

MAXIMUM REACH ENTERPRISES

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INTRODUCTION TO HEAVY HAUL TRAILERS

Part 2 of 2

(Contains the last two types of heavy haul trailers)

PULL TYPE MODULAR TRAILERS:

The two photos shown below show a 150 Te (metric ton) vessel being moved by utilizing two hydraulic trailers. Each trailer is 3 meters wide and has 6 axle lines. The payload for this type of trailer is approximately 26 Te per axle line, so the trailers are each good for 156 Te. The weight of the trailer, tires and axles is approximately 4 Te per axle line. I want to point out here that when a trailer is called out at say a 6 axle trailer, that it actually means 6 axles lines and that there are actually 12 axles, two per axle line. This will be true for either the pull type or the SPMT's. Each axle & wheel assembly for a pull type trailer has four tires where a SPMT has two tires.



TWO, 3 METER WIDE, 6 AXLE TRAILERS HAULING A 150 Te REFINERY VESSEL

Two things that need careful attention with pull type trailers are. 1) The size of the prime mover and the amount of counterweight required for the worst slope needs to be calculated. There are several sources

available to calculate these values. More on this later. 2) The front pull type trailer will follow the prime mover in turning as the steering of the trailer comes about when the tongue moves manual linkage connected to each wheel assembly. The maximum turning angle is approximately 55 degrees. This is the maximum angle that the tires will turn relative to the centerline of the trailer. The rear trailer is steered by the use of an auxiliary engine, but can still only turn up to 55 degrees. The trailers are hard to back up so the rigging superintendent must lay out the route so that the load can be staged under the crane(s) hook the first time.

Note in the photos for this move that staging beams are located under the saddles and they stick about 1 meter past the side of the trailers. These beams are required to stage the vessel on stanchions at a laydown yard. More will be said about this topic later. Also note that bolsters are being used under each staging beam. They can add as much as 0.5 to 1.0 m to the overall height of the load. They are required for turning, unless the trailers can be driven in a straight line.



TWO, 3 METER WIDE, 6 AXLE TRAILERS HAULING A 150 Te REFINERY VESSEL

The photo below shows two pull type trailers moving a 600 Te vertical vessel. The trailers are each 3 meters wide and are separated about 2 meters from each other to provide better stability for the high combined center of gravity of the vessel and trailers. This load was rolled off from an ocean going heavy lift ship and moved up a 6 % ramp in order to reach the construction site. The payload capacity of these trailers was 16 axle lines x 2 trailers x 26 Te per axle line = 832 Te.



TWO, 3 METER WIDE, 16 AXLE TRAILERS HAULING A 600 Te REFINERY VESSEL

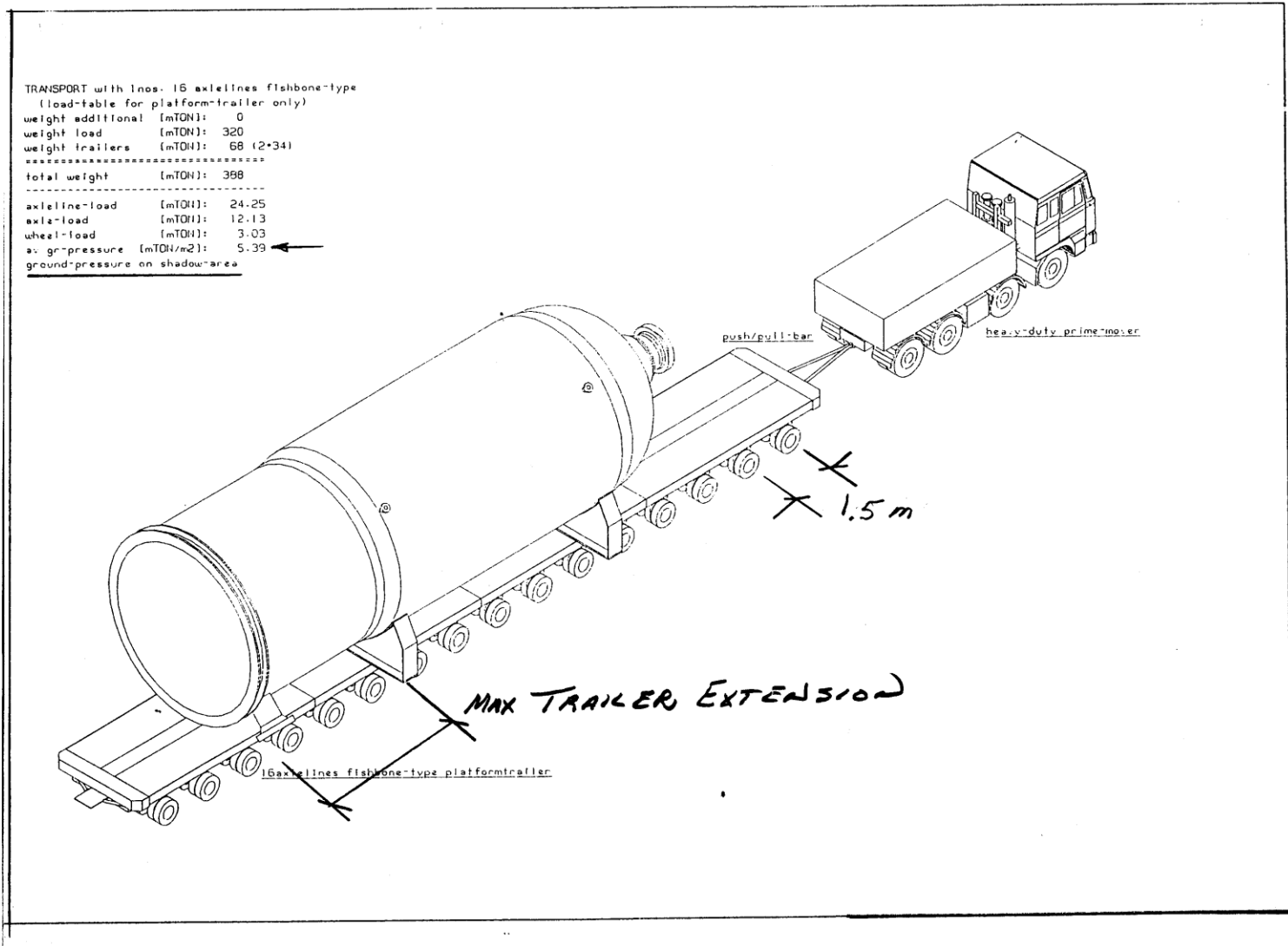
Tipping, Structural and Ground Bearing (Applicable for pull type trailers and SPMT's)

