Zephyr leaves the Budd factory. (Hagley photo) Inset: Edward G. Budd, founder of the E.G. Budd Manufacturing Company. During the Depression of the 1930s, he found a way to build a train of stainless steel, thus keeping his company intact. (Hagley photo)

was an expert at electric resistance spot welding. He thought he might be able to solve the problem. It took several months, but Col. Ragsdale invented a welding process that overcame both problems. He used an extremely high current and a very short welding time of one-hundredth of a second. Controlling these and other welding parameters resulted in strong welds, no annealing, and no carbide precipitation. The result was a successful spot weld between to two thin sheets of stainless steel, in which the weld penetrated to about the center of each sheet. The colonel promptly applied for a patent of the process.

Meanwhile, Budd engineers acquired drawings of a small Italian amphibious airplane, a Savoia-Marchetti, that was reputed to be stable and easy to fly. By 1931, the plane was built, substituting stainless steel sheet 0.006 inch thick for the original wooden structure. The plane was assembled by spot welding. It could carry a pilot and two passengers in an open cockpit, and weighed just 1750 pounds.

The Savoia-Marchetti was being manufactured at a shop on Long Island where Lou Argentin, a former French army pilot, demonstrated the plane to prospective buyers. When his job was terminated because of the Depression, he applied for and immediately got a job flying the Budd plane. The plane was officially a Budd BB-1, and was called "The Pioneer."

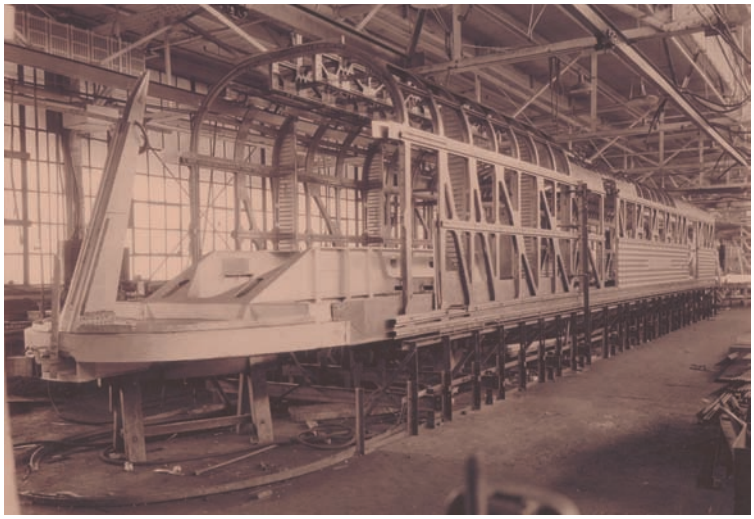
The plane made exhibition flights in America and was then sent to Europe for demonstation flights in England, France, Germany, and Italy. One objective was to obtain licensees for the Budd ShotWeld Process. Some licensees were lined up in France, where Argentin also took orders for stainless steel airplane parts.

After the tour, the Pioneer was brought back to America, and Mr. Budd donated it to the Franklin Institute at Philadelphia, where it is on display in front of the building.

Steel rail cars

Possibly as a result of the Pioneer's visit to France, or their joint dual-wheel venture, the Michelin company inquired if Budd could produce a lightweight rail car that would run on Michelin's pneumatic tires. André Michelin had the idea that railroads would be interested in a train that would give a very quiet ride, while adding tire sales for Michelin. Michelin had invented a steel flange for the wheels to keep them on the rack. He actually had been experimenting with the idea by running an old Citroen bus on a railroad track.

The Budd Company accepted this as a challenge



The front car of the Burlington Zephyr under construction. Note the two stanchions that support the diesel engine at the front of the car. (Hagley photo)

and maybe the start of a substantial business. A lightweight, thirty-two passenger stainless steel railcar was designed and built. It had a gasoline engine under the front of the car.

A railcar named the *Lafayette* was built and shipped to France in the fall of 1932. By then Budd had obtained orders for three more Budd-Michelin trains, from the Reading Company, the Pennsylvania Railroad, and the Texas-Pacific.

