Integral Construction

Rails, platforms, web frames and sleds

by Larry Plachno

Integral construction is a primary factor in the safety, durability and resale value of today's modern coaches. Originally developed in the 1930s in two different versions, integral construction has been modified, improved and blended over the following years. This photo was taken on the Van Hool assembly line in Belgium and shows a coach with a wheelchair lift being built for sale in the United States. NBT.

Many people take integral design in buses for granted. Others may not fully understand the value of integral construction and how it shapes our industry. If you are a commercial coach operator, you should know that integral design is responsible for the durability and longevity of modern intercity coaches as well as their resale and residual value. Moreover, integral design is at least partially responsible for several coach improvements and passenger items such as high quality suspension, large underfloor compartments and passenger safety. If you have converted a used coach into a motor home, it was integral construction that gave the coach the durability that allowed you to do this.

Recently, we have seen a substantial increase in reader questions regarding integral construction. Commercial operators are finding that shorter coaches are either not available or are not much less expensive than longer coaches. Hence, operators seeking an economical, smaller bus are faced with giving up the advantages of integral construction. In the conversion market, used professionally-converted coaches are now available at very economical prices. Potential buyers are comparing a used integral coach to a non-integral but new factory RV with a similar price.

With the appreciated help from several sources we were eventually able to track down the history and background of integral construction in two separate versions. Strangely, we found very little written on the subject of integral design in the past and ended up finding information in several different locations. Hopefully, the following will help explain about integral construction and its history for us non-engineers.

Early Chassis Construction

The Mack Brothers did build a motorized truck-type bus in 1902 which was used for sightseeing in New York. While this is credited as being the first bus in North America, most of the early bus operators used automobiles, and later stretched automobiles to transport passengers. It was not until 1920, when paved roads began to appear, that the bus industry as we know it started to develop. In 1921, Fageol offered a vehicle specifically designed as a bus. By 1922, you could actually buy a chassis designed for bus use. By mid-decade, a bus chassis was available designed for intercity bus service. Coast-to-coast intercity bus service was inaugurated in September of 1928 by Pioneer Yelloway Stages.

A chassis typically consists of front and rear axles plus wheels and brakes, a drive train (engine and transmission) plus steering and sometimes a dash and some systems. All of this is usually connected by two beams which are called rails. In most cases, a chassis can actually be driven but would obviously not be legal on public roads. The early bus companies typically selected a chassis from a manufacturer and then had a body builder build and place a body on the chassis. Some of the larger bus companies actually built their own bodies or at least did some of the construction work.

While there were only a limited number of chassis builders, body builders were more numerous and some were fairly local in nature. There are reports of bodies surviving one chassis and being placed on a second chassis, or a chassis getting a second body. However, these incidents became less and less frequent as the the years went on.

Two different basic types of integral construction were initially developed in the early years. Platform-type integral construction originated with the Pickwick Nite Coach while cage or web frame construction developed from the aviation industry. In the early years these two types were fairly distinct but in more recent times they have been modified and even combined.

A typical chassis usually includes at least an engine, transmission, axles and wheels as well as a steering system. The various components are almost always joined to two beams or "rails" which also serve as a platform for mounting the body. Shown here is a Freightliner rear engine chassis which is designed for recreational vehicles. NBT.