Moving heavy loads on any type of heavy haul trailer requires careful planning from ground bearing, tipping stability and structural stability to make sure that the road & trailer are not over stressed or that the load is not damaged by overstressing or over turning. Calculations should be made for each movement to insure that the load can be safely transported. The following example of a pull type trailer will be used to show how these calculations are made. It is applicable to SPMT's as well.

Shown below is a trailer configuration proposed by a contractor. There are several things of note in this drawing. First, it shows the vertical vessel being transported on one pull type trailer, single wide x 16 axles with a total load of 320 Te + 68 Te of trailer weight = 388 Te. This results in an axle line loading = 24.25 Te. Each axle line has two axles which = 12.13 Te per axle. Each axle has four tires which = 3.03 Te. per tire. The ground bearing pressure is 5.39 Te/sq meter and is based on the **shadow area** of the trailer. For example, note the 1.5 meter between axles lines that I marked on the drawing. It is approximately 0.75 m from the centerline of the end axles to the ends of the trailer platform. Therefore the length of the trailer is 15 x 1.5m + 1.5m for the two ends = 24m. The width of the trailer is 3m (not shown on this drawing) so the shadow area of the trailer is 3 x 24 = 72 sq. m. The ground bearing pressure is therefore 388 Te/72 = 5.39 Te/sq. m. In Europe it is common practice to extend the shadow area out and down from around 0.5 m to 1.0 m (at a 45 degree angle) and use this as the adjusted shadow area. If we use a 0.5 m extension, then the shadow area becomes 4 m x 25 m = 100 sq. m and the GBP = 3.88 Te/sq. m. Using this adjusted shadow area could mean in our case of being able to use a dock that has a maximum capacity of say 5 Te/sq. m.

Note that the drawing is marked up showing three axle lines outside the saddles. In order to insure that the trailer frame is not overstressed in bending, most trailer manufactures limit the number of axle lines outside the

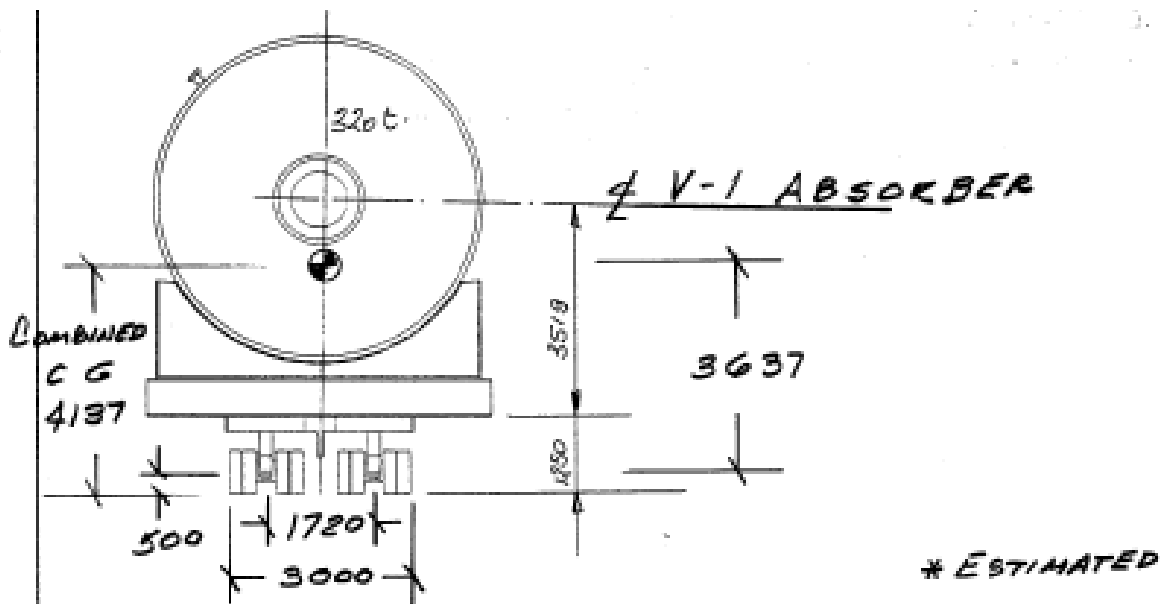
supports or saddles to three axles. Otherwise, a buildup frame would have to be fabricated and laid on the trailer platform and the load positioned on it.



16 AXLE SINGLE WIDE TRAILER

In the drawing below, I have reworked the weight figures given by the contractor based on the latest information for the move. Note that the total weight of the load, lift attachments, the saddles, weight contingency and the weight of the trailers = 447 Te. The weight I used for the trailers of 75 Te included the staging beams. I took the dimensions shown from the contractor's dimensional drawing. As you can see, I try to always be as conservative as possible.