Meanwhile, in the city of Chicago, another company president was trying desperately to dream up a way to boost rail passenger traffic. He also happened to have the name of Budd, Ralph Budd, and he was president of the Chicago, Burlington, & Quincy Railroad.

Ralph Budd learned that the E.G. Budd Company in Philadelphia was building lightweight passenger cars that were self-propelled and built of a new material called "stainless steel." He noted that the company was not one of the America's four train builders, America Car & Foundry, the Pullman Company, Brill, or Bethlehem Steel.

Ralph Budd had been president of the railroad since January with not much to show for his efforts. He arranged a visit to the E.G. Budd Company and was given a test ride on one of the Budd-Michelin trains. He was favorably impressed and promised to be in contact. Legend has it that while he was reading one evening he came across "Ode to the West Wind," a poem in which the Greek god, Zephyrus, was the god of the West Wind. In a flash, Budd decided the he would call his train the "Burlington Zephyr."

Streamlined engine

On June 17, 1933, Ralph Budd came to Philadelphia to discuss the contract. He told Edward Budd that he wanted a three-car train equipped with a Winton diesel engine, and no rubber tires. The interior design would be left entirely to the E.G. Budd Company.

The contract was promptly signed and plans were laid. The lead designer was to be Albert Dean, who would modify and refine the design of the rubber-tired car. He took many ideas from aircraft design to enhance the streamlining, although trains had never been streamlined. Albert Dean completely enclosed the underside of the car to reduce drag. He tested his design with a model in a wind tunnel at the Massachusetts Institute of Technology. Tests later determined that the amount of wind resistance brought about by Dean's streamlining had reduced drag by 47% at a speed of 95 miles per hour.

The front of the train was designed by an architect by the name of John Harbeson, who made it sloped down like a shovel for reduced wind resistance. The front had no handles or other objects protruding, not even rivets, only smooth shot welds.

Innovative undercarriage

Walter Dean, who was Albert Dean's older brother, was in charge of designing the undercarriage of the cars. This included the heavy steel trucks, which consisted of the wheel and axle assemblies that supported the entire weight of the car. On conventional trains, each car is supported by two trucks, each with two axles and four wheels positioned at each end of the car.

Walter Dean's idea, on the other hand, was to save weight by having the truck at each end of the center car share the load of the cars before and after. This also permitted the train to be built with four trucks instead of six, for a weight saving of several tons. This created what is called an "articulated train," which permits the cars to turn on roller bearing pivots as the train rounds a curve. Two couplings were also eliminated.

The three-car train would be 196 feet long and weigh 104 tons, or about the weight of a single Pullman coach. It would be powered by a newly developed Winton 8-201A 660 hp, two-cycle engine, which would drive an electric generator. The generator current would be fed to electric traction motors in the train's front truck, and would provide power for lighting, heating, and air conditioning. The unpainted sides of the train would be fluted stainless steel sheet to increase rigidity and enhance appearance. It would be fast – maybe one hundred miles an hour – and would quite often be called "The Silver Streak."

The train represented the largest application by far of stainless steel in any structure. Twenty-three tons of Allegheny Metal stainless steel were used in its construction.

The stainless steel car body was built primarily with steel as thin as 0.012 inch, formed and spot-welded to make hollow square and rectangular subsections that were then joined by spot welding. The hollow sections created the lightest possible structure, although requiring much more assembly time than solid bars and plates. A lighter car body meant that the supporting wheel trucks could be lighter. The roofs are constructed of corrugated stainless 0.022 inch thick, or about the thickness of a stack of seven sheets of paper. Col. Ragsdale said the roof would easily support a man walking on it.

Zephyr interior

Paul Phillipe Cret, head of the University of

Pennsylvania School of Architecture and a noted interior designer, was hired to design the train's interior. He wanted the passenger compartments to reflect a state-of-the-art appearance in keeping with the exterior streamlining. The cars would look stark and unadorned when compared with the Pullman coaches of the day. Fluorescent tubes would supply indirect lighting, and the walls would be pastel colors of pale green, blue, and light brown. The plush separate armchairs would be comfortable and covered with fine but sturdy fabric.

