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Homemade Rubber Tired Wagons and Trailers

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BULLETIN 349 APRIL, 1941

Homemade Rubber Tired Wagons and Trailers

Agricultural Engineering Department
AGRICULTURAL EXPERIMENT STATION
South Dakota State College
Brookings, South Dakota

Summary

1. Used car wheels, axles, frames and entire chassis have been used in this experiment with good results.

2. The 6-16 drop center rim welded to the old car wheel or hub has been the most satisfactory size of tire rim. It holds a tire (1) sufficiently large for loads, (2) large enough for cushioning much of the road shock and (3) easily and cheaply obtained.

3. The wagon type of steering has given better trailing performance than the auto type steering, for fast road speeds.

4. The two-wheeled light car trailer gives best results when the load is balanced over the axle.

5. The two-wheeled light car trailer gives better results with a long tongue than with a short one.

6. The common car hydraulic bumper jack has proven adequate for the lift mechanism on farm trailers.

7. The one-wheel caster wheel trailer is suitable only for light loads up to 600-700 pounds.

8. In gasoline mileage tests at 30 miles per hour the two-wheel trailer with a 2900 pound load took 7 percent more fuel than for the car alone.

9. In gasoline mileage tests at 30 miles per hour the four-wheel trailer with a 5470 pound load took 22 percent more fuel than for the car alone.

Contents

Homemade Rubber Tired Wagons and Trailers

By Henry H. DeLong[1]

Introduction

Farmers in South Dakota and neighboring states have, in the past 15 years, accepted the homemade rubber tired trailer and wagon to the extent that it is now a standard piece of farm equipment. Almost every farm has some sort of a rubber tired trailer, while many farms have several.

There are definite reasons for this acceptance. Rubber tired vehicles pull easier, under almost all conditions, than steel tired vehicles. Tests showing this were reported in Bulletin 333, "Homemade Rubber Tired Carts and Trailers," of the South Dakota Agricultural Experiment Station. These tests agree with information from many other sources on tests of steel wheel versus rubber tired wheels.

The rubber tired trailer provided a vehicle that would travel at high speeds and thus reduce the time spent in long distance hauling. The trailer also made it possible for the farm family to combine its shopping or social trips with hauling trips; thus doing the two things at the same time.

In late years when tractors have replaced a large number of horses on farms, there are times of rush work such as threshing or silo filling when the family car needs to be used for hauling work. The rubber tired vehicle is best suited to use with the automobile.

Several distinct types of trailers have been developed which necessitated individual tests and studies of each type. The light two-wheeled trailer was probably the first to be used and it originally had a small box and a limited capacity. Problems studied in connection with this type were: size of box, shape of box, length of tongue, balance and springs.

With the four-wheeled trailer, the standard wagon box or hay rack is ordinarily used. Studies on this type include methods of placing the car axles under the wagon or rack; and methods of making the wagon trail nicely.

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1. Assistant Agricultural Engineer, South Dakota Agricultural Experiment Station.

The large platform dual-wheel trailer is not common on farms as yet. Now that the small tractors, with their rubber tires and fast road speeds, have become common, this type was tried out to find its usefulness and workability with the small tractor.

A small caster wheel trailer was made and tested to find out if it was practical to make them in the home shop.

The economic phases of the rubber tired trailer and farm wagon have been studied. By using salvaged automobile parts and used tires, the farmer or the local mechanic can build trailers more cheaply than factory built trailers. However, the first cost of a machine is not the only factor to be kept in mind. Operating costs, conveniences and performance of the vehicle should all be considered. Tests have been run on all types to determine the quantity of fuel needed to pull them under given loads, road and speed conditions.

Two trailer plans have been prepared for future use. These two are original plans and are in addition to the common plans now used by local mechanics and farmers. They are the rubber tired wagon with hydraulic dump and the dual wheeled trailer with hydraulically tilted platform.

The Two-Wheeled Trailer

The two-wheeled light farm trailer similar to the one shown in Fig. 1 is a very popular kind in South Dakota and is used for many light hauling jobs. This type of trailer has advantages and disadvantages as follows:

Advantages:

1. They are simple, easily built and cheap.
2. They are light in weight (300 to 600 lbs.)
3. They have only two tires to buy and maintain.
4. They trail nicely.
5. They can be stored in a small space.

Disadvantages:

1. They are more difficult to back when attached to the automobile, especially if the tongue is short.
2. They must be disconnected to be accurately weighed.
3. They are difficult to connect or disconnect if the load is not balanced over the axle.
4. They some times are hard on car springs, bumper or hitch when load is unbalanced.
5. They have but two tires and this limits their load capacity.

Balance in Design of Two-Wheeled Trailers

The two-wheeled trailers that are homemade vary somewhat in the way the box is balanced over the axle. A test trailer was built to experiment with the balance factor. It was a trailer on which the body and box could be bal-

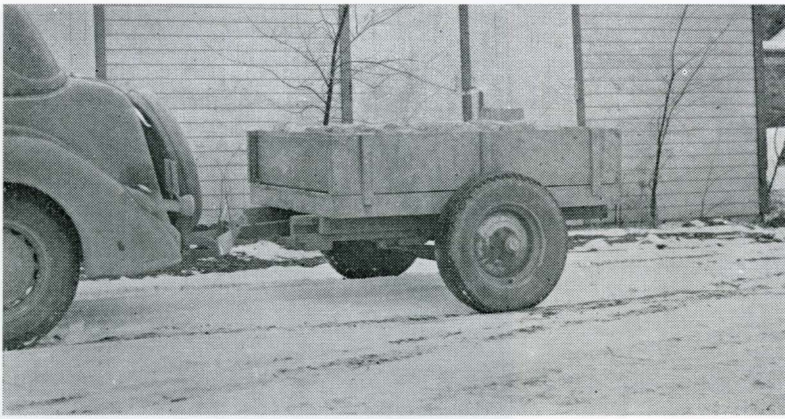

Fig. 1. The two-wheeled trailer with balanced load.

anced directly over the wheels or moved ahead as much as two feet. Fig. 1 shows the trailer with the load balanced and a very short tongue. Fig. 2 shows the same trailer but with a long tongue and the box pushed forward until much of the weight rested on the car.

Tests were run to determine what effect the various balances would have upon the fuel consumption and the general operation of the car and trailer. The fuel consumption was recorded on a "Gas per mile Gauge" as is shown

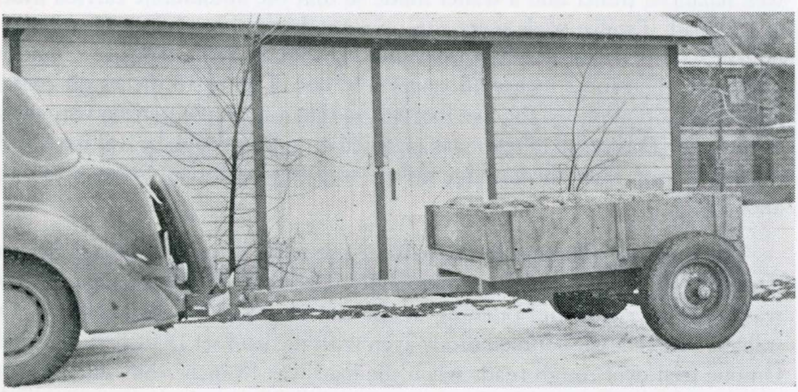

Fig. 2. The two-wheeled test trailer with unbalanced load.

Fig. 3. A "gas per mile" gauge used in the fuel tests.

in Fig. 3. The gas per mile for the car alone was determined for a certain type of road at a given speed. Then the trailer at a given load and setting was added and tested and the gas per mile noted. Following this a different loading or a different setting was run. Each miles per gallon figure given in this bulletin is the average of from four to eight individual tests. Each test consisted of two runs, the second run coming back over the road in the reverse direction to eliminate the influence of grade and wind effect.

No appreciable difference was found between the gas consumption of a well balanced trailer and a trailer made so that the automobile carried much of the load. Twelve trials were run on smooth asphalt road at 30 miles per hour. First the trailer was balanced, then the load shifted forward to 6 inches off center, then to 12 inches off center and last of all to 18 inches off center. The last position placed the five foot box so that a four foot portion was ahead of the axle. This series of tests was repeated on rather rough gravel road at 25 miles per hour. Here the gasoline milage was very slightly in favor of the balanced load.