What is not shown on the above drawing is the maximum capacity per axle line for the trailer which is 32 Te. Or 16 Te per axle.



TOTAL LOAD

VESSEL	320 Tc
LIFT ATTACHMENTS	8*
SADDLES	12*
WT CONTINGENCY 10%	32*
TRAILERS	75
TOTAL	447 Tc

KEG
21 FEB 95

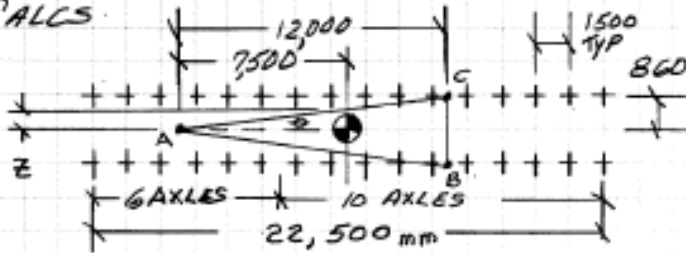
With any pull type or SPMT haul, the contractor must show on his drawing the way the trailer(s) are plumbed, ie, are they in a three point hydraulic or a four point hydraulic suspension mode. Bear in mind that there are several ways to plumb a trailer in a three point hydraulic suspension but the one chosen is because it usually provides the best tipping stability, ie, the greatest horizontal distance between the CG and legs of the stability triangle. Note in the calculations below that this trailer is in a three point hydraulic suspension mode with twelve axles in the left group at point A and 10 axles in each of the two groups on the right at points B & C. Z is the horizontal distance from the CG to the edges of the stability triangle. First, the maximum CG shift is calculated that will overstress the trailer. The limit of overloading is usually in the tires as they are usually the weakest link. The CG shift usually occurs when the trailer is driven on one side of the road that has a crown or on a curve with a super elevation.

I need to point out here that whenever possible, the CG of the load should be positioned on the CENTERLINES of the trailer configuration. This makes it easy to determine how much load is being carried by each hydraulic group or point. If the CG of the load is not on the centerlines, then a more complicated method has to be employed to determine the load to each group.

V-1
 ABSORBEE

STABILITY CALCS.