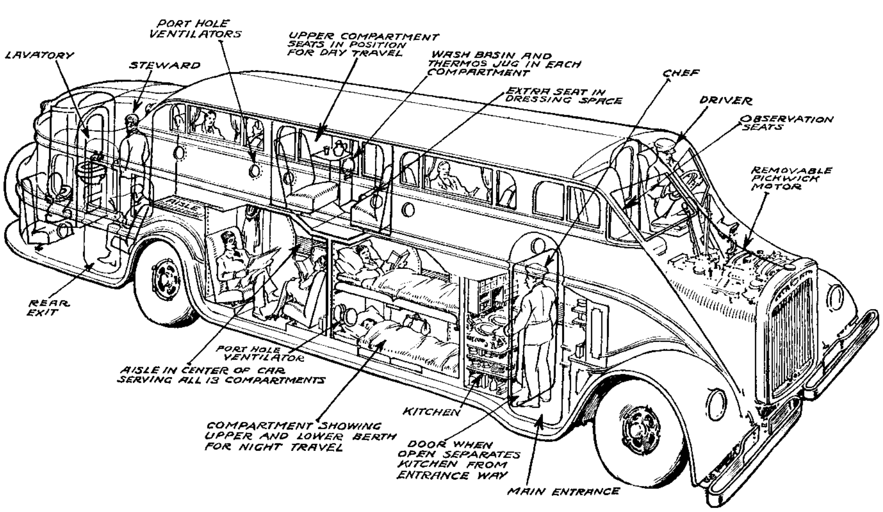
Pickwick and Platform Construction

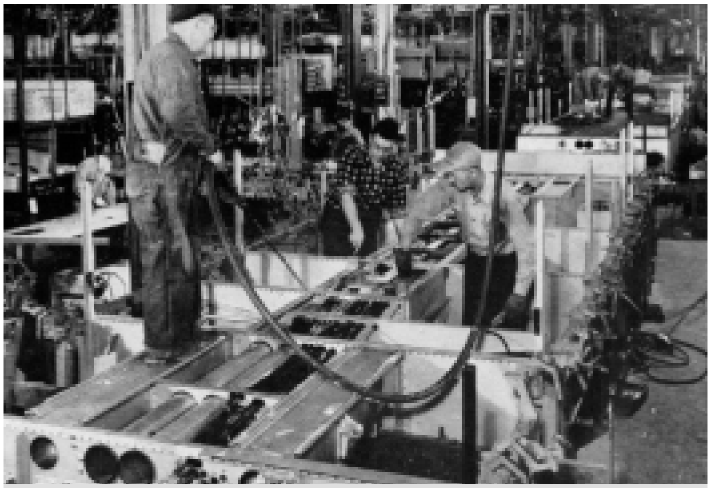
Founded in 1912, Pickwick Stages was at one time the largest intercity coach operator in the United States. Unlike many other bus operators who used cheaper buses, Pickwick had very high standards. The company regularly used the Pierce-Arrow car chassis which was then stretched and fitted with oversize radiators. By 1924, Pickwick had its own shop and was building its own bodies.

In the late 1920s, Pickwick developed a huge bus with two levels, 13 compartments with running water and folding berths, two restrooms and a kitchen which came to be called the Nite Coach. Dwight E. Austin, Pickwick's vice president, took charge of the project. The resulting bus was 10 feet high and nearly 35 feet long – about the size of the PD4104 which would be built in the 1950s. However, in 1930 this was considered huge. Any existing chassis was either not large enough or was too high off the ground for what Dwight Austin wanted to do. The result was that Pickwick is credited with the first real attempt to build up complete buses from purchased parts. Austin developed an early form of integral construction in order to build the Nite Coach.

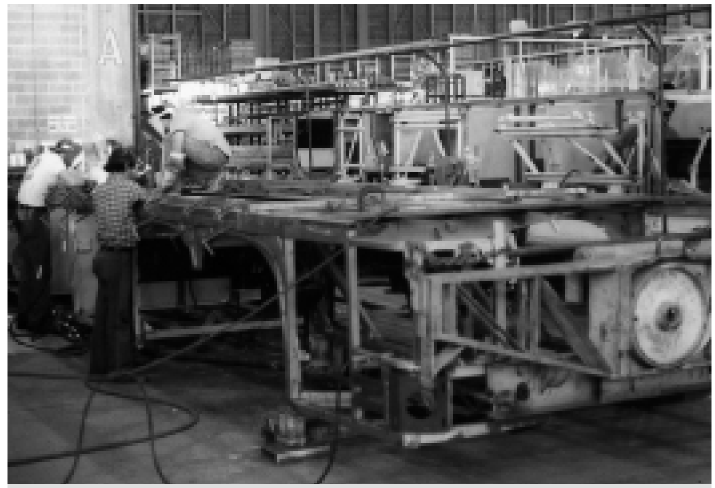
Surviving records indicate that the Nite Coach had chassisless construction. Longitudinal beams were used under the coach to support the body and mount the axles. These beams circled in the rear to provide additional support for the engine area and safety in the event that the coach was struck from the rear. The Night Coach was innovative in many other areas including developing a rear transverse engine and angle drive. However, the stock market crash of 1929 severely limited the market for an upscale bus, and the Nite Coach was never successful financially.