The greatest difference in the balance test was not in the mileage figures, but rather in the effect on the automobile. When the load was balanced there was far less jerking and pitching of the car on rough or choppy roads. On smooth roads the car handled nicely even with the load set 18 inches off center. On one trial over rough roads when the load was 18 inches off center a 4" x 4" fir trailer tongue was broken; showing that that kind of a tongue would not be adequate for continued use at that unbalanced setting.

All tests in the balance series were run with a total trailer load of 1850 pounds. The trailer itself weighed 400 pounds.

The size of the trailer box shown in Figs. 1 and 2 was 42 inches by 60 inches. This size gave a capacity of 1.16 bushels per inch in depth. The heaviest load used in the test was that of 2,500 pounds in addition to 400 pounds for the trailer. A 2900 pound load compressed the original car springs so that the load rested on the axle. Also with such a load the light automobile used in the tests would tend to loose speed on up-grades of more than usual slopes. Connecting the trailer to the car with such a load was difficult unless the load was perfectly balanced.

A box 36″ deep on the above-mentioned trailer would haul about 40 bushels of small grain; and the heavier varieties would weigh nearly 2,400 pounds. For ear corn, livestock and similar loads such a box is not large enough to always take the maximum load. A weight of 2,000 to 3,000 pounds is safely hauled at 30 and 40 miles per hour on good roads and is stopped by the car brakes in an adequate way when slowing up for corners or stop signs. One should remember, however, that it takes a longer distance to stop with the additional weight than with the car alone.

Effects of Load on Mileage

The amount of weight on the two-wheeled trailer had a direct relation with the amount of gasoline consumed in the car. The result of 50 road tests showed the correlation between weight of trailer and miles per gallon of fuel.

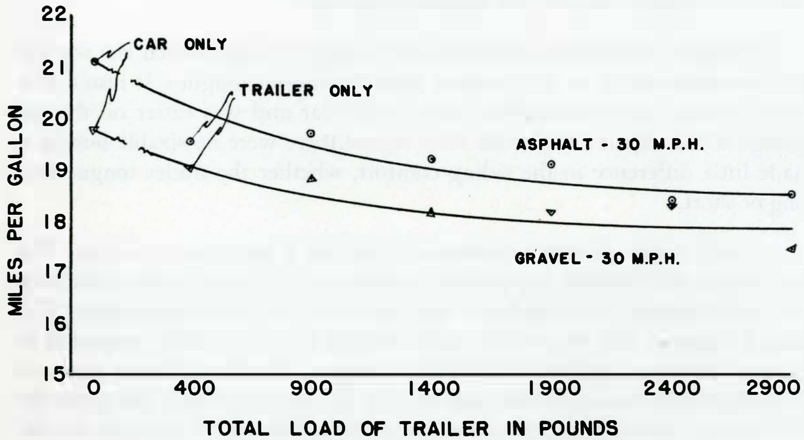

Fig. 4. Fuel consumption curves for the light two-wheeled trailer.

These tests were run at 30 miles per hour on asphalt and gravel roads.

Starting with the automobile alone as a check test, the empty trailer was next added, followed by increases of 500 pounds in the load until the total of 2900 pounds was reached.

On gravel roads with the car alone the mileage was 19.75 miles per gallon. As the load increased the mileage dropped until at 2900 pounds the mileage was 17.41 miles per gallon. Fig. 4 shows the mileage curves of these tests on both gravel roads and asphalt roads.

It was encouraging to note that the 2900 pound load could be pulled with a gasoline expenditure of about 7 percent more than for the car alone.

Length of Tongue

Four different lengths of tongue were used on the light test trailer. The tongue lengths were measured from the trailer axle to the ball and socket of the coupling. The different tongues measured respectively: 4 feet, 5½ feet, 7 feet and 8½ feet.

Tests were run at 30 miles per hour on concrete roads and at 20 miles per hour on dirt roads at each tongue setting. On the smooth concrete roads there was no apparent difference in the gasoline consumed to pull the trailer at the different settings. On rough dirt roads, however, with the trailer going 20 miles per hour 18.25 miles per gallon was recorded for the shortest tongue and 19.62 miles per gallon was recorded for the longest one. For these tests loads were slightly ahead of the balanced position.

A possible explanation was that with the longer tongue much less vertical jerk was transmitted to the car than with the shorter tongues. It resulted in more pleasant and comfortable riding in the car and was easier on the car springs and bumper. On smooth roads where there were no sizable bumps it made little difference in the riding comfort, whether the trailer tongue was long or short.

There are two distinct advantages in having a long trailer tongue. The first is that the operator has greater leverage on the load while connecting and disconnecting trailer and car; and therefore can do this task easier. The second reason is that the trailer can be backed up easier while connected to the car, than one equipped with a short tongue. The long tongue prevents the trailer from turning to the side quickly or "jack-knifing," and gives the driver more time to manipulate the car and keep the trailer going in the desired direction.

Spring vs. No Spring

The light test trailer was equipped with two semi-eliptical leaf springs which were originally on the front car axle used in building the trailer. These springs would compress and strike the bumpers when the load was about 1200 pounds. A set of auxiliary springs was installed to aid the flat springs. These were short pieces of coil spring, three inches in diameter and three inches long. Brackets were brazed to the ends of these springs so that they could be attached and held in place. They were attached just above the axle. The auxiliary springs did not support the load until the regular springs came down to the last two inches of their vertical travel.

The 1500 pound load used in the springs vs. no springs tests, was carried nicely on these double sets of springs. The change-over to the "no springs" setting could be quickly made by jacking up the trailer several inches, inserting a large piece of wood between spring and axle, and then letting the load down on this solid support.

Tests were run over rough or choppy roads only, as on smooth roads the springs did not sustain a great amount of flexing. The tire equipment was the 6-16 size used car tires inflated at 30 pounds per square inch pressure. Two set of trials were run to see if the springs were an advantage over no springs. No appreciable difference in gasoline mileage could be detected. The trials were then repeated over very rough roads and again the miles per gallon figures were the same.To the driver no differences in operation could be detected.

An interesting development in the use of springs occurred when tests were being run on short trailer boxes vs. long trailer boxes. The trailer box was 3½ feet wide by 5 feet long. A temporary, but solid box, was superimposed on the original one to make a box 3½ feet wide and 8 feet long. Loads could then be concentrated in the original 5 foot part or spread out over the entire 8 foot length. A total load of 1350 pounds was taken in this series of tests.

The first tests were with the extended load and no springs; the second series with the extended load, with springs; and the third series with a short or centered load on springs. The respective miles per gallon of these trials were as follows: 17.50, 18.37, 18.50. The difference in gasoline consumption which reflects the amount of pull did not vary a great deal between the tests.

The chief difficulty was that with the extended load the trailer did not trail perfectly but would sway from side to side at speed of 25 or more miles per hour. All of the gas mileage tests were therefore run at 25 miles per hour. The road used was dirt and gravel and was rough and slightly rutty. Driving

was made dangerous with the trailer with 8 foot box at speeds of 25 miles per hour, even on smooth roads. This was with the load on springs. When the load was solid without springs a speed of 30 miles per hour on smooth road was attained before serious swaying occurred. With the load in the short part or the 5 foot box, the trailer was pulled 60 miles per hour on several roads and trailed perfectly, either with or without springs.

A long box on a two-wheel trailer may introduce faulty trailing in a trailer chassis that would trail perfectly if the box were shorter. A very rigid frame and hitch are advised for trailers having a box 6 feet long or longer. A tongue merely consisting of a common 4 x 4 running down the center of the box usually is not adequately braced for the long trailer box.

Recommendations for the Light, Two-Wheeled Trailer

Size: Length 60-70 inches, inside box dimension. Width 42-44 inches inside box dimension. (There are many special hauling jobs which may require variations in size.)

Axle: Light car axles—front or rear with wheels properly aligned and bearings good.

Wheels and Tires: Wheels should be cut down or altered to accomodate a 6-16 tire and should have steel drop center rims welded on.

Balance: The box should be balanced over the axle or not more than 1/10 of its length forward from the balanced position.