REF
 MAMMOET
 DWG
 5552-12



PLAN VIEW
 16 AXLE TRAILER
 IN A 3 POINT SUSPENSION

$\theta = 4.1^\circ$
 $Z = 538$

CALCULATE THE CG SHIFT THAT WILL OVER
 LOAD THE TRAILER

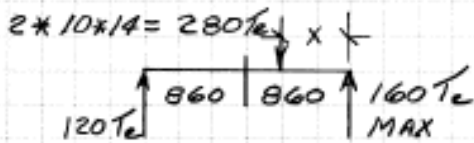
TOTAL LOAD TO THE AXLES = 447 Tc

MAX CAPACITY / AXLE LINE = 32 Tc

✓ PAYLOAD / AXLE LINE = 27.3 Tc

✓ CAPACITY / 10 AXLE GROUP = $16 \times 10 = 160 Tc$

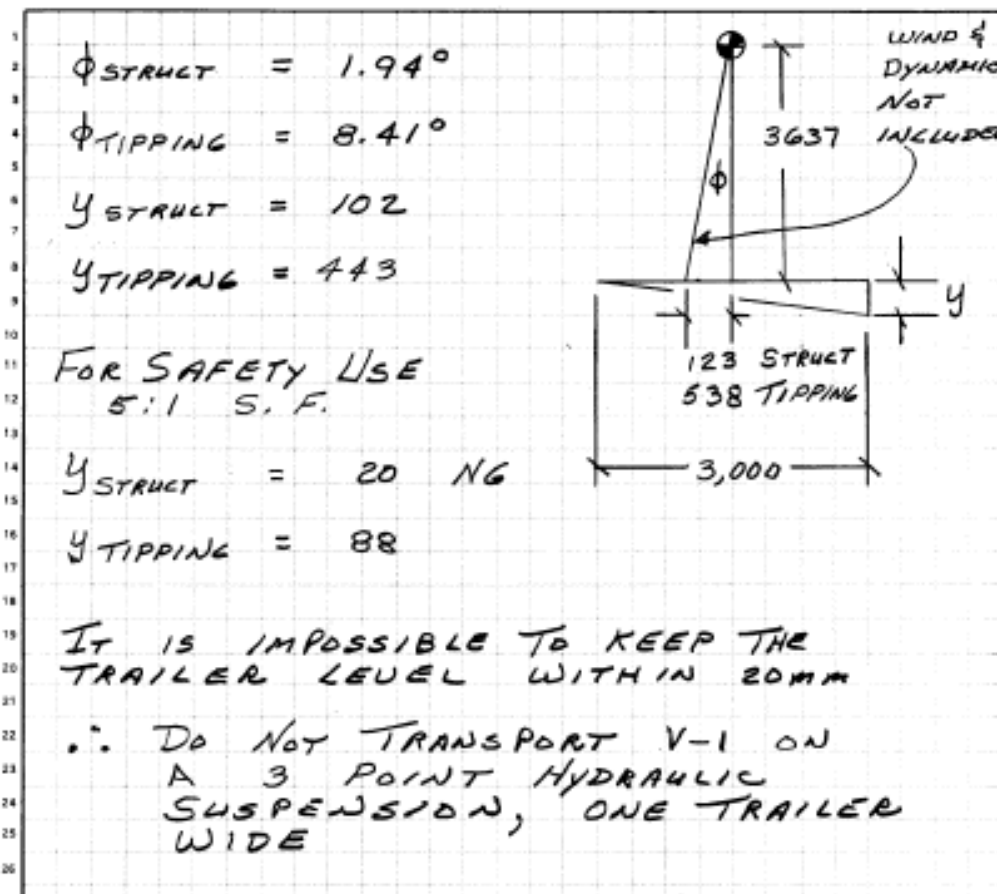
ACTUAL LOAD / AXLE = $447 / 32 = 14 Tc$



$X = 120 \times 1720 / 280 = 737 \text{ mm}$

MAX CG SHIFT = $860 - 737 = 123 \text{ mm}$

In the calculations below, the vertical distance Y is calculated, which is the maximum the trailer platform can be out of level before it goes into a tipping mode or becomes overstress structurally. Note that the worst case for Y is for structural stability and is 102 mm. Using a 5:1 factor of safety, this becomes 20 mm. As it is pretty hard to keep a trailer platform level within 20 mm, I recommended that this load not be hauled in a three point suspension.



I want to explain the purpose of the sheet below by pointing out that putting a trailer in a four point suspension is very similar to placing a load on a table top that has one leg shorter than the other three. As the table is rocked over the two diagonal legs that are the same length, there are times when the total weight of the load and table are on these two legs with zero load on the short leg and the other long leg. At other times, a small percentage of the load is carried by the short leg with most of the load divided between the two diagonal legs whose lengths are the same. When the table rocks the other way, then a small percentage of the load goes to the other long leg. But the two diagonal legs are always carrying the biggest percentage of the load and at times each carrying 50% of the load.

From testing, you can see why I recommended that this load not be hauled on a single wide trailer in a four point hydraulic suspension system. I recommended using double wide trailers. Another reason was because of the six axles extending beyond the rear saddle.

4 POINT

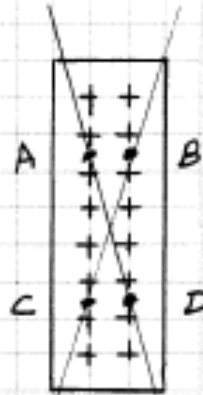
TESTS HAVE SHOWN THAT WHEN A TRAILER IS IN A 4 POINT HYD. SUSPENSION MADE THAT THE MAX LOADINGS ARE TYPICALLY:

$$A = 40 \Rightarrow 50$$

$$B = 0$$

$$C = 20 \Rightarrow 0$$

$$D = 40 \Rightarrow 50$$



4 POINT SUSPENSION SYSTEMS ARE MORE STABLE THAN A 3 POINT DUE TO THE RECTANGULAR LOAD KERN.

$$\text{MAXIMUM CAPACITY OF 8 AXLES} = 8 \times 16 = 128 \text{ Te}$$

$$50\% \times 447 \text{ Te} = 223.5 \text{ Te} > 128 \text{ Te}$$

∴ DO NOT TRANSPORT ON ONE TRAILER WIDE IN A 4 POINT!

USE A DOUBLE WIDE TRAILER CONF.

REF DWG 5552-15

BENDING IN TRAILER PLATFORM

MANUFACTURERS OF RUBBER TIED TRAILERS RECOMM. THAT A MAX. OF 3 AXLE LINES EXTEND OUTSIDE THE SADDLES.

FORM E50 (Rev. 8-91)

The drawing below shows that the vessel was actually transported on a double wide 12 axle line trailer. Note that having 24 axle lines under the trailer reduced the GBP to 5.17 Te/sq. m.

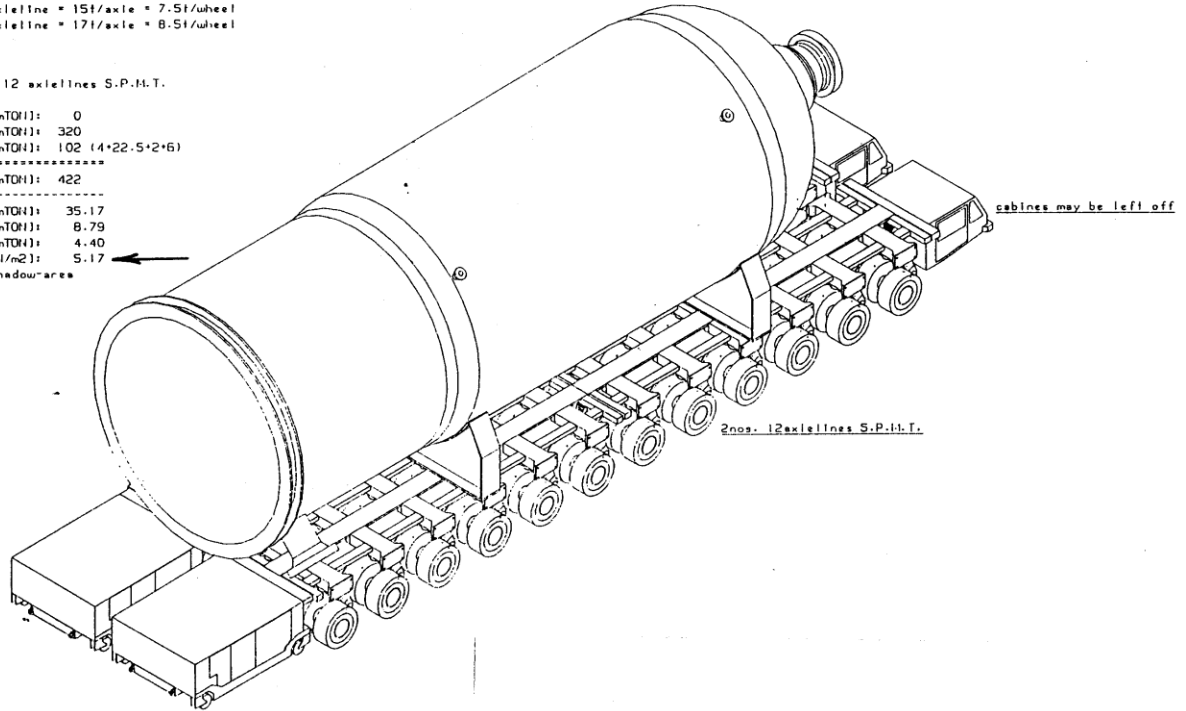
S.P.M.T. stands for Self Propelled Modular Trailer
 Trailer height is 1500 +/- 300mm. (minimum 1200mm..maximum 1800mm.)
 Trailer width 2430mm. & Axle-spacing 1400mm.