Necessity proved to be the mother of invention when Pickwick developed an early version of integral construction for their Nite Coach. Due to the size of the bus as well as the two passenger levels requiring a low floor, there was no suitable commercial chassis on the market. Since Pickwick had done work on their own buses for years, they took the next step and developed an integral bus that met their requirements. DON COFFIN COLLECTION.





Taken from a 1950s GM brochure, this photo shows platform-type construction as used on the PD4104. Close inspection reveals tubes and conduits from front to rear for wires and other systems. MOTOR BUS SOCIETY.



Taken about 20 years later, this photo shows platform construction at MCI on what was probably an MC-8. This differs from GM's earlier construction in using both tubular steel and stainless. DON COFFIN.

After the demise of the Nite Coach, Austin went on to develop a small bus known as the Utility coach which he built in El Segundo, California. It had an angle drive, a transverse rear mounted engine, and carried 21 passengers. Its chassisless construction was considered remarkable at that time. Unfortunately, the Utility Coach matched the Nite Coach in being pioneering but not very profitable.

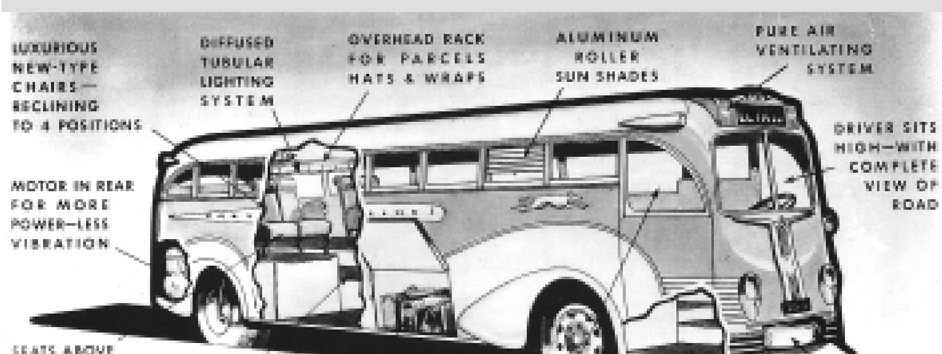
Austin joined Yellow Coach in 1934 bringing along his ideas. By that time Yellow Coach was already a part of General Motors and based in Pontiac, Michigan. Austin was substantially responsible for helping GM develop the Model 719 Supercoach which had a rear engine, underfloor luggage compartments and the start of GM's platform-type integral construction.

Instead of a continuously moving assembly line, GM used the station method of construction at their plant in Pontiac. It started when sub-assemblies were brought together to create what GM called an "understructure" which served as a platform on which the coach was built. This allowed some of the major systems to be installed (such as electrical and air) in protected pipes and conduits near the floor level. Eventually a sealer would be applied to the understructure, and a chemically-treated plywood floor would be installed.

The upper portions of the body, for both parlor and transit coaches, were assembled in a different area and were called shells. These were then mated to the understructure. At a following station, wheels and axles were raised from pits in the floor and bolted to the understructure. From this point the coaches rode on their own wheels through the remaining stations which included the installation of glass, seats and other interior finish items.

One of the things I find interesting is that GM did not use tubular steel in the 1940s and 50s. Historical photos showing production of the PD4104 and "Old Look" transit buses show that the upper bodies were constructed form various type of steel beams, including "T" beams. However, GM did use a lot of aluminum in their buses which cut down on both weight and corrosion.

When Dwight Austin moved to GM, he began to perfect the platform-type integral construction at Yellow Coach in Pontiac. One of his first efforts was the model 719 Yellow coach which was introduced in 1935. Known as the Supercoach, it introduced several improvements including a higher passenger level, underfloor luggage compartments, and a rear engine. DON COFFIN COLLECTION.



