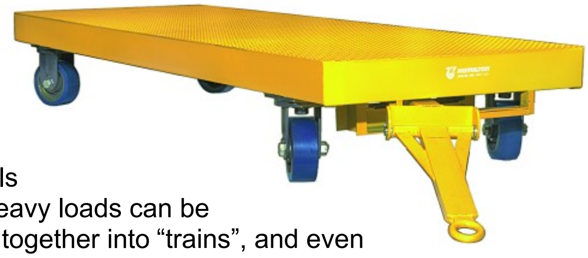
Design Principles of In-Plant Trailers



By Dave Lippert & John Yater

In-plant trailers represent a “tried and true” method of moving materials through plants safely and efficiently. Since these are power towed, heavy loads can be moved with little ergonomic risk. Additionally, trailers can be coupled together into “trains”, and even larger material volumes can be moved economically with little manpower.

These days one often hears terminology such as “manufacturing cells”, “kanban”, “material presentation”, and “JIT” (Just In time). Efficient, competitive production depends on minimal waste, and on having the right materials at the right place in the right quantities at the right time. Everyone is working hard to reduce costs. Emphasis on ergonomics argues for judicious handling of parts, particularly heavy ones. Frequently, the best solution to material handling challenges includes the use of industrial trailers.

While trailers look alike at first glance, there are some significant differences that greatly affect performance and cost. The wise purchaser will study the differences and select the system that makes the best sense for the specific application. Obviously, there is no universal right answer.

Design Load Factors

When specifying a trailer, the intended load is the primary consideration. If all loads are about the same, the selection process is easier. If not, then one must work with worst-case scenarios or “typical” loads.

The size of the load surface, or deck size, is perhaps the most obvious choice to be made. The load or loads to be carried will factor heavily in the determination of a deck size. Additionally, deck size has a great impact on required aisle width and practical length of trains that can be safely pulled. Anyone involved in the layout of a warehouse understands the importance of minimal aisle width and its impact on the overall cost of storage. Clearly there are tradeoffs in this process. Wider aisles permit wider trailers and longer trains with the accompanying reduction in handling costs, but they cost dearly in terms of space required (or rack storage space lost to wider aisles).

The total weight of a load unit is important, but don’t overlook the center of gravity. While most loads are presumed to be uniform (load distributed evenly within the container), some may have a significant portion of weight concentrated at one point. Load size and units to be carried simultaneously determine optimum deck size. If varying loads will be transported, consider the potential combinations when determining deck size. Also, will loads be stacked? Stacked loads and very tall loads require caution due to a much higher center of gravity. While turning presents a serious risk for taller loads, the presence of ramps or uneven floor conditions may completely rule out stacking loads.

Design engineers may project likely load combinations and limitations in “ideal” conditions, but they should try to anticipate how trailer systems might actually be used by the operators. “Creative” operators have been known to stack extra loads over the ends of trailers, and actually had them supported by the couplers! Welded end racks or more appropriately sized trailers may reduce the likelihood of such misuse.

The capacity rating of a trailer is based on the running gear and the frame or structure. The rating considers the maximum load as a uniform load spread over the entire deck area. Besides the maximum weight of the anticipated loads, consider the possibility of shock loading due to improper loading and unloading techniques and obstacles on the floor. Large floor imperfections or debris will create significant shock loading to trailers, as will dropping a load from a lift truck or overhead hoist.

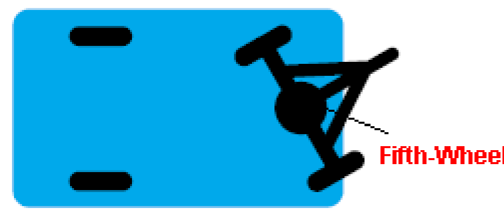
Basic Designs

The deck is important, but what exists under the deck is the most important aspect of a trailer. The “running gear”, or wheel system including the steering portion, is crucial to performance. Stability, tracking, and pulling force are some of the factors affected by running gear.

There are at least five basic categories of steering systems: caster steer, fifth wheel steer, four wheel steer, auto steer – two wheel, and auto steer – four wheel. All of them share the inherent capability requisite for trailers – they “track” in a consistent pathway (each trailer tracks in the preceding one’s footprint). As one might guess, the differences are in both cost and performance.

