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THE HISTORY, MANUFACTURE AND PHYSICAL TESTING
OF THE WOOD WHEEL

ROBERT F. GRAY

1921

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**The History, Manufacture and Physical
Testing of
The Wood Wheel.**

**A Report Submitted to the Faculty
of
Michigan Agricultural College**

by
Robert E. Gray
Robert E. Gray

**Candidate for Degree of
Bachelor of Science.**

June 1921.

THESE

INTRODUCTION.

The material and data for this report was obtained from the various automobile magazines and other engineering periodicals available at the College, State, and Lansing Libraries and deals with the wheel from its earliest mention in history up to its present state of development and perfection.. Notes were taken from these various magazines and all the available sources of information were exhausted. The report has been built up on the more valuable portion of this data.

The construction of the wheel was studied at the Prudden Wheel Factory. Every detail of the construction will be taken up from the importing of the raw material to the complete product ready for use on a car.

After the construction has been taken up as thoroughly as possible I will deal with the various tests run on the wheels to determine what lateral strains they will stand and how much deformation these strains will produce, the strength of the felloes and spokes under various conditions, and what effect hub flanges and bolts of various sizes have on the ultimate strength of the wheels.

All of the construction data has been obtained thru the kindness of the Prudden Company. The tests

were run at the Michigan Agricultural College Testing Laboratory by Mr. Jones and Mr. Blades, engineers with the Prudden Wheel Company, and myself. Some of the test data, however, was obtained from tests made previous to my entering upon the work. Mr. Jones, however, explained all of these tests to me and I drew some of the curves from the data they obtained so I was thus enabled to become familiar with the data even though I did not work on these tests personally. Some of the time that I spent down at the factory was spent in the office drawing up curves from the various tests showing comparative value of the materials under the tests and how the wheel acted under the conditions it was subjected to.

The above gives the extent of the material and authorities used in this report, and in what follows I will try to compile it in as logical and interesting manner as possible.

INTRODUCTION.

For every one of man's purposes some one thing has been found to be the most efficient. In every case this one thing has been determined by actual usage and actual experience.

Throughout the ages we have experimented with all sorts of methods, with all sorts of mechanical devices, with all kinds of raw materials, until at the present time there is a generally recognized best method, best device and best raw material for accomplishing every desired result. The business of making wheels for motor vehicles is no exception to this rule.

Every experiment, every test, has proved beyond the shadow of a doubt that certain varieties of hard wood, constitute the best material for the making of these wheels. From our most ancient records we learn that wheels have always been made of wood. Possibly the first wheels were merely sections of round logs used as rollers. Later man learned to make solid wood wheels such as we still find in general use among the more primitive peoples.

The introduction of the wheel made of spokes, hub and felloes came along naturally as man learned more about mechanics and woodworking, and finally we have evolved the modern wood wheel with its superior construction, its great strength and its undoubted fitness. We have improved on the wheel as a mechanical device, but we cannot improve on the wood as a basic material,

The long continued use of wood as a wheel-building material has had the effect of blinding us to the obvious advantages of wood, just as the long use of wool has caused us to forget just why wool is ideal for this purpose.

The following is some of the reasons for the continued use of wood for wheels and why it will be the material used on motor vehicles for some time to come:

1. Its strength as proved by ages of use without failure to meet every practical test.
2. Its capability of absorbing road shocks.
3. Its long life under all conditions of road and climate.
4. Its freedom from flaws and unseen weak spots.
5. Its ease of repair.
6. Its lightness in proportion to its strength.
7. Its low cost.

These are the properties that wood wheels have always possessed and which they will continue to possess. These are the advantages which will cause them to hold first place as long as motor-driven vehicles are run upon roads and streets.

It is an absolute fact that the strength of a properly designed and well manufactured wood wheel, whether for a light passenger automobile or a commercial truck, has never been questioned by anyone. This for the simple reason that wood wheels have proved their ability to carry any load which a motor can propel and upon any roadway over which a vehicle can be driven.

Of course, wood wheels are made in various sizes and weights for different vehicles and different loads. Yet, strangely enough, investigations have shown that in spite of the fact that vehicles, especially commercial trucks, are almost constantly carrying heavier loads than they were built to carry, the wood wheels have actually outlived the vehicles. Investigations recently made by a tire manufacturer to determine the excessive wear upon truck tires established the fact that motor trucks are being overloaded constantly without damage to the wood wheel. In one instance a truck designed to carry three tons was regularly carrying loads averaging seven and one half tons. The wood wheels were in perfect condition.

While it is the general practice of truck users to load a truck with as much merchandise as the truck space will accommodate, regardless of the weight of the goods, instances of wood wheel breakage are practically unknown.

The property which a wood wheel has of absorbing shock is undoubtedly one of its greatest advantages. It not only enables the wheel itself to stand up under the most severe road conditions, but prevents the deterioration of the other parts of the vehicle.