mass of 4 axleline-unit 15500 kg.
 mass of 6 axleline-unit 22500 kg.
 Average Nett mass ca. 4ton/axleline
 Nett capacity 30t/axleline = 15t/axle = 7.5t/wheel
 Gross capacity 34t/axleline = 17t/axle = 8.5t/wheel

TRANSPORT with 2 nos. 12 axlelines S.P.M.T.

weight additional [mTON]:	0
weight load [mTON]:	320
weight trailers [mTON]:	102 (4*22.5*2*6)
total weight [mTON]:	422

axleline-load [mTON]:	35.17
axle-load [mTON]:	8.79
wheel-load [mTON]:	4.40
av. grn-pressure [mTON/m ²]:	5.17
ground-pressure on shadow-area	



12 AXLE DOUBLE WIDE TRAILER

SELF PROPELLED MODULAR TRAILERS:

The Self Propelled Modular Trailers are very seldom street legal because of their high load capacity, are not usually allowed by the Department Of Transportation (DOT) on USA highways, and travel between 3 & 5 mph.

The photo below shows split trailers where each trailer is 6 axle double wide. They are moving a horizontal storage vessel usually referred to as a bullet. Note that with split trailers, bolsters must be used so that the trailers can turn under the bullet. The exception is if the split trailers only go in a straight line. Go to slide show number 3 on my website (www.maximumreach.com) to see the full move of the five 390 Te bullets and where the bolsters were removed in order to go straight under twin pipe racks. Each trailer is steered by an operator with a computer control box hanging from his chest. The slide show shows that both trailers are turned 90 degrees to the centerline of the bullet at the end of the move in order to move the bullet over the foundation.

The travel speed is so slow that the two operators can coordinate the two trailers by synchronizing the travel pressure from the power packs. The front operator will be the lead operator and the other operator will match his movements and speed.



TWO 6 AXLE DOUBLE WIDE SELF PROPELLED MODULAR TRAILERS

The photo below shows a 28 axle double wide SPMT trailer moving a 1,460 Te reactor. This is the longest trailer that I have seen moving a single vessel. The length made it pretty hard to make the turn on some corners. One operator controlled this trailer and he could make the trailer steer in the following modes ie, crab anywhere from 1 to 90 degrees to the centerline of the trailer, or turn around the center point of the trailer ((carousel mode).

The reactor on the trailer is blocked so that there are not more than three axles extending beyond a saddle or support. Note that the basering has a 75 mm plate bolted to it that is square on the bottom and is resting on some dunnage for support. This plate was also used to tail up the reactor. Also note that there are four saddles under the load. These are not required for bending in the reactor as it has a 12" wall thickness, but they are for spreading out the load first to the ships bulkheads during ocean shipment and then to the SPMT platform trailer during land shipment. This requires a lot of communication between the fabricator, the ocean shipper and the heavy haul contractor to make sure the saddles are placed where they are acceptable to all parties. Of course, the design of the saddles was made by Fluor and included in the specifications for the fabrication of the reactor. This reactor was made by the Japanese Steel Works (JSW).

In 1995, the cost of this trailer was \$50,000 per axle line or \$100,000 per axle line for a double wide. For 28 axle lines, the total cost of this trailer would have been \$2,800,000



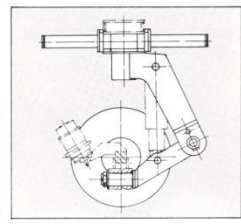
28 AXLE, DOUBLE WIDE SPMT TRAILER

Steering Self Propelled Modular Trailers:

In the photo below, you can see that each wheel assembly is made up of an axle with two tires and it swivels on a plate at the top for turning. Two weldments that are pinned together connect the axle to the swivel plate at the top. They form sort of a knee joint. A vertical hydraulic cylinder between them provides the power to move the platform up or down, usually about +/- 250 mm. Normally during a move, the knee joints are pointed forward in the direction of travel. One operator is able to steer multi wheel assemblies because there is a potentiometer located in the computer in the operator's control box and a potentiometer is located in the swivel plate at the top of each wheel assembly. When the operator moves the joy stick to say make a carousel turn, the computer sends a signal to each of the potentiometers in the wheel assemblies and tells each one of them how many degrees to turn and which way to turn, ie, the end axles would turn the most and in opposite directions to each other. It is interesting to watch the wheel assemblies turn in say the carousel mode, as they do not all turn at once. It is the law of the path of least resistance and that is how they turn, ie, some not turning until the others have already turned.

Something that the operator has to take in to account is the position of the tires under the centerline of the swivel plate at the top of each wheel assembly. During the normal move, the trailer platform height is such that the tires are located pretty much under the centerline of the swivel plate. If the trailer platform is raised to full height by extending the cylinder, then the lower part of the knee joint is rotated toward the front of the trailer with the result that the tires end up in front of the centerline of the swivel plate. If the trailer platform is lower to its lowest level by retracting the cylinder, then the lower part of the knee joint is rotated back toward the rear of the trailer platform with the result that the tires end up in back of the centerline of the swivel plate.