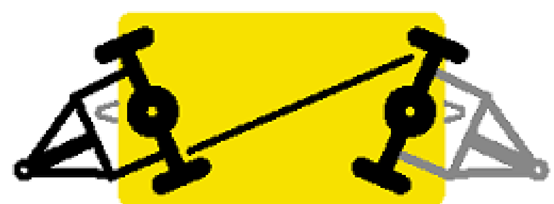
Caster Steer

Caster Steer Trailers have two swivel casters at one end and two rigid casters near the other end. Placement of the rigid casters is critical to the trailing characteristic. This type is the most economical due to its inherent simplicity.



Fifth-Wheel Steer

Fifth-Wheel Steer Trailers, like a child’s wagon, feature a single pivot point for the front axle/wheel assembly and fixed rear wheels. Again, placement of the rear wheels is critical. The steering axle is “pinned” along the centerline of the trailer, and typically contacts the trailer body through a fifth wheel plate assembly. The trailer width and load capacity determine the appropriate size of the plate assembly. Typically there are “stops” (limit the degrees of available turning) to prevent oversteering the trailer.

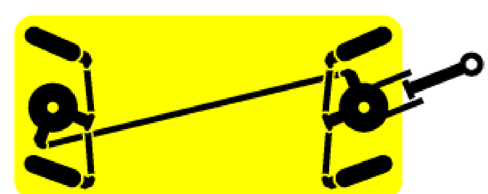


Four Wheel Steer

Four Wheel Steer Trailers have no fixed axles. Both axles pivot for steering, and they are connected to each other by a steering rod. This arrangement enables a tighter turning radius and more accurate tracking than two wheel steer models. Cost is higher, and there is a potential stability problem depending on the width of the trailer and load being carried. One quality feature to look for is proper coupler structure. Optimal tracking is achieved when the rear coupler is tied to the pivoting axle and not the rear end of the frame.

Auto-Steer (2 wheel steer)

Auto-Steer Trailers (Two Wheel Steer) have a steering system that mimics an automobile. The turning wheels pivot similar to automobile wheels, maintaining much more stability than the fifth wheel steering trailer. As before, the rear wheels do not steer but must be located precisely for accurate tracking. Due primarily to the complexity of the steering mechanism, these trailers are rather expensive, typically about double the cost of a caster steer trailer.



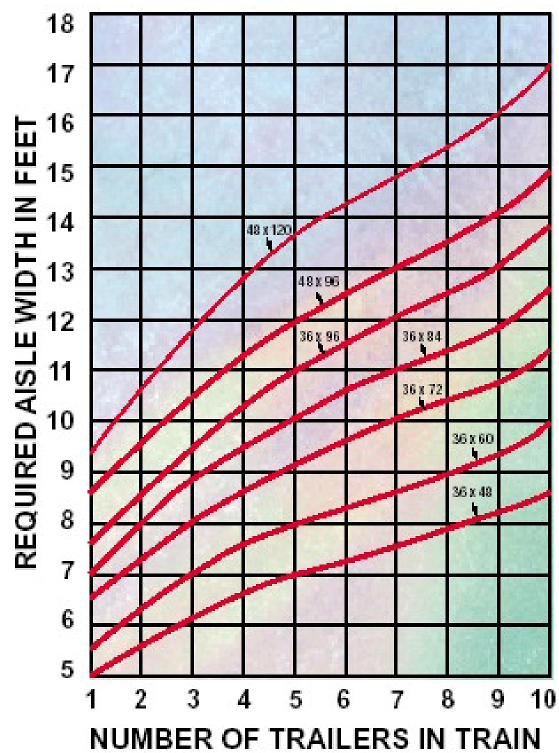
Auto-Steer (4 wheel steer)

Auto-Steer Trailers (Four Wheel Steer) have all four wheels steering as described above, and the front and rear steering assemblies are connected by a steering rod to coordinate turns. Fairly tight, accurate turns result while maintaining solid lateral stability, albeit at a price. Trailers with this steering type can cost 2-1/2 times a caster steer trailer of the same deck size.