Tongue: A strong and well braced tongue 6½ to 7½ feet in length from axle to. coupling

Couplings: A well-made ball and socket coupling.

Springs: Springs are not essential for most conditions, or for slow speeds and smooth roads. If installed they allow the load to sway more.

Height: Distance from box floor to ground—18 to 24 inches. The lower the load, the greater the stability in travel. Springs usually require that the floor be raised several inches higher than otherwise would be necessary. Special situations, such as a frequently used loading platform may dictate the height of the trailer box floor.

The Rubber Tired Farm Wagon

The four-wheeled rubber tired wagon is better suited to many farm hauling jobs than the light two-wheeled trailer. The carrying capacity of the tires is double that of the two-wheeled trailer. There are some definite advantages for this type of trailer and some disadvantages. These are listed as follows:

Advantages:

1. The standard farm wagon with its standard sized box can be combined with the convenience of rubber tires and high speeds.

2. The trailer box and the four wheels make the trailer large enough for common farm loads.

3. The four-wheel trailer is easy to connect and disconnect because there is no load on the tongue as in the case of the two-wheel trailer.

4. This type can be made in a variety of ways, some of which use old farm wagon parts, while others use the old car chassis with very little change or welding.

5. The standard sized hay rack can be used on many of these wagons as well as the standard wagon box.

6. The trailer always stands with its load level, rather than like the two-wheel trailer which is not level when disconnected unless a prop is placed under the tongue.

Disadvantages:

1. The four-wheeled vehicle does not back up conveniently when attached to car or truck.

2. Many of the types with automobile steering develop bad trailing characteristics.

3. The cost of the four-wheel type is slightly higher, as more materials are required.

The Cost of Hauling With the Rubber-Tired Wagon

Fig. 6 shows the results of over 100 test runs on a typical four-wheeled rubber tired wagon on various roads and with various loads. The empty trailer weighed 1130 pounds. The trailer was equipped with light car rear axles, 6-16

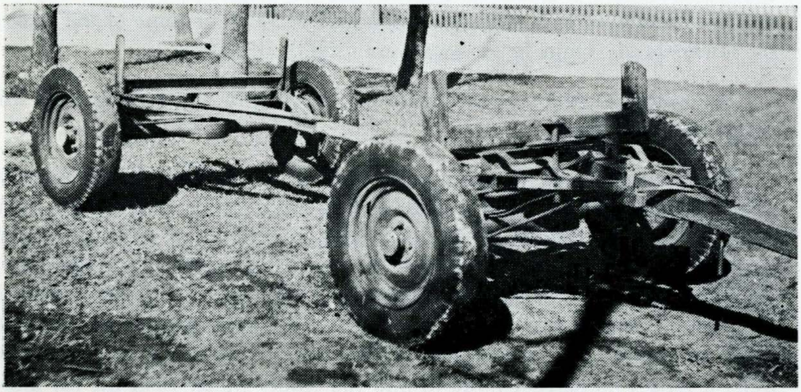

Fig. 5. A typical farm wagon built of used car parts.

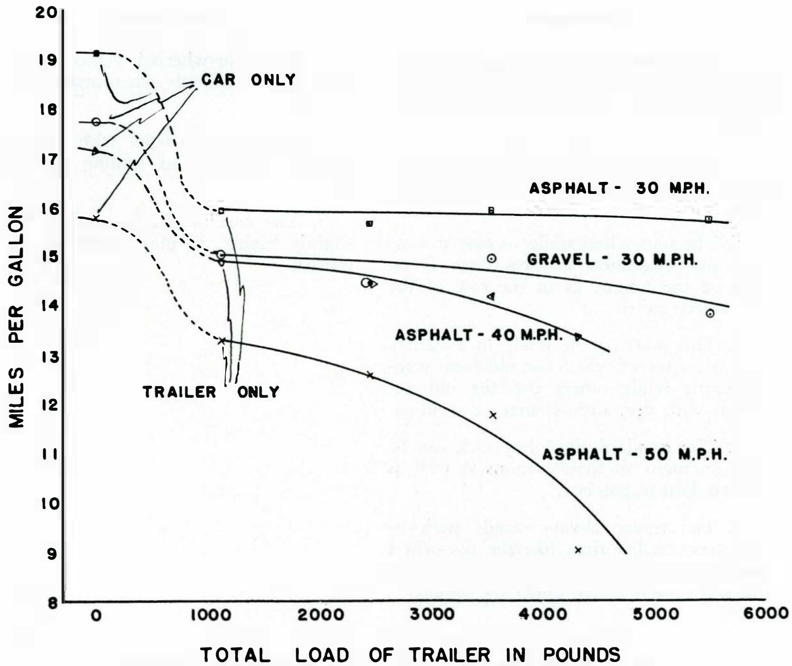

Fig. 6. Fuel consumption curves for the rubber tired farm wagon.

used tires inflated at 30 pounds pressure, and a standard 3-box wagon box. Trials were run with car alone over a given type of road at a given speed. Then the trailer was attached and the same road and speed taken. The load was then increased to a maximum total load of 5470 for some of the trials at the lower speeds. Quite level roads were used in all tests.

The miles per gallon of fuel used was recorded by using the gas per mile gauge shown in Fig. 3.

There was a marked increase in the amount of fuel taken between the car alone and the car and empty trailer, as each curve in Fig. 6 will show. However, thereafter an increase in the load did not cut down on mileage seriously at speeds of 30 miles per hour or less. In terms of mileage, on asphalt road at 30 miles per hour, the car alone averaged 19.08 miles per gallon, with the 1130 pound load or with the empty trailer, 15.92 miles per gallon, and 15.66 miles per gallon with a total load of 5470 pounds. In terms of gasoline per mile, it took 19.6 percent more to pull the empty trailer than the car alone, and it took 21.9 percent more to pull the 5470 pound load.

The other curves in Fig. 6 show this same trend, but they are more sloping. When the outfit was run on gravel roads 30 miles per hour the car alone averaged 17.12 miles per gallon; with a 1130 pound load, 14.88; and with a 5470 pound load 13.75.

There is an explanation for the great increase in gasoline needed to pull the empty four-wheeled trailer as compared to the empty two-wheel trailer—added weight and wind resistance. The latter was caused by the triple-box wagon. Wind resistance remained the same as long as the speed was the same, regardless of the weight added. Later tests showed that it took 6 to 10 percent more gasoline per mile to pull a triple box wagon of 1130 pounds at 50 miles per hour on asphalt than it did to pull a one box wagon of the same weight. The wind resistance is a definite factor in high speed work.

Tests showed that at speeds of 40 to 50 miles per hour the light car with 85 horsepower motor had a definite load-speed limit as far as fuel economy was concerned. The two lower curves in Fig. 6 show that as the load reached 3000 pounds there was no longer economical driving. At 4300 pounds of load and 50 miles per hour the miles per gallon made was 9, as compared to 15.75 miles per gallon of the car alone at 50 miles per hour.

The operator noted this apparent limit in other ways than on the gasoline mileage. At the times when mileage began to be poor, there was also noted a tendency of the car to lose speed and a necessity of a much greater throttle opening on up-grades to maintain a uniform speed. Also at the points where mileage became poor the jerk of the trailer on the car became very pronounced, and caused discomfort whenever bumpy roads were driven over.

These two "tell-tale" signs warn the operator that the car motor has reached its capacity of load-speed combination beyond which one cannot hope for good gasoline mileage.

Axle Types for Wagons

On page 17 are shown simple drawings of various ways of building the rubber tired farm wagon.

Complete Car Chassis. The complete car chassis type permits the builder to strip all body and motor parts from an old car and have frame, springs and axle intact. Those cars with a straight frame are much preferred. Two or more wood cross pieces are bolted on to support the wagon box. A trailer hitch can be made or purchased and attached to the front axle.

Scarcely any welding is necessary if a factory hitch is installed. The farmer with few tools can build this type. The wheel and tire size of the old car is

likely to be other than 6-16 size with drop center rims; and if this common size is to be installed the local mechanic must alter the wheels.

Very often, the old car frame is longer than the wagon box and when these frame ends stick out behind they interfere with backing the wagon up close to bins or elevator dumps. This wagon must have auto-steering which often leads to difficulties in trailing.