In 1977, GM introduced the RTS transit bus which used a new construction technique which effectively joined five-foot sections into one bus. This same technique was looked at for highway coaches but proved impractical for several reasons including excessive weight.

MCI developed a similar platform-type construction but changed and improved it somewhat. Much of this is credited to Harry Zoltok, who ran MCI for quite some time and had a great ability as a natural engineer. Like GM, MCI used a station system for production. Some people say that three pieces come together to make an MCI coach, but the end result is similar to what GM used with a platform and an upper shell. At least in modern times, MCI takes advantage of web frame type construction in the upper body by using a tubular steel structure. MCI uses stainless steel in many areas which considerably increases longevity.

It is interesting that the traditional coach models best known for longevity and durability were built using platform construction. These include the venerable GM Silversides and PD4104 as well as the MCI MC-5A, MC-7, MC-8 and MC-9. I have not yet figured out whether the bigger builders intentionally chose this method for a reason or whether it was merely a coincidence.

One obvious advantage of platform-type construction over web frame construction is that platform construction starts as two or more pieces which can be worked on easier while they remain separate. With web frame construction, you immediately start out with a massive single frame.

This photo was taken in 1940 and shows some of the early web frame integral construction. The location is the Hegewisch (Chicago) Aerocoach plant where the former Gar Wood models had just been put into production. Assembly starts at the far end of the plant with the web frame and continues through various stations towards the camera. The two buses on the far left appear to be completed. MOTOR BUS SOCIETY.

Newer models at MCI have moved more towards web frame construction. The F and G models, originally built in Mexico, are more web frame than platform as are the E and J models which go down a separate assembly line in Winnipeg.

The company that comes closest to the GM system today is Van Hool in Belgium. Van Hool originally developed integral construction in 1957 when they had a close collaboration with Fiat. In fact their first integral coach was called the Van Hool-Fiat 682.

Today, Van Hool uses a platform system somewhat similar to GM. However, they have improved on the old system with tubular steel for the upper body framework and substantial use of stainless steel. Like most integral builders, Van Hool uses a station system. However, what makes Van Hool interesting is that they run completely different coaches down their line side by side. It would not be unusual to find a suburban bus, an articulated bus and a double-decker next to each other in production.

Van Hool's reason for using the platform system is that they build both integral as well as body-on-chassis buses. This allows them to build virtually identical upper body units which can be mated to a bus chassis or completed as an integral coach.

Web Frame or Cage Construction

A second type of integral construction was developed independently of the platform type of construction used by GM. The original idea apparently was derived from early aircraft monocoque construction where circular wooden strips were covered by canvas. This concept was successfully transferred to metal by aviation designers including Douglas Aircraft which introduced their DC-1 in 1933.

William Bushnell Stout was primarily an aircraft designer and is best known for his work on the Ford Tri-Motor. In 1934 he helped develop the PCC streetcar body for the Pullman Car company. Soon after that he began working on a plan to develop a lightweight bus. Stout developed the concept of a framework of welded metal tubes covered by a thin aluminum-alloy skin. The tubular steel apparently provided the dual advantages of maximum strength for minimum weight while also being at least somewhat flexible and resilient. While the engineers usually call this web frame construction, some people have called this framework a cage since it visually is similar in appearance to a bird cage.

Stout's original design was for a 24-passenger bus which weighed only 6,000 pounds. The upper web frame was so light that four men could lift it. A prototype of Stout's bus was built by Gar Wood Industries of Detroit, Michigan, a company that had been active in building hydraulic parts and truck bodies. Stout searched for a company to put the bus into regular production but was unsuccessful. Meanwhile, the prototype had impressed so many local bus operators that Gar Wood eventually agreed to put the bus into production in 1936. Approximately 175 buses were built in the following two years. They had rear engines and primarily used Ford gasoline power and

In addition to being the first bus to use web frame construction, the Gar Wood was also revolutionary from the standpoint of design and styling. Shown is one of the early Aerocoach buses. MOTOR BUS SOCIETY.