Trailability

Good, accurate tracking is crucial to an effective trailer system. The benefits are huge, ranging from minimal aisle space (cost savings) to fewer collisions during turns (more cost savings). Generally the accuracy in tracking coincides with the steering type and complexity. Caster steer trailers track the “loosest”, while four wheel auto steer trailers are the best. The progression follows the description order listed above.

Depending on how a system of trailers is used, the individual maneuverability of each trailer may be important. Interestingly, the ranking order of maneuverability is opposite to that of tracking. That is, the more accurately a trailer tracks when being towed, the less maneuverable it is when handled individually. Caster steer trailers are by far the easiest to steer manually, while four wheel auto steer are the most difficult. System engineers may elect to compromise somewhat on trailability to achieve a highly maneuverable trailer. This approach might be useful when a train will be towed to a general area and individual trailers will be disconnected and moved into specific positions for loading/unloading. When uncoupling and manual moving is expected to be a rare event, the auto steer design may be most efficient.



The number of trailers that can be safely towed is another significant factor. There is a mathematical interdependency between trailer length, width, aisle width requirements, and number of trailers. Hamilton Caster has developed a nomograph to assist in using these factors for good planning (see graph). High productivity normally demands maximum loads be towed in longer trains. On the other hand, longer trains require wider intersecting aisles, and wider aisles reduce available storage space in a warehouse. For this reason there is seldom a "right" or "wrong" answer, but there are certainly better and worse approaches. For general safety and practical reasons, Hamilton normally recommends a maximum of five trailers in a given train.

The trailability factor is dependent on the length of the trailer from connecting point to connecting point. The points where the couplers connect to adjacent trailers determine the length. The type of coupler used is an important factor. A "sloppy" coupler, such as an automatic coupler, permits lots of movement between trailers. The relatively wide "bail" on an automatic coupler affords significant lateral movement of the adjoining trailer jaw. This can degrade the trailability and cost in extra aisle width or reduced train length. Of course, automatic couplers bring some benefits to the material handling equation and may be worth having despite their negative impact on trailability.

One other facet of trailer design impacts trailability and trailer deck size – corner design. The distance from the front coupler to the rear coupler is a key dimension. The actual deck length must lie between those two points. One way to maximize the deck length while conforming to the width requirement is to round the outside corners. During tighter turns, trailers may actually "pinch" at the corners. Rounded corners permit tighter turns or reduce the likelihood of contact between trailers. An additional advantage of the rounded corners is the inherent safety (for nearby personnel) of rounded corners vs. sharp 90-degree corners.

Stability

Safety is paramount in every trailer application. Cutting corners in this area can be costly in both human and economic terms. Design impacts trailer stability, and clear safety instructions for those who use the trailers are also necessary.

Running gear placement or orientation greatly determines stability. Any trailer with fixed running gear poses a stability risk during loading. For proper trailering, the running gear must be set well forward of the rear edge of the deck. It is very possible to load such a trailer behind this running gear and create a tipping situation. Much like a waiter or waitress loading or unloading drinks from a carrying tray, simple physics explains that loading a trailer first at the unsupported end causes problems. Likewise, unloading the unsupported end last can have the same deleterious result. All personnel involved in loading trailers must know the proper sequence, and understand the consequences of improper loading.

Trains of trailers will be pulled around corners as they weave through plants. Loads stacked high raise the center of gravity of a trailer, creating a tipping tendency during turns. Wheels with some "give", such as pneumatics, are particularly susceptible to this. The pressure of business sometimes motivates material handlers to stack loads too high and/or travel too fast. The combination of the two is particularly hazardous. Training and supervision will prevent either of these from happening. The size, configuration, and weight of loads determine appropriate stacking practices. In-plant speed limits and even towing equipment governors may be appropriate to address excessive velocity.

Ramps pose problems for fifth wheel, auto four wheel steer trailers, and for trailers connected with automatic couplers. It is possible for the automatic couplers to twist in such a fashion as to become disconnected, posing an obvious safety risk. Connecting steering rods are vulnerable to ramps and may bind against the pavement in extreme cases. If ramps must be negotiated, consider employing only "straight on" approach and departure routes, and strict enforcement of slow speeds during travel up or down.