Wagon Parts with Front Axles. This type of wagon calls for the wood axles, reach and bolsters of the common farm wagon. The steel skeins are removed and car front axles and wheels are placed under the wooden axles and securely bolted there with U-bolts. The front wheel steering knuckles must be aligned and welded rigid and it is again best to have the old wheel rim removed and a 6-16 drop center rim welded on.

If this type of wagon is used with the horse hitch the original tongue and eveners can be left in place. If it is to be used with a car the tongue should be shortened to about four feet and a good ball and socket coupling fitted to the end. The wagon box may need some blocking up on the bolsters to raise it high enough to let the wheels turn under it and facilitate short turning.

Wagon Parts with Rear Axles. This type is built much the same as the one just described, except that two rear axle and wheel units are used. The rear wheels need no aligning. The banjo type of axle is best suited for the change. The entire differential and inner bearings are removed. The axle is then turned ¼ turn, so that the banjo part is flat, thus allowing the wooden wagon axle to rest along the car axle.

The inner ends of the axle shafts must be supported if the old car axle was any other type than the full-floating axle type. The welder can make a plain bearing for the inner ends out of a short length of pipe. The pipe is welded into the banjo head parallel with the axles. The axles turn inside of this pipe, independent of each other. The pipe must have a zerk grease fitting.

The Model T Ford Chassis. This has been a very popular model in the past but the supply of such chassis has dwindled. Such a wagon was extremely simple and light, and the car frame was shorter than the standard wagon box. The tire size was usually not changed and the original sizes were almost impossible to get in used tire shops. Usually the car radius rods were used and the old motor pan left in place to support these radius rods. A reach could be used, however. Auto-steering was usually used but wagon steering could also be installed.

Variations of the Above Types. There are almost as many four-wheeled rubber tired wagon plans at there are local mechanics and welders. No one plan stands out as being so superior that is has replaced all others either in the homemade or the factory-made types.

Some types are made with springs, others without. Those without springs are recommended for carrying hay racks or other wide and top-heavy loads that tend to sway.

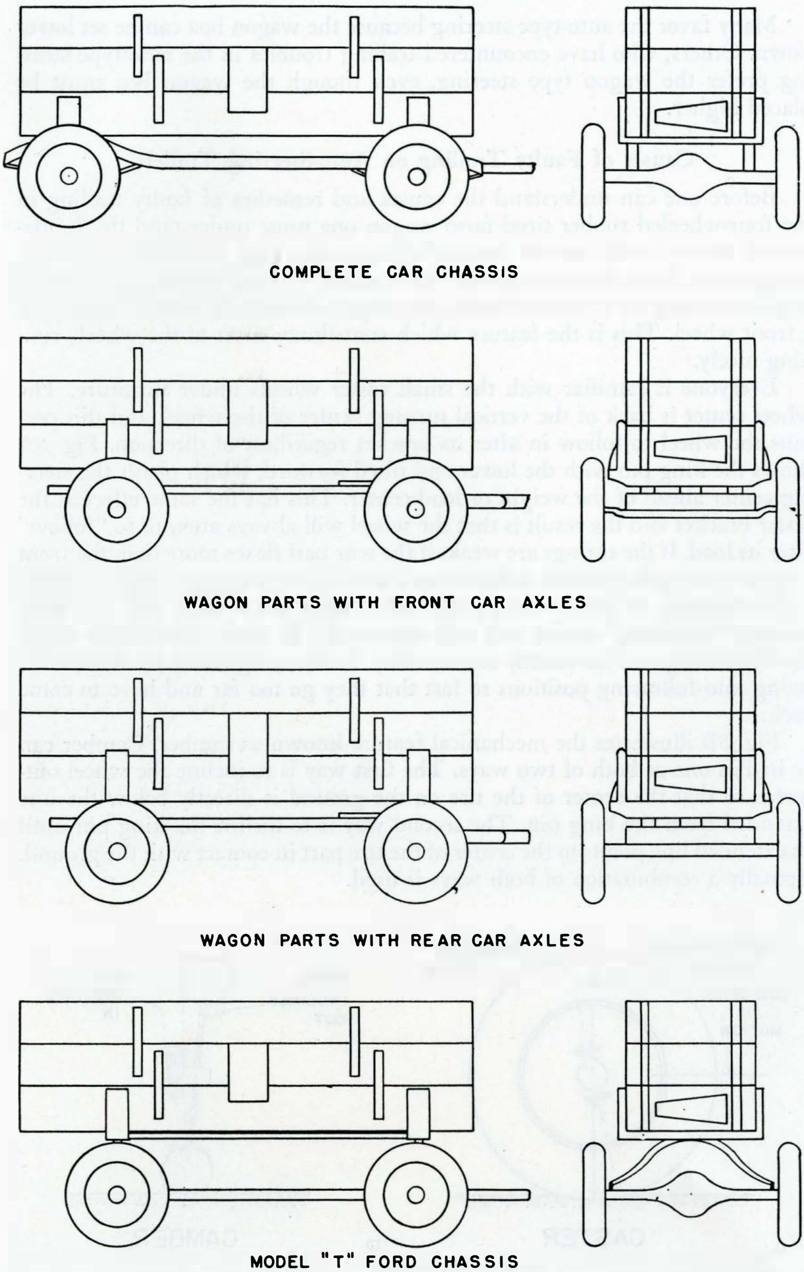

Fig. 7. Various types of rubber tired farm wagon.

Many favor the auto-type steering because the wagon box can be set lower down. Others, who have encountered trailing troubles in the auto-type steering prefer the wagon type steering, even though the wagon box must be placed higher.

Causes of Faulty Trailing on Auto-Steering Trailers

Before one can understand the causes and remedies of faulty trailing in the four-wheeled rubber tired farm wagon one must understand the fundamental features built into the front wheel assembly. Figs. 8 and 9 will show in exaggerated form the features that are essential to good steering on a car or to good trailing on a trailer. Sketch A in Fig. 8 shows how caster is built into a front wheel. This is the feature which contributes most to the wheels running nicely.

Everyone is familiar with the small caster wheels under furniture. The wheel center is back of the vertical turning center of the wheel, and this permits the wheel to follow in after its bracket regardless of direction. Fig. 8A shows the king pin with the lower end tilted forward, which places the steering center ahead of the weight or load center. This has the same effect as the caster bracket and the result is that the wheel will always attempt to "follow" after its load. If the springs are weak, if the rear part flexes more than the front part, or if the axle has been bolted onto a new frame, this caster angle is likely to be changed. If there is too little caster angle the wheels will not have enough "following" ability and will steer badly. If there is too much caster the wheels respond too readily and shimmy. Shimmying is to have the wheels swing into following positions so fast that they go too far and have to come back.

Fig. 8B illustrates the mechanical feature known as camber. Camber can be had in one or both of two ways. The first way is to incline the wheel outwards so that the center of the tire on the ground is directly below the line extended from the king pin. The second way is to incline the king pin until its extended line points to the center of the tire part in contact with the ground. Actually a combination of both ways is used.

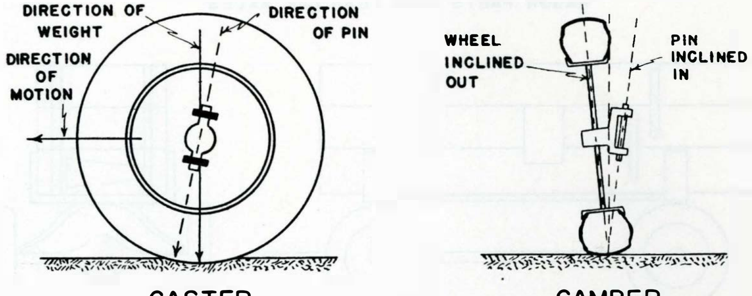

Fig. 8. Sketches showing two important features built into automobile steering assemblies.

The purpose of camber is to reduce shock in steering and to provide for easier steering. When the contact point of the tire is in line with the king pin, a bump or shock against the tire will not cause it to turn one way or the other.

The purpose of the "toe-in" wheel setting is to overcome one result of camber—that is, a wheel which leans out will tend to run in an outward circle rather than straight ahead. The wheels are "toed-in" just enough to counteract the effects of camber and make the wheels run straight ahead. Fig. 9C shows the wheel setting greatly exaggerated.