Aerocoach correctly decided that the market needed a larger bus and developed their new Mastercraft series. Here is the prototype web frame for the larger series developed by the Aerocoach engineers. MOTOR BUS SOCIETY.

running gear although Dodge or Chevrolet engines were available. In 1937, a Gar Wood advertisement stated, "It's still the world's lightest and strongest, lowest priced rear engine coach."

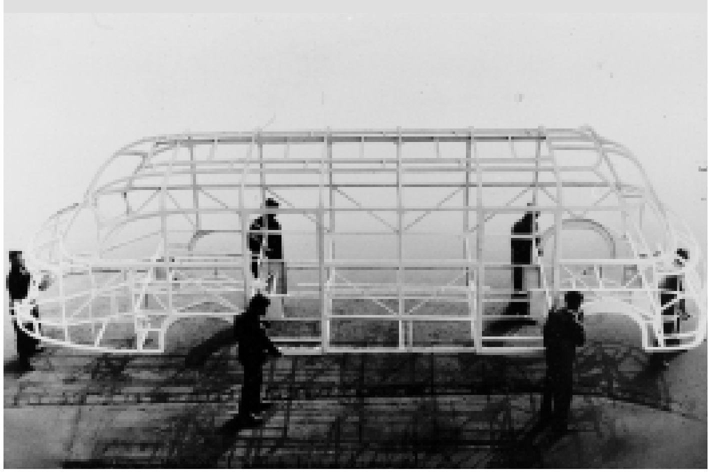
In 1939, Gar Wood sold their bus manufacturing business to the General American Transportation Corp., a company that had built and leased railroad cars. Due to the aviation background of the frame structure, the new bus was called an Aerocoach, and a new production line was set up in Chicago in 1940. Although Aerocoach continued to manufacture the Gar Wood buses, they correctly realized that the real market was for a larger coach. As a result, Aerocoach developed their Mastercraft series of larger 29- and 33-passenger coaches using the same welded steel framework. These larger buses soon became more popular than the smaller Gar Wood design. When production was suspended in 1943 because of the war, Aerocoach had built approximately 250 coaches of the smaller Gar Wood type and about 300 of the newer and larger type.

Aerocoach resumed production of the larger type buses in 1944 but discontinued the smaller type. Several went to major bus operators including Trailways members. An additional 2,350 buses were built before production ceased in 1952. However, this type of construction eventually became popular with several bus builders.

Integral Construction in Europe

Integral construction first reached Europe in the late 1930s. Carrosseries Besset S.A. of Annonay in the south of France was a well-known builder of bus bodies. In 1937, Gar Wood gave the company rights to build their tubular steel integral coach under license. Several coaches were then constructed under the Isobloc name. Most were built with a Matford V-8 gasoline engine although a George Irat diesel engine was briefly available. Production ceased because of the war, but the company did resume production after the end of hostilities.

It was not until the 1950s that tubular steel integral construction began to spread to other European manufacturers. Early examples were primarily scattered, smaller companies with limited production. Nordwestdeutsche Fahrzeugbau GmbH in Wilhelmshaven, Germany built a few forward control buses with integral construction from 1952 to 1955 powered by Ford gas and diesel engines. Metallwarenfabrik Theodor Klatte GmbH in Bremen, a newcomer to bus building, offered a forward control bus in 1952 and later developed a design with a rear, air-cooled Deutz diesel engine before discontinuing production in 1954. Krauss-Maffei A.G. in Munich, undoubtedly a larger company than the previous two, was known for its Maffei road tractors but got into bus building (for about two decades) starting in 1946. They introduced their chassisless bus in 1954. All of this was fairly revolutionary in Europe because body-on-chassis front



The Kässbohrer company in Ulm, Germany was one of the pioneers in web frame construction in Europe. This famous 1951 photo shows six employees holding the upper web frame structure on the new Setra to show its light weight. DAIMLERCHRYSLER.