What this means is that the operator has to take into account this forward/backward shift when setting a load down into place on the centerlines of the foundation, ie, if he stopped the trailer where the load is directly over the centerlines of the foundation and lowers the trailer from a normal height to a lower level, the platform will shift backwards a few millimeters. He would have to move the trailer slightly forward before setting the load.



Calculating Tractive Effort:

Just as you have to figure the size of the prime mover and the weight of the counterweight for pull type trailers, the number of drive motors has to be determined for SPMT's to provide the proper tractive effort. On SPMT's, there are not drive motors on every axle. For example, a standard six axle trailer has four drive motors located on the corner axles so that if the trailer is moving sideways for example, the drive power will be symmetrical about the centerline. Most manufacturers provide trailers with more drive motors than normal, ie, Scheuerle makes a super six axle trailer that has six drive motors. I should point out here that the standard size trailers used to make up large configurations are the four axle single wide trailer and the six axle single wide trailer. These are then bolted end to end or side by side to make up the configuration required.

As an example of how to calculate the number of drive motors required for a given load, see the calculation sheet below that was provide by a transportation contractor where a 1,417 Te crusher was being moved up a 6 % grade. Note that the contractor used 9 % total resistance x 1,417 Te = 127.53 Te of Tractive effort required. He then divided the 127.53 by 158.4 to get the percent of utilization of 80.5 %

Client	SKM MINMETAL	Job No	C8224	Ref No	Eng2/004	Page	1	of	1
Project	ESCONDIDA WEST 9 RELOCATION PROJECT	Issue	B1	By	DM	Date	08/03/2007	Checked by	RJM
Subject	CRUSHER No. 2 - WEIGHING 1059 TONNES								
Tractive Effort Calculation when Travelling up 6% Gradient.									

Self Weight of Crusher = 1059 Te.
 Self Weight of Temp Steel = 126 Te.
 Self Weight of Transporters = 232 Te.

Total Combined Load = 1417 Te.

This transporter configuration comprises 6 No. 6 axle units to make 3 No. 12 axle SPMT transporters, together with 4 No. 4 axle units.

Each 6 axle unit has 4 drive motors, each of 5.5 Te capacity.

Each 6 modified 6 axle unit has 6 drive motors, each of 5.5 Te capacity.

Each 4 axle unit has 2 drive motors, each of 5.5 Te capacity.

Total No. of 6 axle units = 4
 No of Motors per unit = 4
 Drive Capacity per unit = 5.5 Te.

Total No. of 6 axle (modified) units = 2
 No of Motors per unit = 6
 Capacity per unit = 5.5 Te.

Total No. of 4 axle units = 4
 No of Motors per unit = 2
 Capacity per unit = 5.5

Total Drive Capacity Available = 198 Te.
 Capacity to overcome friction = 20 %
 Equiv. Drive Cap.Available = 158.4 Te.

Rolling Resistance = 3 %
 Gradient = 6 %

Total Resistance = 9 %

Tractive Effort Required = 127.53 Te.

Note: The Tractive Effort Required is expressed as Total Resistance x Total Combined Load

Utilisation of Available Tractive Effort = 80.51%

I felt that the contractor's calculations were a little light and did not take into account stopping and starting on the 6% slope. So, I used another way of calculating the tractive effort required:

3 % Rolling Resistance:	$0.03 * 1417 \text{ Te} = 42.51 \text{ Te}$
3 % Internal Resistance:	$0.03 * 1417 \text{ Te} = 42.51 \text{ Te}$
6 % Grade:	$0.06 * 1417 \text{ Te} = 85.02 \text{ Te}$
Total	$= 170.04 \text{ Te}$

Reserve to accelerate to 3 kph in 60 seconds

	$0.02 * 1417 / 9.81 = 3.32 \text{ Te}$
Total	$= 173.36 \text{ Te}$
Utilization	$= 88\% \quad (173.36 \text{ Te} / 198 \text{ Te from above sheet})$

Some sources recommend using 4 % for rolling resistance, which would increase the tractive effort required to 187.53 Te for a utilization of 95 %.

I made the above calculation to demonstrate that the actual demand for tractive effort could be up to 95 % of capacity. To be on the safe side, I recommended to the client that the drive capacity be increased from 198 Te to 220 Te. Swapping out two regular six-axle trailers for two super six trailers could add 4 more drive motors and 22 Te of tractive effort. This way, even if the trailer was stopped on the 6 % slope, it could start again without any trouble.

Two power packs were used for this move that had sufficient capacity to make each drive motor put out 5.5 Te. There should always be a fair amount of over or reserve capacity in the power packs due to the fact that during driving there is capacity required to operate the steering motors and to activate the pumps for leveling. If the power packs are just barely large enough for travel and the transporter needs to be leveled, the transporter will just stop moving. This could be problematic on a hill because all hydraulic motors don't start at the same exact moment due to internal friction, etc, so the wheels for one motor may start slipping first, which could cause the compacted soil to be disturbed and the trailer could get stuck.

Staging Vessels:

Quite often, equipment is brought to a construction site before the foundations are ready, so the equipment needs to be staged until it is ready to be set. In order to eliminate a crane for offloading and reloading, the equipment is set on stanchions that are high enough for the trailer to be lowered and driven out from under the load. Most trailers platforms can be adjusted in height from 1.0 m +/- 250 mm. In order to make staging happen, the saddles of the equipment must be placed on staging beams already on the trailers. The staging beams need to extend past each side of the trailers by about 1.0 m. If the equipment is heavy, steel load spreaders that are say 2 m wide x 6 m long should be buried at ground level. Stanchions that are made of 1 m diameter heavy wall pipe with cover plates x 1 m high or reinforced concrete that is 1 m sq. x 1 m high are placed on the load spreaders. When the load reaches the staging area the trailer platform is raised higher than the stanchions, the trailer is driven between the stanchions, lowered down until the staging beams are resting on the stanchions and then driven out from under the load. The load would be picked up in the reverse order.