Fig. 9D shows how steering rods may be connected up for "over-steering" or "under-steering." By "over-steering" is meant the condition whereby a turn of 5 degrees on the trailer tongue would cause the wheels to turn 6 or 7 degrees. This is a complicating factor which enters into drawn vehicles which did not affect self-propelled ones.

With these basic facts and definitions of terms stated, and with the illustrations in mind it will be possible to discuss the causes and remedies of poor trailing in four-wheeled trailers.

Cause and Remedies of Poor Trailing

The causes and remedies of poor trailing will be discussed from a practical standpoint. The simple, easily applied remedies will be suggested first. Later some of the more difficult adjustments will be suggested. It should be kept in mind that usually there is more than one thing wrong, and rarely will the changing of a single part completely remedy the trailer. The causes and their remedies are listed alternately.

1. High speeds while not the cause of bad trailing, aggravate the condition.
   Drive at slow speeds on the road until the faulty trailer can be fixed.
2. Unequally inflated tires will cause faulty trailing—even on a trailer that has wagon type steering.
   Have all tires with the same pressure—and have casings well matched as to type of tire.
3. The automobile type of steering gives most of the trouble.
   If one is having a trailer built he can very often order the wagon type of steering and avoid most or all of the difficulties.

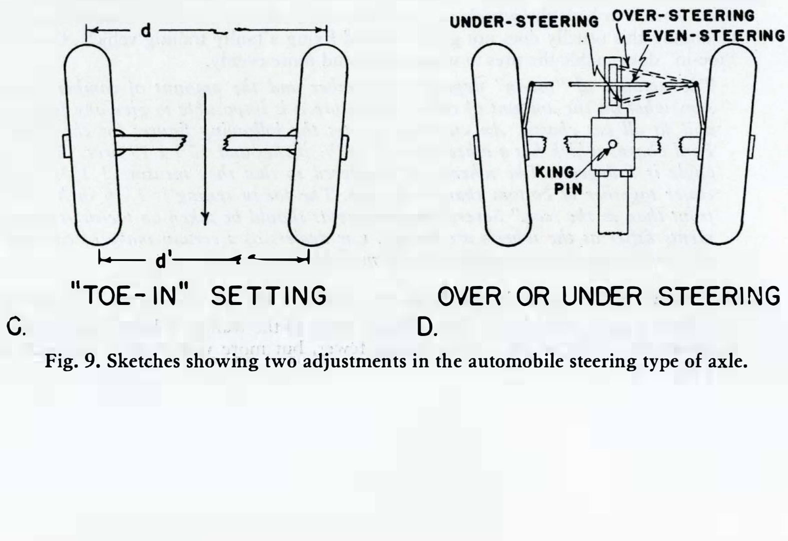

Fig. 9. Sketches showing two adjustments in the automobile steering type of axle.

4. Loose parts can cause bad trailing.

   All loose joints and connections in steering rods and tongue should be tightened up so there is no play. Steering members must not be tightened to the extent that they turn hard.

5. Worn tongue king pins which are turned up too tight may cause bad trailing.

   The remedy here is to ream out the worn hole and install a larger pin. This will take out the play without necessitating turning the nut down too tight.

6. Over steering is one cause of faulty trailing.

   Most commercial trailer hitches and some homemade ones have a slot in the tongue member. Along this slot one can set the steering rod to give varying degrees of over steering or under steering. It usually takes very little time to reset this to find the place where it works most satisfactorily. The most satisfactory setting found in tests run on several trailers in this experiment was to have even steering or a very slight under steering effect.

7. Bent axles or other mis-alignments may cause a variety of troubles. Axles bowed up or down will change the camber angle. If the bend is toward one end of the axle it will cause the wheel with the greatest camber angle to pull out.

   The axle that is twisted causes unequal caster on the wheels. This makes one wheel have a different "following tendency" than the other. If there is a great difference in them they cannot both be right and poor trailing will occur.

   One should choose only good axles or properly straightened ones to go into a trailer used in high speed travel. Garages and machine shops with special equipment can straighten axles and check up on the camber angle, king pin angle and the caster angle of a certain type and model of axle. The farmer is not equipped to do this work. Axle parts must be bent while cold—heating destroys the strength of the heat treated parts.

8. An axle that has turned slightly due to weak springs or other causes may cause the trailer to weave irregularly. If the axle has rotated backwards the caster angle has increased and this may cause shimmy.

   The remedy here is to restore the axle to its proper position. Thin wedges can be placed between the spring and axle. Where radius rods are used, they must be adjusted or bent to facilitate the change. If the longitudinal springs are weak the axle will likely rotate forward. This would necessitate putting the thickest part of the wedge to the rear. Some garages carry in stock suitable wedges to remedy cars with steering troubles.

9. Too much or too little "toe-in" causes severe wear on tires and may affect trailing. The effect here is to have the wheels pull out from each other or crowd in toward each other. Changing this usually does not go far toward fixing a faulty trailing vehicle. Correcting "toe-in" does enable the tires to wear longer and more evenly.

   The amount of "toe-in" depends on camber and the amount of camber depends somewhat on the amount of caster. Therefore it is impossible to give any figure that will fit all car chassis. An authority quotes the following figures for the Model A Ford chassis which has a wheel base of 103½ inches and 4.75 x 19 tires. "The caster angle is 5 degrees. The wheels are cambered so that they measure 1 13/16 inches closer together at bottom than at the top. The toe-in setting is 1/16 inch closer in front than in the rear." Several measurements should be taken on toe-in as measurements differ as the wheels are turned. Car dealers of a certain make of car may be able to look up the information for old models of that make.

10. The changing of tongue length helps very little, if any, on trailers which trail badly.

    Short tongue will give a short, choppy sway to the trailer. A long tongue will just lengthen the swing of the trailer, giving fewer, but more violent swayings from side to side.

Fig. 10. The wagon with hydraulic lift, shown unloaded with the portable elevator.

The Rubber Tired Wagon With Hydraulic Lift

A four-wheeled rubber tired wagon with a hydraulically operated lift or dumping mechanism was built by the Agricultural Engineering Experiment Station. Figs. 10 and 11 show this wagon with the box in raised position.

There were several reasons why this type of wagon was placed in the experimental project. First, it is an advantage to have the dump mechanism with the wagon at all times. Secondly, the fact that the lift is on the wagon

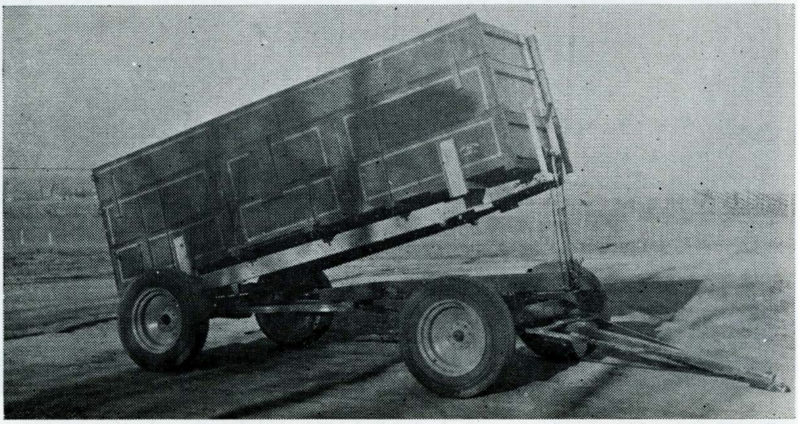

Fig. 11. Front view of the dump wagon showing box raised.

itself means no super structure is needed, allowing a cheaper and more compact lift unit. Thirdly, the writer wanted to know if a hydraulic bumper jack built for use with automobiles could be used as the lifting mechanism, as well as to know whether such a lift unit could be built in a shop with average equipment.

The rubber-tired wagon with dump box differs from the common rubber-tired wagon in two ways. The frame must be double, one to connect the front and rear wheels in "reach fashion" and one to raise and lower with the box. The hydraulic bumper jack is the second additional part and it is accompanied with some upright braces, two small rollers and a cable and fasteners.