The first three S-8 coaches built from that web frame were lined up for this photo in August of 1951. In addition to being the first significant production integral coaches in Europe, they were also the start of the Setra product line. DAIMLERCHRYSLER.

engine buses were still being built as late as 1950.

The Kässbohrer Company (then Karl Kässbohrer Fahrzeugwerke GmbH) in Ulm, Germany deserves credit for being one of the first European builders to recognize the value of integral tubular steel construction and adopting it for regular production. By 1951, Kässbohrer had already developed the tubular steel frame for a new model. A famous photograph shows six employees holding the frame to demonstrate how light it was. Kässbohrer's new model built from the frame was introduced to the public in March of 1952. This was the first substantial production model with integral construction in Europe. The company called the concept "selbsttragend" or self-supporting from which the Setra name was derived.

In later years the company would improve on the concept in several ways. I was personally impressed by a hydraulic jig developed by Kässbohrer engineers which allowed the frame structure for different model variations to be assembled in the same jig.

To some extent, the tubular steel integral concept gravitated back to North America from Europe. Kässbohrer built the first Eagle buses at their Ulm plant in the late 1950s using their primary Setra concept and procedures. After being built in Belgium for a while, Eagle production moved to Brownsville, Texas where the tubular steel frame showed the Setra influence. While none of the integral bus builders I have visited ever had a true powered assembly line, Eagle did use little rail carts to move their partially-completed frame structures from station to station.

Prevost Car uses web frame construction for their coaches. Like most manufacturers, they use a station assembly system but have their stations located on both sides of this wide aisle at their modern production plant in Ste. Claire, Quebec. A transborder acts as a transfer table to move coaches between the various stations. NBT.

Likewise, Neoplan in Stuttgart, Germany also embraced the tubular steel frame concept. Some of this technology was transported to Lamar, Colorado for the new licensee in the United States. The similarities between the Stuttgart and Lamar plants are interesting. Both used the station concept but actually ran production in lines with buses nose to tail. As I recall, both also had some observation walkways above the production floor.

Prevost Car in Ste-Claire, Quebec deserves credit for taking the tubular steel frame concept and bringing it up to state-of-the art. Among other things, Prevost now uses stainless steel to give their coaches a longer life with less problems from corrosion. Prevost also uses the station concept for production with stations located on either side of their plant. A moving platform, similar to a railroad transfer table, moves the partially-completed coaches from station to station.

Sleds

At least a brief mention should be made of sleds. Particularly in Europe, it is not unusual for one company to build an integral coach but get the drive train and axles

In some cases, such as Eagle and Neoplan USA, web frame construction returned to the United States from Europe. Taken in the late 1950s, this photo shows one of the original Golden Eagles built at Ulm being tested on the South German A8 Autobahn between Salzburg and Munich prior to being shipped to Continental Trailways in the United States. Note the Kässbohrer "K" on the nose under the "mustache." The Kässbohrer company photographer had great luck this day because a Setra S-8 just happened to be passing over the bridge as he captured the Eagle in his camera. DAIMLER-CHRYSLER.

Taken in the Van Hool plant in Belgium, this photo shows the start of work on the lower platform for a C2045 coach which will be exported to the United States. Of all the manufacturers, Van Hool probably comes the closest today to the original General Motors construction procedure. However, Van Hool has improved the process by using stainless steel and tubular steel. NBT.

from a major manufacturer. Both Scania and DAF in Europe offer components for this purpose. They deliver a front section with a front axle and steering wheel and a rear section with a rear axle(s) and engine. Typically, these components are temporarily bolted together and arrive at the bus builder looking like a short chassis although any structural members holding the components together are temporary. Once the integral frame structure for the coach is built, these components are then slid underneath and connected, which is why some people call them sleds.

Chassis vs. Integral Construction

The two major differences between chassis construction and integral construction are price and longevity. However, depending on several factors, there may be other differences including the quality of the suspension system or even the size of underfloor compartments. What with ongoing improvements in body-on-chassis construction and so many differences in integral construction, it is difficult to be very specific.