Wood wheels mean less unsprung weight, greater mileage from tires, longer life to the motor, less wear and tear upon the springs, axles, bearings and the body of the car or truck. The wood from which wheels are made possesses considerable elasticity in addition to its toughness and strength.

When a wood wheel strikes a rough spot in the road

therefore, it does not transmit the full force of the shock to the other parts of the car. It gives a little and because it gives, it absorbs the greater part of the shock, with the result that the other parts of the car or truck are easily able to take care of their respectively smaller shocks without excessive vibration.

Excessive vibration, which results when more rigid than wood are used, not only causes bolts and nuts to loosen and the mechanical parts of the car to wear upon each other, but it very soon causes the metal parts of the car to crystallize and develop flaws and cracks which in turn are responsible for breakdowns, costly repairs and disastrous wrecks. It is perhaps needless to state that this vibration and its inevitable consequence, crystallization, greatly shorten the life of the vehicle.

An interesting case along this line is found in the experience of the London Omnibus Company with wood wheels. For years the big London buses were equipped solely with wood wheels, and in spite of the cobblestones over which most of the buses traveled, the wood wheels gave perfect satisfaction. Then partly as an experiment and partly because of important difficulties due to the war, the London Omnibus Company equipped a number of their new buses with wheels other than wood. The new wheels were given a thorough test, with the result that the company is now replacing the new wheels with wheels made of wood.

A wood wheel, properly made to support a given load,

has been found almost invariably to outwear the car or truck on which it has been used. In the rare cases where wheels have broken down, investigations have shown that they were either grossly overloaded or subjected to other abuses. While it is almost impossible to find instances of breakage or wearing out of wood wheels, examples of the wood wheels outwearing the vehicles upon which they are used are almost without number.

Extremes of climates and temperature seem to have little effect upon the wood wheels, for they have demonstrated their ability to stand up equally well in all parts of the world.

A striking example of the long life of wood wheels under all possible road conditions as well as weather and temperature conditions is found in the famous which to date has been driven 270,000 miles or 250 miles a day for three years, from one end of the country to the other. The fact that this test was made only to demonstrate the wearing qualities of the bearings makes the performance of the wood wheels all the all the more remarkable for no effort was made to secure especially strong wheels.

Not only are wood wheels made from the strongest and toughest woods, but from the most perfect specimens of this wood that it is possible to secure. A flaw in a piece of wood is easily detected, so that by the time a billet is worked into spokes and material for felloes, the slightest flaw or weak spot is almost certain of discovery. The

smallest flaw or imperfection should send the wood to the waste pile. Wood being comparatively inexpensive, there is no incentive for a wheelmaker to take chances on anything short of perfection. When a wood wheel passes its final inspection it should be a perfect wheel.

Wood wheels are considerably lower in cost than wheels made of materials other than wood.

Wheels may be reckoned among the oldest mechanical devices, and the fact that we have been so long accustomed to them with the little obvious change, combined with their ubiquity, has tended to obscure the they play in all forms of traction. With the exception of the bullock sleighs in maderia, and perhaps a few other places governed by special circumstances, wheels are used for vehicles of all classes, from the wheelbarrow to the coach or the racing car, and though a man, a team of horses or a motor be required to propel them, they would all be quite unequal to the task were it not for the unconsidered wheels upon which they run.

While the wheels should, of course, always be suited in construction to the class of vehicle on which they are to be used, in case of vehicles drawn by horses or other means extraneous to themselves, the only function of the wheels is to carry the weight, and they play no part in propelling the vehicle. The advent of the cycle, however, introduced other considerations into the design of the wheels adopted to the purpose.

In the earliest prints of the bicycle, which was known

as the "bone-shaker" period, we find it fitted with iron-tired wooden wheels, in fact the usual wagon type of wheel.

This proved too cumbersome and uncomfortable, and gave way to the lighter wire wheel with rubber tire, but still with straight spokes. Then it was found since the propulsion force was no longer extraneous to the machine, but was transmitted thru the hub and spokes, that this arrangement was not entirely satisfactory, and accordingly tangent spokes were introduced.

Again, solid rubber tires were cemented to the rims, and, with the force of propulsion acting thru them they used to stretch and roll off. Were it not for the introduction of the cushion or the pneumatic tires, with the different methods of attachment, no doubt the natural sequence would have been to wire on solid rubber tires, as is done today in the case of perambulators and motor vehicles using this form of tire.

The introduction of the pneumatic tire was at first not so much an outcome of conditions necessitating its emplacement, but a desire of greater comfort, and it is apparent that without its use speeds would never have increased as they have.

The motor or self-propelled vehicle has again necessitated changes in the design of road wheels, but the conditions governing those modifications have differed considerably in nature as well as in degree, and were at first but little realized or understood. To some of us of the present

day who " know all about it" it may, perhaps, cause a little wondering amusement of our exemplars of a previous decade. Thus on the introduction of the motor vehicle, makers in general devoted their whole time and attention to the mechanism, the new and fascinating acquaintance, as it were, while their old and treid friends were ignored. Their extreme importance, increased even beyond what it had been previously, remained comparatively unrecognized, and they were not improved to the occassion.