The photo below shows the load spreaders and stanchions already attached to the staging beams and are being used as a work platform for the riggers to ride on. When the load reaches the staging area, the trailer platform is merely lowered until the load spreaders are resting on the ground and trailer can be driven out from under the load. The load spreaders do not have to be buried in this case as there is clearance between them for the tires. Generally, the trailer tires just clear the edge of the stanchions, thus the need to bury the load spreaders.



LOAD SPREADERS AND PIPE STANCHIONS CONNECTED TO THE STAGING BEAMS

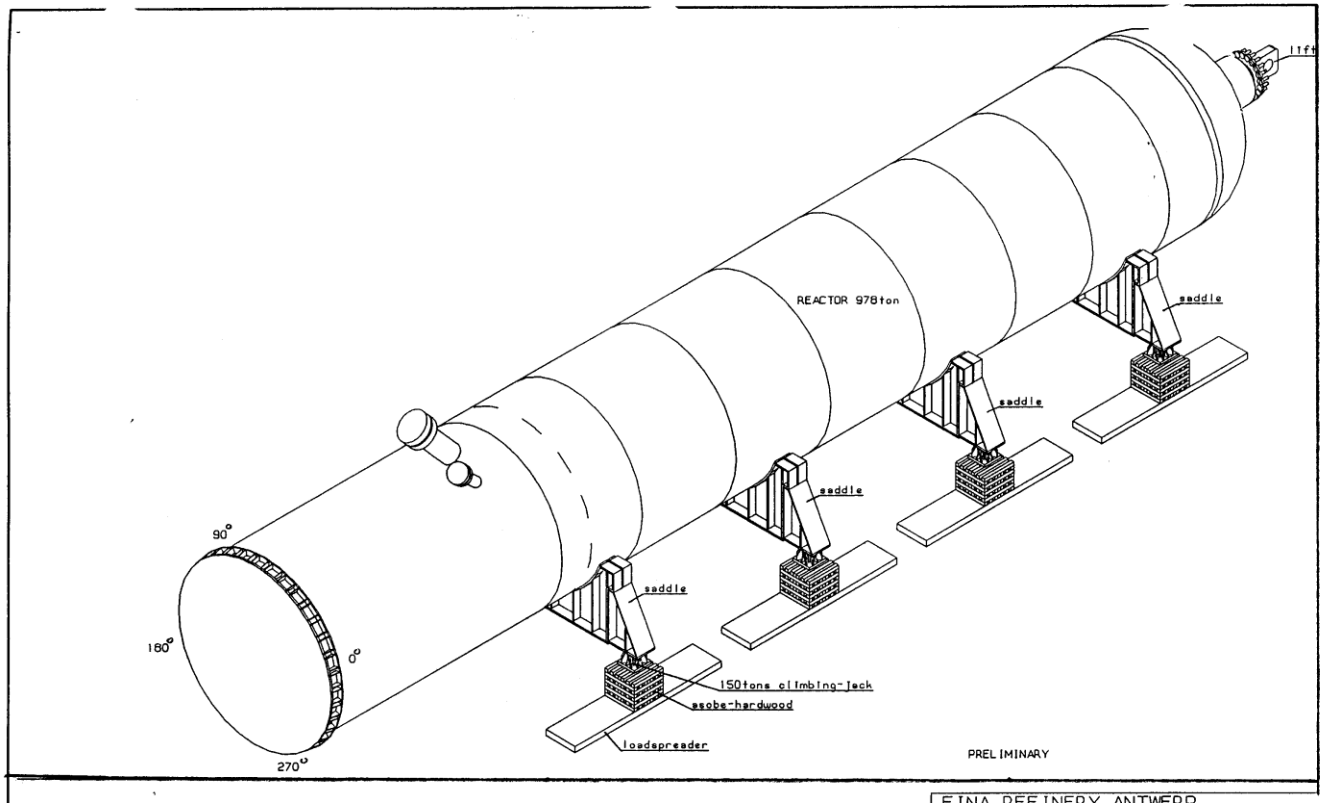
Jacking Vessels Down Or Up Into Place:

In some cases, the load is driven to the foundation and needs to be jacked up or down into place.