Fig. 12 shows a detailed drawing of the lift parts. A ½-inch cable of good quality wire rope was used. The small pulleys were picked up from used machinery. The hydraulic jack was purchased at a local store for $5.50 and was one intended for use with passenger cars as a bumper jack. The plunger stroke of the jack was 15 inches. The cable and pulleys were so arranged as to lift the load twice this distance or 30 inches.

A blue print showing all of the frame, axle, and lift details has been prepared and may be secured by writing to the Agricultural Engineering Department, Agricultural Experiment Station, Brookings. The blue print is in one sheet and costs 10 cents, which covers the expense of printing.

The additional material needed in the wagon was as follows: (1) one additional car frame, $2.00; (2) extra angle and strap iron, $1.00; (3) eight feet of steel cable, $1.50; (4) the hydraulic bumper jack, $5.50, and (5) five feet of additional welding with the electric arc.

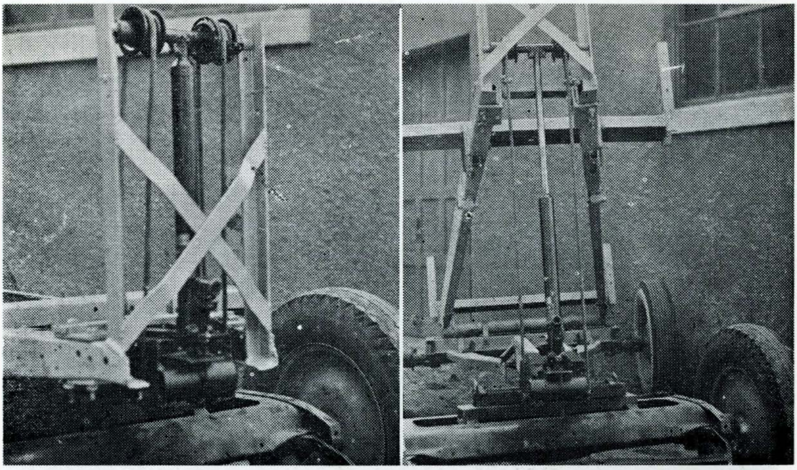

Fig. 12. Two views showing how the hydraulic bumper jack is mounted to form the wagon hoist.

This lift was thoroughly tested. A few changes had to be made in the original design as weaknesses appeared. One very necessary feature found was that of having the jack installed so that the lifting bracket on the load is always directly in line with the plunger. Any off-center mounting will tend to bend the plunger. The pulleys at the top of the jack should be set in close to the plunger and evenly spaced from the plunger, to prevent any severe or unequal strain on the cross rod used for their axle.

This hydraulic lift was found to handle the usual wagon load of 2,000 to 4,000 pounds very nicely. Lifting was easily done by the operator. The load could be lowered very slowly and gently. With an empty box, however, it could be lowered quite rapidly. The lift also was tested for a safety factor and 6,200 pounds of sand was loaded on the wagon. The jack and cables lifted this load several times without showing any signs of failure. The original jack handle was bent lifting this load and had to be replaced with a stronger one, but the jack itself stood the strain with no leakage and no ill effect.

The wagon framework was built up entirely out of used car parts. Rear car axles were used for both front and rear wheel assemblies. The vehicle had wagon type steering. It trailed perfectly at all speeds and was used in many of the tests previously described.

The Heavy Duty Trailer

The heavy-duty dual-wheeled trailer, as shown in Figs. 13, 14, and 15, is not common on farms today. This trailer weighed about 1500 pounds and was

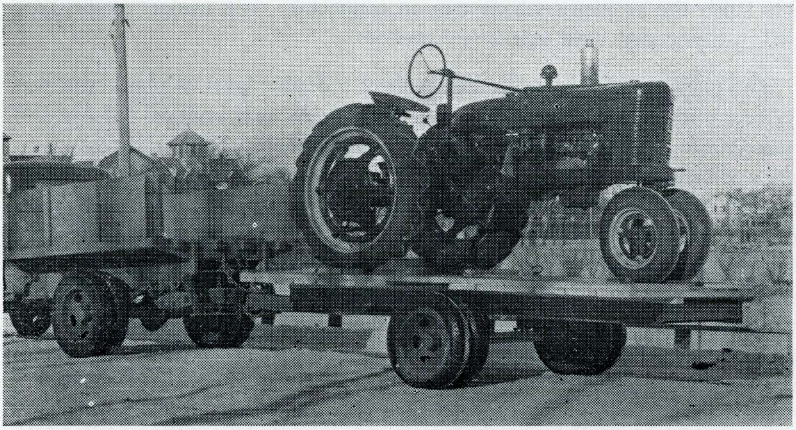

Fig. 13. The dual-wheeled heavy duty trailer.

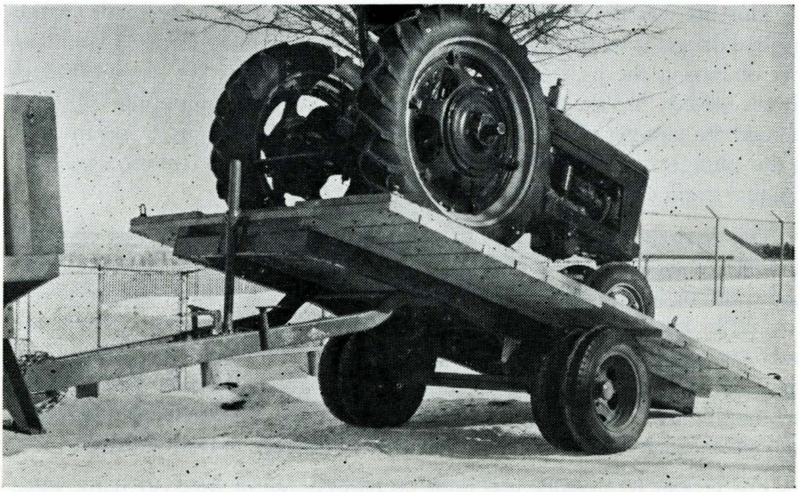

Fig. 14. The dual-wheeled trailer with platform tilted showing hydraulic jack lifting mechanism.

too heavy to use with the light passenger car because its weight when unloaded was well up towards the optimum total trailer load for such cars.

Many of the horses on farms have been replaced by tractor power and many of these tractors have been equipped with rubber tires which makes them suitable for doing hauling work. The dual-wheeled, large tilting platform trailer was built by the Agricultural Engineering Experiment Station so as to study the problems which arise in connection with trailers of this type used in connection with trucks and tractors.

The platform of this trailer was built of a double layer of plank and was 7½ feet wide and 12 feet long. The frame work was built of old car and truck frames. An old truck frame of six-inch channels and several cross members was secured and cut down to 11 feet, 6 inches. All cross members were then cut with the torch which severed the side channels from each other and allowed them to be set out wider than before. The cross members were then built up with other pieces of channel and pieces of steel. One extra cross member was added. Finally an "x" shaped member consisting of a light car frame material was welded in to prevent the frame from twisting. Short pieces of the 6-inch channel were placed between the main frame and axle to raise the platform above the wheels.

Special dual wheels had to be purchased in order to use the popular 6-16 sized tire. These rims were not drop center rims but had one piece rim rings

which could be slipped over the rim edge when tires were mounted. The drop center rim has a smaller inside diameter and does not allow adequate space for hub and brake parts such as these heavy duty wheels require.

The wheels were then mounted on a special axle which was built up in the Agricultural Engineering shops. The spindles were made out of $2\frac{5}{8}$-inch shafting and turned down on a lathe to accommodate the bearings. These spindles which projected from the wheels about 12 inches were then connected to each other by four pieces of angle iron arc-welded around the round part in such a way that they resembled a square, hollow member.

The reason for the built-up axle was to place the wheels as far out as possible under the $7\frac{1}{2}$-foot platform, thus making the trailer better for high or top-heavy loads. It would be rather difficult to take any kind of old truck axle with dual wheel equipment and lengthen the axle. In addition, the truck wheels have larger tires; thus they would raise the platform of the trailer higher.

The "A" shaped tongue was made out of heavy car frame members and was attached 35 inches back of the front end and extended 48 inches beyond the front end. The attachment of the rear end was made from two pipe members; a 1-inch pipe welded to the frame inside of a $1\frac{1}{2}$-inch pipe welded to the A. This formed a hinge to let the platform tilt to the rear.