Finally, fifth wheel trailers, particularly those with four wheel steering, pose their own unique stability challenge. Despite the obvious fact that the wheels are at the outside edges, the axle assembly is essentially "pinned" along the centerline of the trailer. Only a fifth wheel plate assembly, varying in size depending on the size and capacity of the trailer, provides the lateral support for at least one end. In four wheel steer trailers, lateral stability comes only from the two fifth wheel plates. Users must employ extreme caution in loading (maintain low centers of gravity), traveling (slow considerably in all turns), and ramps (best to avoid these completely with this running gear arrangement).

Structural Considerations

To a casual observer, the size of side and end frame members may seem to be the most important aspect of the "strength" of a trailer. But only by checking the entire structure underneath the deck can one discover the truth.

Considering the longitudinal pull on any trailer, a center rail is an absolute necessity. There simply must be adequate structure to withstand the tremendous longitudinal pulling forces at either end of a trailer. Extraordinarily heavy loads may warrant two center rails, located at or near the centerline. The absence of a center rail is a recipe for serious structural problems down the road.

Side loads represent another serious matter. These may be imposed during loading and unloading. Forklift operators may occasionally misjudge the height of their load and the trailer deck height, and hit the trailer side rail with either their forks or the load itself. This puts incredible force on the wheel sides, or the plates on either side of the wheels. Caster steer trailers do have at least one advantage here. If this happens at the swivel end of the trailer, the swivel casters will turn to align with the side load, and probably avoid damage. But the end with the rigid casters remains at risk.

Actual movement of trailers, particularly when loaded, may also present side loads. Simply turning a corner places side forces on a loaded trailer. In some instances, corner posts designed to protect rack uprights at the ends of large warehouse aisles become "rubbing posts" for trailer trains, and extreme side forces suddenly emerge.

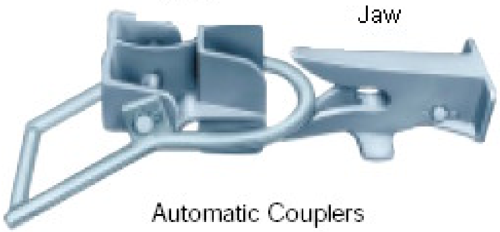
Wheel sides, or steel plates welded between cross members, are generally more resistant to these forces than rigid casters. Casters may be strengthened with gussets, and even wheel sides may have lateral reinforcing members to add strength. Prudent planning normally involves "worst case" scenarios, and the wise planner anticipates factors such as side loads and designs accordingly.

Fifth wheel plate size, particularly in four wheel steer trailers, impacts lateral stability. Smaller diameter fifth wheel plates may be adequate for a given load in static conditions, but they can be woefully inadequate for a capacity load in turning situations. Generally, a larger fifth wheel plate translates into more lateral stability.

Rigidity can be described as the trailer's resistance to twisting and flexing. Selection of the structural members and deck plays the largest roles in rigidity. Open frame trailers, where there is no deck, typically employ structural tubing in the frame for both structural and aesthetic purposes. Steel deck trailers, the most laterally rigid design, more frequently use structural channel in their frames. Wood deck trailers feature structural angle frame members, although the extremely heavy duty versions use channel frames and have the wood decks bolted on and secured with angle hold-down strips. Size and location of structural members can be key differences between competing trailer bids. Inadequately designed trailers are subject to twisting and flexing during use, and risk premature failure.

Ergonomics

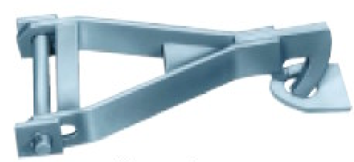
At first glance, a system of trailers pulled by a tugger appears to be a perfect ergonomic choice. After all, the only exposure to ergonomic problems seems to lie with the driver. Actually, there is much to consider: coupling and uncoupling trailers, lifting the tongues, including unguarded jaws, and moving trailers manually into position.



Automatic Couplers

By definition, trailers have the capacity to be coupled together and then uncoupled as required. The physical effort required for these activities varies by coupler design. The automatic coupler, as its name implies, allows trailers to be coupled "automatically". The loop or bail, as it is known, can actually engage the "jaw" of the adjacent trailer simply by pulling the two together. Uncoupling involves stepping on a jaw pedal and simultaneously pushing the two trailers apart. It is the pushing or pulling of a trailer that carries the risk of injury.