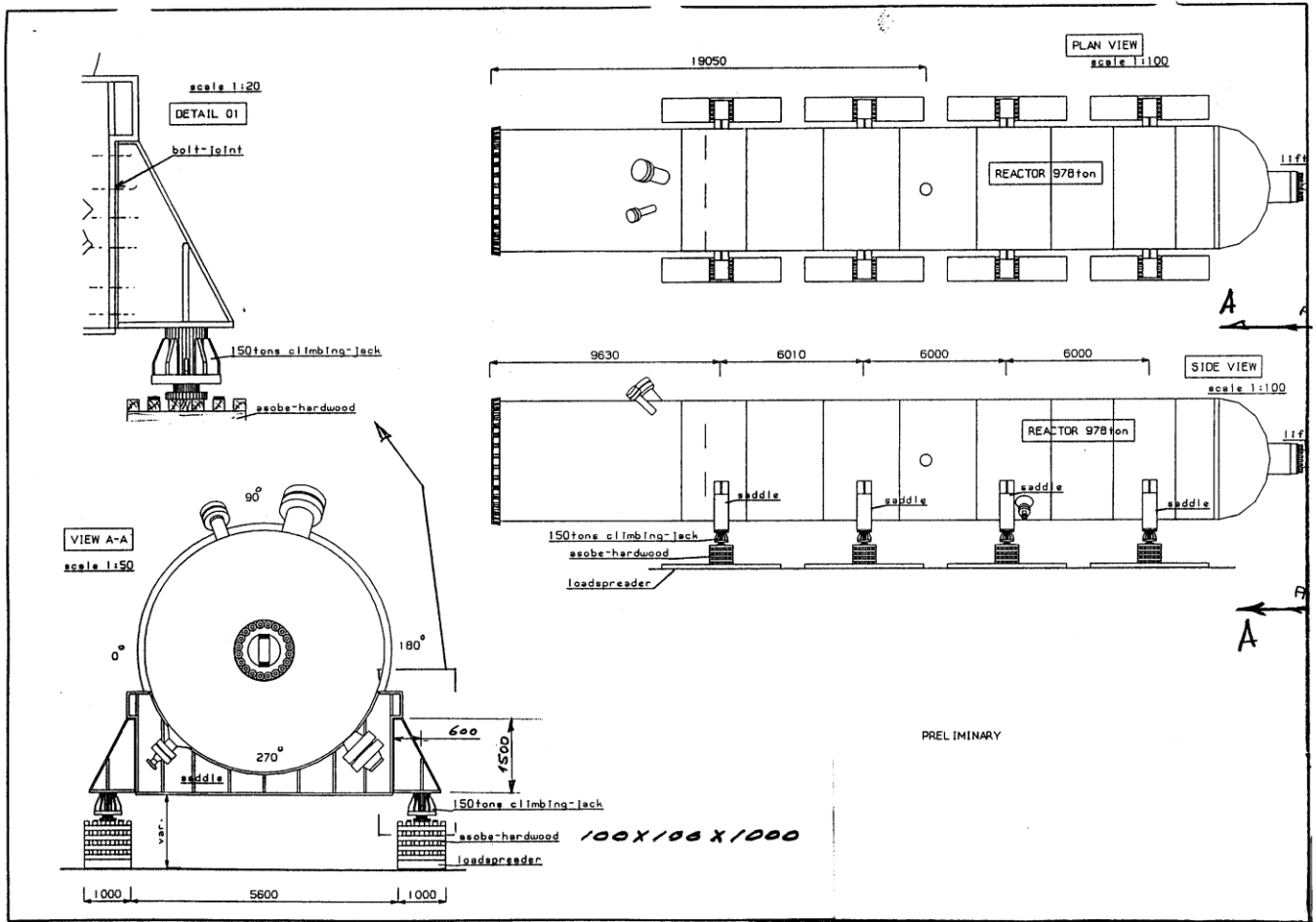
An example of this is shown in the drawing below where a 978 Te reactor was staged on load spreaders, cribbing and 8 climbing jacks. The trailer was then lowered and driven out from under the load. An upending device was then mounted on the trailer platform. The reactor had to then be raised 1.0 m so the trailers could then be driven back under the reactor.

Before starting to jack up the reactor, the climbing jacks were bolted to the jacking pockets so that they didn't have to be manhandled during the jacking process. The wooden cribbing used was 100 mm square x 1.0 m asobe hard wood. This type of hardwood is so dense that it will not float in water and is almost indestructible. The eight climbing jacks had 150 Te capacity each and were designed with a round heavy plate that connected to the bottom of the ram.

The procedure for jacking up the reactor was to first extend all eight rams about 150 mm, then placing cribbing on either side of the ram plates and then laying strips of 20 mm thick steel plate x 100 mm wide x 1.0 m long on top of each piece of cribbing. The rams were then retracted and the weight of the reactor was supported by the cribbing and steel plates on the outside of the ram plates. Cribbing was then pushed under the ram plates and the rams were once again extended about 150 mm. The steel plate strips were removed and cribbing was then added next to the ram plates only at 90 degrees to the layer below. The steel strips were again placed over the cribbing and the rams were retracted. Cribbing was then pushed under the ram plates and the process began all over. The steel strips were required to provide clearance so that cribbing could be pushed under the jacks each time. To lower the reactor, the above procedure would be reversed.



By looking closely at the drawing below, it can be seen that the CG is not located symmetrically between the four saddles. If you will go to quiz number 8 on my website, the question will be asked to determine the actual load to each jack. I will leave it up to each of you to do this for your own edification.



There are several types of climbing jacks available. You have seen one type above. Another type is shown below on the drawing by Van Seumeren. Note that with these jacks, the steel strips are not required as the jack base is contoured to allow clearance for the cribbing to be pushed under the ram plate.

The series of photos below show an equipment module being moved onto site and then being jacked down using climbing jacks. Note the wet conditions, with is usually the case when an operation is being made in the field. Murphy will make sure of that.



EQUIPMENT MODULE ARRIVING AT SITE



CRIBBING AND CLIMBING JACKS IN PLACE

Note in the photo below the baskets that the cribbing is stored in for easy reach and transportation. Also note the power pack/pump at the center of the module. This photo also shows a third type of climbing jack.



JACKING DOWN READY TO BEGIN



JACKING DOWN HAS BEGUN



THE MODULE DOWN ON THE FOUNDATION



JACKING COMPLETE

SUMMARY:

This presentation has only been an introduction to heavy hauling. If you want more information, just go to my website and click on my Partner link at the bottom of the home page and it will take you to “The Works International”. This is Marco Van Daal’s website on transportation. You might want to even consider purchasing his book titled “The Art Of Heavy Transport”. I know that several of you already have. Marco can tell you how to calculate the size of the prime mover and the counterweight required for a pull type trailer.
THE END