The tilting mechanism was made by setting a hydraulic bumper jack on a cross member of the "A" shaped tongue and fastening the movable part to the

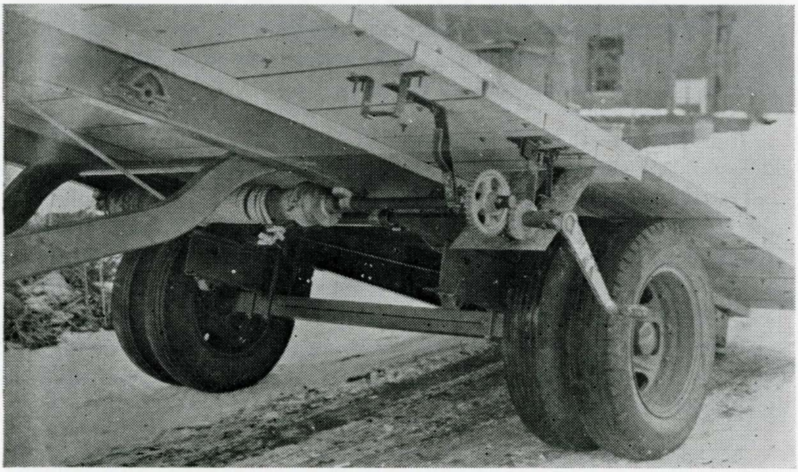

Fig. 15. The geared windlass placed under the platform is to pull machines onto the trailer when loading.

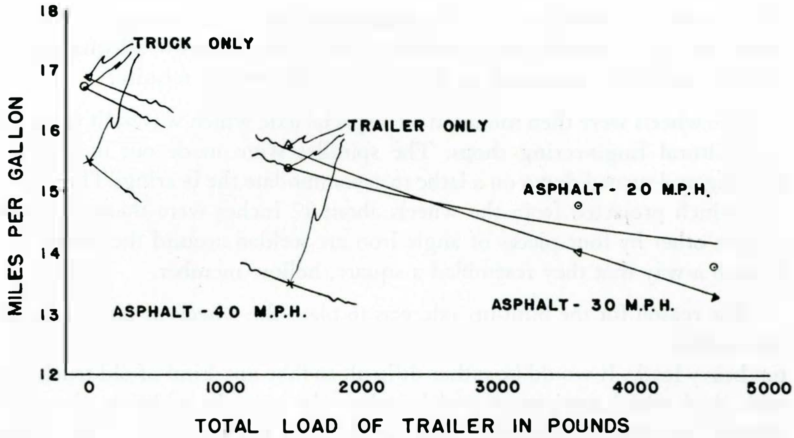

Fig. 16. Fuel consumption curves for the truck and dual-trailer.

front end of the platform. This jack had a rated capacity of 1½ tons, a lift of 17 inches and cost $5.50. The jack lifted the loads into the tilted position very nicely. If the load was placed toward the rear, however, the jack let the load down rapidly as soon as the platform locking device was released.

In loading machines, the platform was tilted, and the machine pulled or driven up the incline. The machine had to be placed "over center" before the platform would begin to level itself due to the weight of the load. The hydraulic jack was used to lower the load slowly, rapidly or to hold it in any desired position. Its ability to ease the load into position was as useful at times as its ability to lift the load and tilt the platform.

Fig. 15 shows the hand-operated geared windlass that was installed to use in loading machines which do not propel themselves. A two to one gear and ratchet assembly was located in the junk yards and served very well when mounted on shafts and bearings. A large 3-inch pipe was brazed to the front shaft to form a roller on which the rope or chain wound up. The rope ran over a pulley and guide on the platform's front end and back to the implement being pulled up the incline. Such a windlass if purchased new would cost considerable money and would need to be altered to fit the trailer chassis. If parts can be found, however, the windlass is not hard to make or install and has proved very useful.

A 1-sheet blue print has been made of plans for this dual-wheeled trailer. These can be secured for 10 cents a sheet by writing to the Agricultural Engineering Experiment Station, Brookings.The plan is a helpful guide to build-

ing such a trailer but many minor changes may need to be made to make possible the use of the kind of old car or truck parts that are available for use by the mechanic who is doing the work.

Fuel Consumption With Dual Trailer

The dual wheel trailer has been tested for its fuel consumption with a 1½ ton truck and several tractors. Fig. 16 shows the curves of miles per gallon with various loads and various speeds on asphalt roads with a 1½ ton truck which had an 85 horsepower motor, a high speed rear axle and dual wheels.

With the truck alone at 20 miles per hour and at 30 miles per hour the miles per gallon were 16.75 and 16.83 respectively. The 1500 pound trailer reduced the mileage at those speeds to 15.37 and 15.75 miles per gallon respectively. As the load was increased the mileage dropped so that at a total load of 4590 pounds the mileage was 13.76 miles per gallon at 20 miles per hour and 13.25 at 30 miles per hour.

In terms of gasoline per mile the empty trailer took 10 percent more than the truck alone at 20 miles per hour. The 4590 load took 22 percent more gasoline than the truck only at the 20 miles per hour speed.

The 40 miles per hour curve is much lower on the chart showing that the truck and trailer ran more economically at 30 miles per hour than at 40. Due to the nature of the loads and the condition of the roads the heavier loads were not tested at 40 miles per hour.

Dual-Wheeled Trailer and Tractor

The dual-wheel tilt-platform trailer was used with several tractors in tests to determine the fuel consumption of this kind of a hauling unit. Four tractors were used: two of the one plow size and two of the two plow size. One tractor in each size group was built for burning distillate; and one was built for burning gasoline.

One mile courses were used to run these fuel consumption tests. Fuel for each test was measured in a tall 1-gallon container with glass tube gauge with divisions of 1/100 of a gallon. First the outfit was run over the one-mile course one way, then the return mile trip made, and the average of these two results was taken as the figure for that trial. This procedure eliminated the effects of grade and wind direction.

Tests were run with each tractor first with the empty trailer and tractor and then with the loaded trailer and tractor. Table 1 shows the results of the tests. By noting the data in Table 1, one sees the desirability of having a high road gear on the tractor, if road hauling is to be done economically.

Tractor No. 3, with a road speed of 15 miles per hour, pulled the 5250 pound load at about the same miles per gallon of fuel as did the truck pulling a slightly lighter load as shown in Fig. 16. In addition, the fuel used was distillate rather than gasoline; but the speed of travel was only one-half or less than that of the truck.

As the road speed of the tractors was reduced by shifting to a lower gear the fuel consumption per mile increased beyond the point where the tractor and trailer unit could be compared favorably with truck and trailer, or car and trailer units. Only the high gear tests are recorded in Table 1 in most cases.

Table 1. Fuel Consumption with Tractor and Trailer

Tractor	Size	Weight	Fuel	Gear	Speed M.P.H.	Total Trailer Load	Road	Miles Per Gal.
No. 1	1-Plow	2590	Distillate	3	6.52	1500	Asphalt	10.8
No. 1	1-Plow	2590	Distillate	3	6.50	4590	Asphalt	9.1
No. 1	1-Plow	2590	Distillate	3	6.52	1500	Gravel	8.5
No. 1	1-Plow	2590	Distillate	3	6.42	4590	Gravel	7.4
No. 2	1-Plow	2620	Gasoline	3	9.85	1500	Asphalt	9.7
No. 2	1-Plow	2620	Gasoline	3	9.45	4590	Asphalt	8.0
No. 2	1-Plow	2620	Gasoline	3	8.84	1500	Gravel	9.5
No. 2	1-Plow	2620	Gasoline	3	8.15	4590	Gravel	7.76
No. 3	2-Plow	2900	Distillate	5	8.68	1500	Asphalt	11.7
No. 3	2-Plow	2900	Distillate	5	8.95	5250	Asphalt	8.7
No. 3	2-Plow	2900	Distillate	6	15.30	1500	Asphalt	15.6
No. 3	2-Plow	2900	Distillate	6	14.90	5250	Asphalt	13.3
No. 4	2-Plow	3800	Gasoline	3	4.80	1500	Asphalt	4.0
No. 4	2-Plow	3800	Gasoline	4	12.2	1500	Asphalt	8.7
No. 4	2-Plow	3800	Gasoline	4	12.0	5250	Asphalt	6.4

The lower gears of a tractor are of great advantage in starting loads, in pulling over soft roads, in climbing hills, or in maneuvering tractor and trailer about yards and through gates. A tractor used in high speed hauling should have gears which can be shifted while the tractor is in motion, as this adapts the tractor nearer to the "stop and go" driving, often encountered in hauling work.