Manual couplers require a person to raise or lower a wishbone tongue into or out of an "eye" mounted on an adjacent trailer. Jockeying trailers into position while lowering the tongue can create an ergonomic problem. Manual couplers typically have an "over center" position for stowing the disconnected tongue in an upright position, and can be fitted with spring-loaded stops to prevent the tongue from dropping to the floor. Additionally, attaching convenient handles to tongues permits easier grasping by personnel.


Manual Couplers

When disconnected, the jaw end of a trailer can be a real hazard to shins. For this reason, optional toe/shin guards are available to minimize likelihood of injury.

The greatest ergonomic hazard present during the use of trailers comes from manually moving them. Caster steer trailers have an advantage of a handle at one end, while other trailers are unlikely to have a superstructure available for pushing leverage. Obviously, maneuvering empty trailers is much easier than fully loaded ones, and good procedures and training should encourage this practice.

Wheels

Arguably, wheels may be the most important aspect of a trailer. Wheels affect noise, pulling force required, floor and load protection, and longevity of the investment. Efforts to economize in the selection of wheels may result in extra maintenance costs as premature failures lead to unplanned downtime and additional costs. Perhaps it is unfortunate in some ways that there are so many choices to make when selecting wheels!

Load capacity and maximum speed are the primary factors to consider. Additionally, noise considerations, anticipated side loads, usage, floor and load protection, and shock loading are important. Constraints include deck height and cost.

Trailers by definition are intended to be towed. For this reason, we expect higher speeds and longer travel distances with trailers than with manual carts. Straight roller bearings are typically inadequate. They provide virtually no resistance to side forces, present in every trailer application. Also, they are generally not intended for continuous duty and higher speeds in conditions typically experienced by trailers.

Tapered roller bearings are the best choice for trailer wheels. Tapered roller bearings have a long history of capable service on trailers. They are designed for both higher speeds and the rigors of impact loads and side loads encountered when cornering. These are the best choice for severe towing conditions.

Tapered Bearing

Precision ball bearings feature the ergonomic advantage of minimal rolling resistance. Like the tapered roller bearings, they are suitable for both horizontal and vertical loads as well as higher speeds and sustained use. But for trailers that may see manual movement, these bearings will be the choice of those who must push or pull loaded trailers.

Precision Bearing

Available tread types for wheels are numerous, and offer a myriad of both advantages and limitations. Softer treads, either pneumatic or solid rubber, provide load cushioning, quieter running, and better traction. Harder treads, typically of polyurethane, protect floors and offer some noise reduction over the hardest materials. Solid materials, such as forged steel, have the maximum load capacity and are virtually indestructible.

Disadvantages of each major tread type can complicate the selection. Rubber tread wheels have reduced capacities. Polyurethane is susceptible to heat buildup during sustained use. Steel wheels are noisy, abusive to plant floors, and have a greater tendency to slide around corners (particularly when the trailer is unloaded).

Desired deck height impacts the wheel selection. Generally, larger wheels are preferable for trailer applications. Larger wheels turn fewer revolutions per unit of distance, and therefore bearings run cooler and treads last longer. Also, larger wheels are less affected by debris on the floor and other obstacles.

Floor conditions, intended speed, anticipated running time, maximum loads and acceptable noise level comprise the major considerations for wheel selection. One may expect some trade-offs, with no "perfect fit". Experienced trailer manufacturers know the right questions to ask and bring the value of others' experiences to the table.

Options

There are limitless opportunities to customize trailers for specific uses. Most of these involve the superstructure, or features above the deck. But two "below deck" options are noteworthy.

Reversible steering is available on four wheel steer trailers. It is important to note that trailers are not designed to be "backed up" or reversed while connected. This is particularly true of four wheel steer trailers, which will suffer serious damage to the steering connecting rod. Reversible steering enables the operator to disconnect the towing tongue from one end and replace it on the other end. This feature requires mounting pintle hitches on the trailer frame, and probably argues for hitches at both ends.