In general, a body-on-chassis bus is more practical and economical in situations where it is not being driven many miles and will wear out from age before it will wear out from use. An excellent example is school bus operations where a body-on-chassis bus is very typical. In comparison, an integral coach is more practical and economical in situations where the bus must be driven a substantial number of miles and where residual value is important.

A study we did several years ago showed us that the best body-on-chassis buses could be economically driven up to 500,000 miles, but many fell short of that goal. In comparison, integral coaches typically can be economically driven from one to three million miles depending on model, manufacturer, and quality of maintenance. Other major differences between the two types of vehicles include the fact that the integral coach is typically safer in the event of an accident and is more likely to have better systems including suspension.

Differences in Construction

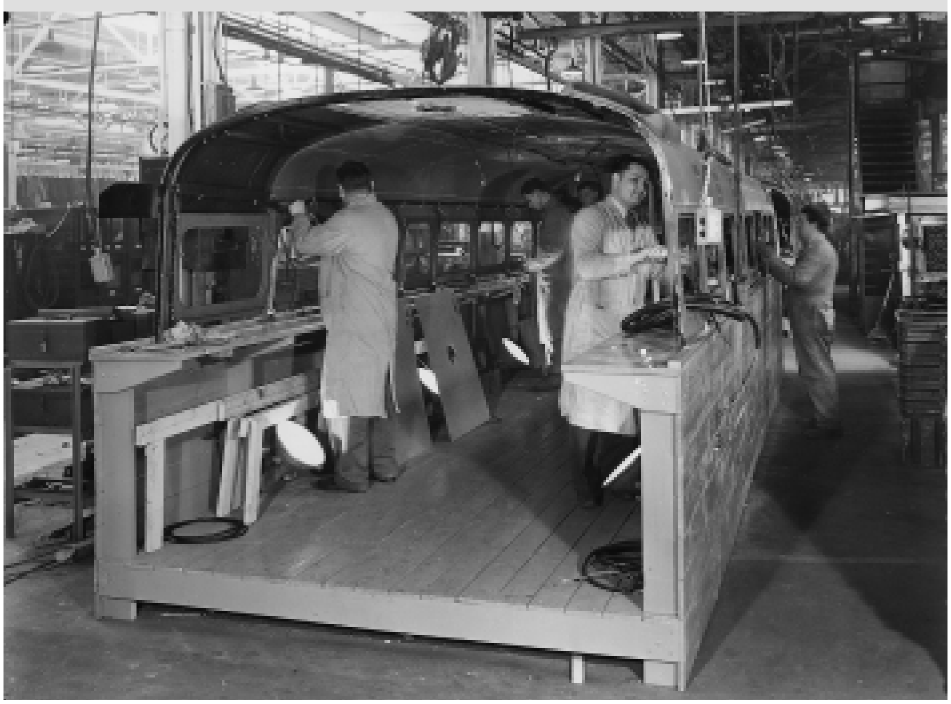
It would be a fairly safe bet that no two manufacturers build their integral coaches exactly alike. While there have been two basic types of integral construction, they are no longer totally separate and have been combined and modified over the years. On some coaches the floor, side skins and roof can be structural members, and on others the integrity of the platform may be critical. If you are a commercial coach operator, this may be of little importance since you do not plan to modify the coach structure and are only concerned with longevity and resale value.

However, those of you who plan to make modifications to the coach structure for a conversion (to raise the roof and add a slide-out) are strongly cautioned to make sure you understand how the engineers designed the coach before you start taking a torch or hack saw to any structural member. Here are a few things we have heard over the years.

• If you alter a frame and do not transfer stress correctly, things can break – typically while you are driving down the road.

• Be particularly careful when dealing with stainless steel. Stainless reacts differ-

One of the major advantages of platform construction is that it is easier to do preliminary work on both the platform and on the upper body structure while they are separate units. In this photo the GM production staff shows how easy it is to install wiring in an intercity coach body shell prior to its joining with the platform section. The photo was taken in 1948. My guess is that the body shell is a PD2903, but some reader may know more. MOTOR BUS SOCIETY.