Tractor brakes should be used with great care in high speed work. Whereever possible, the brakes for the right and left wheels should be locked together. If this is not possible, the operator must use much good judgment in applying the tractor brakes at high speeds.

In most cases the tractor and large trailer can be turned around or backed up with greater ease than a truck and trailer combination, or car and trailer.

The Caster Wheel Trailer

The caster wheel trailer or one wheel trailer is seen occasionally on South Dakota highways. Its carrying capacity is limited to loads up to 600 pounds because its one wheel is usually 16 inches in diameter and the tire a two or four ply 4 inch size. This type of trailer is connected to the rear car bumper at two points which gives it rigidity, while the caster wheel carries only the weight of the rear part.

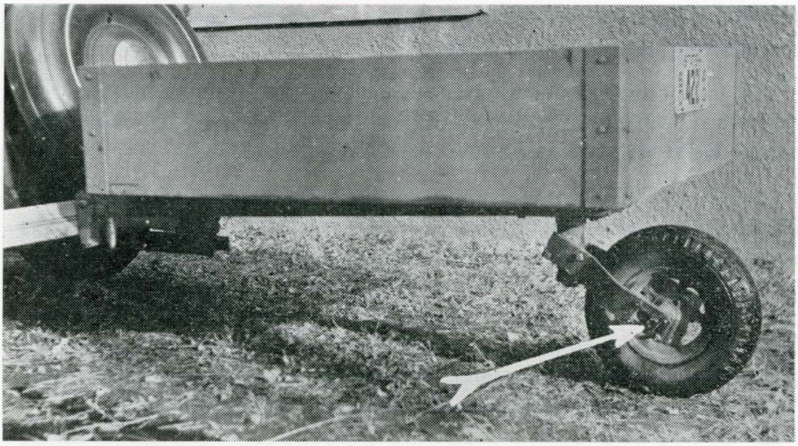

Fig. 17. The caster wheel trailer showing bracket without springs. The adjustment is for aligning wheel.

A trailer of this type was constructed in the Agricultural Engineering Department shops to find out if it was possible or desirable to attempt to make a homemade caster wheel trailer. The trailer was also tested for fuel consumption and for finding its desirable and undesirable features on various kinds of roads and at varying speeds.

The wheel used was a cast iron pneumatic tired wheel barrow wheel with a 4 inch by 8 inch tire of 4 ply size. The wheel had a drop center rim and the

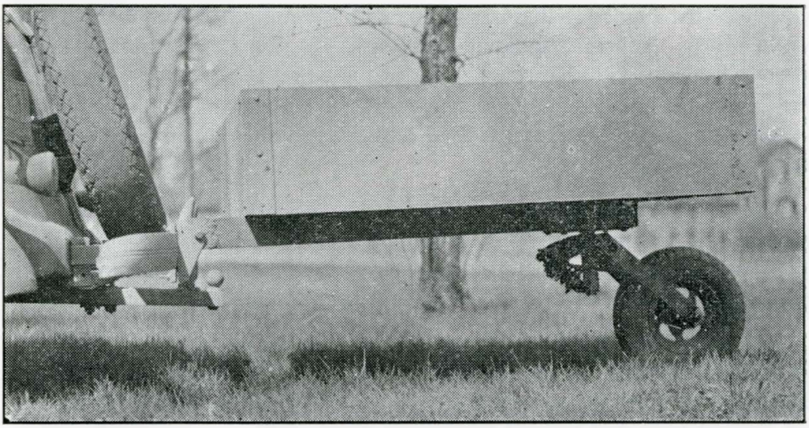

Fig. 18. The caster wheel trailer with hinged fork and spring mounting.

tire was a straight side wall casing using an inner tube. The hub carried two roller bearings and a 5/8 inch shaft.

The remaining parts of the trailer were homemade, required some cold metal work and some welding in addition to the building of a plain rectangular wood box with the bottom and sides of pine lumber.

A rigid "A" shaped frame was made from 3 inch channel irons and a 2 inch pipe. The ends of the "A" frame were secured to the car bumper by special hinges, so that the trailer could be disconnected from the car by removing two bolts. To the rear part of the "A" frame a heavy piece of sheet steel was bolted. This sheet was 8 inches square and ¼ inch thick. In the center of this a hole was bored and the upright shaft was fastened which supported the wheel. This part was the most difficult to make and several parts were broken before the caster wheel bracket and part worked satisfactorily.

The ¼ inch steel plate was adequate. A 1 1/8 inch steel shaft was found satisfactory for the upright part but the attachment to the plate had to be very strong. In one case a large bevel pinion was welded to the top of the plate and drilled out to take the 1 1/8 inch shaft, which was then welded into the pinion. In the other case the shaft was extended through the plate about 2½ inches, brazed securely to the plate, and then the upper extension strengthened by brazing in strap iron braces.

One caster wheel was made without springs. While this operated quite well on smooth roads it did bounce the box a great deal and was noisy. The caster wheel without springs is not recommended even though it is easier to make than the one with springs. Fig. 17 shows this type of wheel. The arrow points to an adjustment on one arm that was used to align the wheel. The wheel must be aligned so that it is in line with the upright shaft on which the bracket turns. Any misalignment will cause the wheel to wobble at high speeds. If there is any chance whatever of the wheel being out of alignment due to poor workmanship or inadequate tools, an adjustment should be placed on one of the arms. When this is done the wheel can be properly set after the trailer is assembled.

Fig. 18 shows the spring mounted wheel. Such a wheel and bracket require careful measurements and good workmanship but can be done in the shop where welding or brazing equipment is at hand. Materials consist of various sizes of pipe, strap iron, and springs from old machinery.

A one-page blue print describing this caster wheel trailer can be obtained by sending 10 cents to the Agricultural Engineering Experiment Station, Brookings. In ordering the wheel and the tire one should specify a high speed ball bearing with dust seals, if much high speed work is to be done with the trailer.

Advantages:

1. The caster wheel trailer can be backed up any time or any place with the same ease that the car alone can be backed up. This is a distinct advantage in some yards, or lanes where turning space is limited.

2. The trailer requires very little space to store it.

Disadvantages:

1. The carrying capacity is limited to about 600 pounds.

2. The trailer is not as easy to attach as the two or four wheeled kind.

3. On slippery roads the trailer, if loaded heavily, makes driving unsafe by making the car sway.

4. On roads with ruts, steering of the car is affected by the caster wheel following along a certain rut.

Fuel Required for the Caster Trailer

The caster wheel trailer weighed only 165 pounds and therefore did not require a large additional amount of fuel to pull it. Fig. 19 shows the results of several tests at various speeds and loads on asphalt roads. The curves obtained from the tests on dirt roads were similar in shape but the mileages were some lower for all respective speeds.

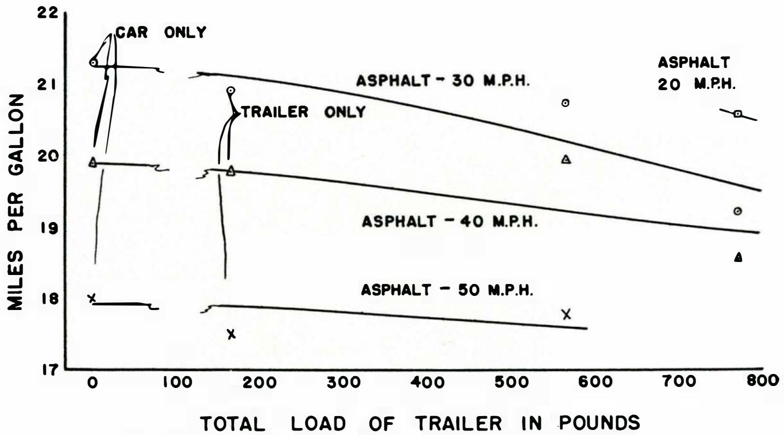

Fig. 19. Fuel consumption curves for the caster wheel trailer.