A parking brake is available on fifth wheel steer trailers. Typically this engages a bar to secure both wheels on one axle, and is activated through the tongue. Brakes are most effective on softer tread wheels, and designed to hold a trailer in a stopped level position, not to stop it when moving or to hold a trailer on a ramp or sloped surface.

Superstructure options are limited only by the imaginations of those designing them. Normally, load configurations drive these choices. Examples include cradles for rolls or tubes, tie down rings, wood cross rails on decks for lift truck access to loads, fork pockets for proper trailer lifting by lift trucks, stake sockets, shelves, tool cabinets, conveyor sections, ball transfer tables, and special deck materials. Customizing trailers can play a significant role in the usefulness of the trailer by improving material handling and reducing waste.

Maintenance

Industrial trailers have few routine maintenance requirements. But total neglect can be counterproductive, so a basic PM plan is well-advised.

The parts that turn require the most attention. Wheels should be checked periodically for tread condition and proper bearing operation. Most wheels with tapered roller bearings will be equipped with lubrication fittings. Precision ball bearings are normally considered “lubed for life”, depending on seals. Fifth wheel assemblies, auto-steering assemblies, and swivel casters have lubrication points. All of the above should be lubricated at least annually, depending on the usage and environmental conditions.

Wheel tread wear may reveal some problems. Softer treads, particularly rubber, may pick up considerable metal chips or other debris from the floor. These will result in reduced tread life. Any flat spots indicate a dragging wheel, and the wheel bearing is an immediate suspect. Tread separation will be manifested by obvious separation from the wheel center. Caused by heat buildup or other means of destroying the tread bond to the center, this renders a wheel unusable and requires immediate replacement. Frequently the separated tread may have shifted to one side of the wheel, and may be held on the center only by the wheel sides or caster legs.

At least annually check the swivel action of the steering assembly (swivel casters, fifth wheels, or auto steer assemblies). Any looseness indicates either excessive wear or the presence of shock loading. Trailers exhibiting looseness should be pulled from service for more thorough checking. Missing steel balls from the main bearing raceway are a sign of probable shock loading. Contact the manufacturer for instructions.

Excessive bearing raceway wear is unusual, but possible in extremely aggressive applications. Heavy loads and continual steering, coupled with nearly around-the-clock use, may lead to this condition. Hamilton recommends heat-treated swivel raceways for caster and auto steer mechanisms when facing such rigors. In some cases where assemblies were not heat treated, it may be possible to tighten the assemblies. A better long term choice, however, is replacement of the worn parts with new heat treated ones.

Excessive side forces become evident in several ways. Serious rub marks on either or both sides of the trailer indicate dragging around obstacles. Wheel treads separating from the centers or with significant cross-tread scuff marks are also signs of extreme side forces. Finally, structural damage, normally bending of the wheel sides or rigid casters, points to a serious problem. While special stiffeners can be applied to a trailer’s running gear, first check the application to be sure there is no abuse (such as rubbing posts or rack uprights during turns or improper loading techniques). Damage to wheel sides or casters requires parts be replaced with stronger or reinforced frames. Simply bending parts back close to their original shape is unacceptable.

Couplers normally require only a visual inspection. Since couplers make contact with one another as part of their design, wear can be expected. The loop, or bail, may show wear on the inside radius. The jaw assembly typically shows wear on the “dog”, or the part that engages the loop. When 1/8” of material (from the original dimension) is worn away, the part should be replaced. Perhaps the most serious sign of trouble, though, is obvious deformation of the loop which indicates some binding or other problem occurring during towing. Any part that is not symmetrical is suspect.

Finally, a general overall inspection is recommended at least annually. During this inspection, look for broken welds, loose deck, and loose or missing bolts. Be particularly cognizant of the welds around couplers and center support rails.

Conclusion

Selecting a reliable and complete material handling system can be challenging. Virtually everyone has limited space to work with and increasing demands for product. A properly designed in-plant trailer system offers speed and flexibility. When that system is built from quality components, it should provide years of dependable service.

Hamilton Caster & Mfg. Co. has been designing and building industrial trailers for many years, and stands ready to help companies with their material handling needs.

Samples of Various In-Plant Trailers