Luxurious carpeting and curtains would be shades of pearl grey. To preserve the clean lines of the interior, baggage racks were not overhead. Instead suitcases were kept in a separate baggage compartment. Each passenger compartment would be individually heated and air conditioned. It would truly be the train of the future.

The entire period of designing, building, and decorating was one of intense excitement, with everyone working as if his job depended on it. The train was completed in only nine and one-half months, two and one-half months ahead of the stated delivery date. The feat was all the more remarkable when it is considered that the equipment for the train had to be procured from one hundred different suppliers.

The cost of the train was around $260,000, which would be about $3,640,000 in the year 2008 after adjusting for inflation.

There was a final inspection. The first car held the diesel engine, an engineer's cab, a 500-gallon fuel tank, a 30-foot railway post office, and a space for baggage. The second car included a larger baggage compartment, a buffet grill, and a 16-foot smoking section for twenty passengers. The third and last car had a 31-foot section with seats for forty persons, and a solarium-lounge at the end of the car with club chairs for twelve. The train had a total of 72 seats, and could carry 25 tons of baggage and express freight.

Two days after the train was completed, it was taken on a 25-mile test run from Philadelphia to Perkiomen Junction on a line that the Reading Company had cleared and inspected. The train ran perfectly and reached a speed of 104 miles per hour for a brief time.

Dedication

The formal dedication came on April 18th at Philadelphia's Broad Street Station directly across from the City Hall. At the appointed time of 10:00 A.M., the ceremony took place amidst a crowd of hundreds. Ralph Budd spoke over national radio saying that "the Burlington Zephyr is a symbol of progress." On the following day, 24,000 people lined up to see the train. The Burlington Zephyr was then taken on a three-week tour to thirty cities in the East, during which time it was estimated that close to a million people went through the train.

But Ralph Budd had a plan that would attract the attention of the entire nation. He was aware that the Chicago Century of Progress Exposition would be opening its second season on May 25, 1934, and that one of the major attractions would be the "Wings of a Century Pageant" showing America's progress in transportation from the Indians to the modern steam locomotive. Budd was going to display his Burlington Zephyr in that pageant, which would open on the evening of Saturday, May 26, 1934.

Ralph Budd planned the big event for weeks. He would have the Zephyr leave Denver at dawn on May 26, and race 1015 miles non-stop to Chicago, pulling in at dusk just in time for a grand entrance at the Exposition.

The Zephyr was moved to Denver on Thursday, April 24, and set on display at the Union Station. Newspapers reported that "a silver train has flashed into the silver state." Visitors went through the train that day and also on Friday up to the time that the train was sent into the shop for inspection before the mad dash the next day. Celebrities and politicians got wind of the wild trip and clamored for tickets. But all tickets were sold and all 85 seats, including thirteen folding chairs to be set up for reporters in the baggage compartment, went to officials of the Burlington railroad, General Motors, Edward Budd, and reporters.

The crew prepares

Ralph Budd had made special preparations for the thousand-mile dash. All of Burlington's employees along the route had been notified to inspect the entire length of track and to post large signs at those places where the train should slow down for some reason. Railroad employees, police, and army veterans would man every one of the 1689 grade crossings to be sure that all road traffic would be stopped at the time the train would be passing. All pas-

It was a world's record for the longest and fastest nonstop railroad run.

senger and freight trains would be sidelined. Guards would also be posted at each railroad station to make sure no one got onto the track.

Never before had such preparations been taken for a train trip, giving the train the clearest right-of-way any train would ever have.

On Saturday morning, May 26, the train left the Union Terminal, breaking the timing tape at 7:04 A.M. In the driver's compartment were three men who would take their turns at the controls in two-hour shifts. These men were J. F. Weber, Burlington's superintendent of automotive equipment; J. S. Ford, an assistant master mechanic; and Ernie Kuehn, a Winton engineer. Three Burlington mechanics also rode in the cab. All of them would scan the road ahead to watch out for any problems.