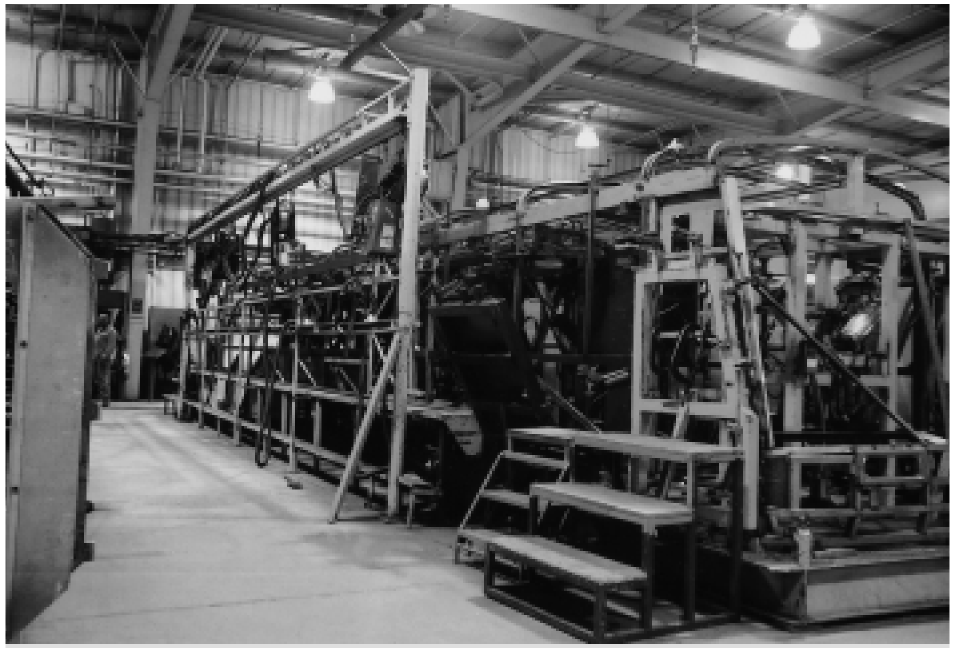
ently than mild steel. It is not as strong as mild steel and can be more brittle. It is generally not a good idea to weld two different types of steel together. However, stainless sure helps in reducing the rust problem.

• On most integral GM buses, the skin was used as a structural member. Some years ago an organization had the rivets on a PD4905 ground flat for aesthetic reasons. The coach had to be carried out on a flatbed in order to be put back together. Likewise, on many of the traditional MCI models, the skin or sidewall panels were also a structural member.

• On newer coaches, the bonded side glass actually adds to the strength of the coach structure

• Extreme caution should be used when cutting into platform-type integral coaches. In many cases the floor, roof, and side skin can be a structural member. On some platform-type construction, the platform and tops can be fragile until they are joined together but then seem to exhibit tremendous longevity. Possibly part of their strength is in their flexibility since several people insist that web frame construction is more rigid than platform construction.

• Eagles were always a favorite of the conversion crowd because the web frame carried most of the stress. The roof on an Eagle is just like a hat – it just keeps the rain out.



Taken at the MCI facility in Winnipeg, this shows a coach frame structure coming together with the help of a fixture which helps maintain close tolerances. The front of the coach is on the far right. MCI uses stainless steel for longevity and tubular steel for strength. NBT.

• The expensive extruded aluminum baggage doors on the Eagle helped prevent body torque. In comparison, the traditional MCI, Prevost and Setra have more strength in their frame and less in their baggage doors.

• Many Neoplan coaches were built with a heavy tubular spine that runs above the luggage bay. This has the advantage of putting less stress on the sidewalls but often required heavier luggage bay doors to reduce torquing.

What all of this goes to prove is that there are as many variations to integral design as there are coach manufacturers. However, integral design continues to be a major factor in coach longevity, resale value, safety and other factors in the bus industry.

We would like to offer our thanks to numerous individuals who helped us in research and finding photos for this article. Included are Richard H. Phillippi of the Motor Bus Society, bus historian Don Coffin, Hugo de Roo from Van Hool, Udo Surig from DaimlerChrysler and Dave Millhouser from Setra and ABC. ❑

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