The two Budds were seated side by side in the Solarium lounge waiting for the show to begin. They had a great deal at stake on this "maiden voyage."

The Greatest Train Ride

The train was now on its way, and the throttle was pushed to ninety miles per hour for much of the trip. She ran at one hundred miles per hour along one nineteen-mile stretch, and reached a top speed of 112.5 miles per hour for three miles.

It was a quiet ride, with only the clickety-clack of the rails and the brief clanging of the bells as the train passed the grade crossings. The telephone poles looked like picket fences. Ralph Budd had guessed that the trip might take about fifteen hours, which would be possible if they could average a pretty fast clip of sixty-seven miles per hour.

The Burlington's crack steam-powered train on the Denver-to-Chicago run, the Aristocrat, took almost twenty-six hours to make the trip, and had to stop several times to take on water, coal, and new train crews.

By the time the *Zephyr* reached Lincoln, Nebraska, which was 483 miles from Denver, the clock showed an elapsed time of six hours and seven minutes. One of the railroad officials announced that the train had just broken the non-stop record set by the Royal Scot in 1928.

News bulletins were dropped off at prearranged intervals and then telegraphed to radio stations and newsrooms. The train attracted bigger and bigger crowds. In town after town across rural Iowa and Illinois, fire sirens shrieked and church bells rang to give notice of the train's approach. Trucks and Model Ts clogged the roads next to the tracks.

It was 5:55 P.M. when the Zephyr streaked though Princeton, Illinois, passing the Burlington Aristocrat, which had left Denver twenty-four hours earlier. At 8:09 P.M., the *Zephyr* broke the tape at Chicago's Halstead Station (which timed the trip), and then continued on to the Chicago Exposition Grounds. It fit onto the 200-foot-long stage with four feet to spare, and pulled to a stop amid the cheering of the crowd. Thousands of spectators poured out of their seats and up to the stage where they could touch the train. Boats in the harbor blew their horns and whistles as if it were New Year's Eve.

Inside the train there was cheering and laughing and hugging and the shaking of hands. The two Budds congratulated each other over and over again. They had achieved something beyond their wildest dreams, and it was another of Edward Budd's stream of "world's firsts."

Impact of the trip

After order was restored, Ralph Budd stepped from the baggage room, leading the train's mascot, the mountain burro named Zeph, and presented him to the officials of the fair. "It was a sweet ride," Ralph Budd exclaimed. "The trip demonstrated three things: First, the morale of the men and officers of the Burlington is proved by the way this run has been planned and carried out; second, the efficient condition of the railroad has been shown; third, the train performs fully up to expectations."

Many records had been set. It was a world's record for the longest and fastest nonstop railroad run, having sped 1014.4 miles across one-third of the continent in just thirteen hours, four minutes, and fifty-eight seconds. The average speed was 77.61 miles per hour. The run was made in a little less than half the normal time. The diesel fuel used was just 418 gallons, and cost an unbelievably low $16.72, since diesel fuel was only four cents a gallon. The Burlington Aristocrat, on the other hand, had burned 85 tons of coal costing $255 at $3 a ton. Put another way, the Zephyr got two miles to the gallon and cost 6.7% of the cost of the steam train.

Newspapers across the land had screaming headlines. There hadn't been such good news since Lindbergh crossed the Atlantic.

The trip changed forever the way passenger trains would be built and spelled the end of the smoke-belching steam engine.

The train was renamed the "Pioneer Zephyr" on its second anniversary, and remained in service for 25 years, having covered 3.2 million miles. The train was then donated to the Chicago Museum of Science & Industry, where it remains on display inside the building.

The Pioneer Zephyr spawned a family of sister Zephyrs, each one a testimony to the Burlington Railroad's dedication to engineering excellence. It was the model for the passenger trains of competing railroads, although none of the other trains were made of stainless steel for many years, mainly by virtue of Budd's patented ShotWeld system.

The Budd Company would manufacture almost 11,000 stainless steel railcars over the next fifty years – enough cars to make a train stretching 175 miles from Philadelphia to New Haven, Connecticut.

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