In the case of motor trucks for the transfer of goods, or steam wagons, the result was seen in the trials of 1898, organized by the Liverpool Self-Propelled Traffic Association, in which, the machines themselves were satisfactory for those early days, the wheels gave trouble all around.

Among the judges " conclusions" following the trials were the forms of wheels adopted by all the manufactures, though probably perfectly efficient as carriers, were all structurally more or less inefficient as drivers.

Some of the wheels were of wood of the ordinary dray type, and others were of steel with straight spokes cut out of steel plates and given a twist where they were risted to the hub and fellow. In every case the propulsion force, or drive, was communicated, whether by chain or gearing, thru the hub or thru a ring attached to the spokes and, therefore, the spokes and their attachments had to stand the strain of driving. But in the case of the steel wheels, at least, it is probable that this cause alone was not responsible for

their failure, and that the set and the cobble roads over which they were driven had much to do with it.

As a result, steel wheels were abandoned and the heavy type of wooden artillery wheel became the standard for all motor car work. With this type trouble was at first experienced with the tires. The usual practice with wooden wheels hitherto had been to weld up a ring for a tire and heat and shrink it on the felloe.

It was found, however, that the tires would soon roll out and crack, while with the tires of the section it was desirable to employ (about 5" wide X $7/8$ " thick) the mass of metal was such as to cause charring of the wood felloe in the process of shrinking it on; and the subsequent jarring, caused the tire to become loose by reason of the breaking up of the burnt wood at the felloe surface. The final practice with this type of wheel, and very nearly the same as that used at the present day, is the use of weldless steel hoops and to press them comparatively cold onto the felloe by means of powerful presses or setters.

In the construction of a driving wheel for motor vehicles are the principal practical considerations, and they may be taken as the conditions necessary for a perfectly satisfactory wheel:-

1. It must be capable of carrying the required load, which, in some cases, may be as much as five tons per wheel, and with this strain it must be able to withstand the strain of being driven over the ground at considerable speed.

2. It must be capable of transmitting power thru itself, either from the hub or a chain ring attached to the spokes at a point intermediate to the hub and felloe.

3. It must be of sufficient diameter and width of tire, the latter particularly, to enable it to run over ordinary roads without cutting them and so absorbing a large amount of the power.

4. The tire must be such, apart from width merely, that it does not damage the road.

5. The tire must also be such that it will not spin or skid under slippery conditions of pavement, greasy roads or in frosty weather.

6. The wheel must be sufficiently resilient to insure for it a reasonable life without jarring to pieces when running over very hard, uneven ground, such as set paved roads.

7. The wheel should not be unduly expensive either in cost or maintenance, though in importance the former is of minor moment compared with the latter.

In the case of pleasure cars and the lightest class of good vehicles, the problem is much simplified by the possibility of employing solid rubber or pneumatic tires. Where the latter can be used, the only considerations of real moment are numbers 5 and 7, slipping should not be such as to damage the roads. The problem of how to prevent spinning and side slipping is, perhaps, the greatest which confronts all motor users.

The influence of speed on the type and construction of wheels is very considerable and the greater the speed the greater the demands on the wheel for strength and stability. Side-strain, dishing and driving strains are the most important factors to be reckoned with in the design of wheels. As the loads to be carried become larger the general design of the wheel is not changed but of course its parts are proportioned to the extra weight and power required.

Of all the various types of steel, wire, and wood wheel developed up to the present time, the builtup, wood, artillery type of wheel has proved the most satisfactory on all of the above seven points.

"The wheel has not unjustly and unreasonably been claimed to be the greatest of human inventions" said the late A.M. Wellington, in one of his characteristic editorials in the Engineering News. One needs only to reflect that practically all transportation by land is now and has been for centuries past dependent on the wheel to perceive the forcefulness of this statement. Without the aid of the wheel burdens could only be carried on the backs of animals or by dragging, and at a correspondingly great expenditure of power. Such methods were all right for nomadic tribes. The North American Indian, for example, never had any means of transportation other than their ponies backs and their dragging lodge poles, even when they inhabited a level, treeless country, where wheeled

vehicles could easily have been used. When the change to a pastoral life was made, however, in the early dawn of civilization, the need was felt for better means of transportation. The simple idea of cutting two disks off the end of a round tree trunk, and thrusting a straight stick thru their centers to serve as an axle was doubtless developed by many different tribes and races. This may be accepted as the most probable manner in which the first invention of the wheel was made, although the actual facts, both as to this and the latter type of built up wheel are lost in the mists that surround the early development of the race.

The wheel, then with all its parts: hub, spokes, felloe and tire was developed long prior to the advent of the engineer. Its organs were fashioned and adapted to their special work with little idea in mind as to the nature and character of the stresses to be sustained. It represents one of the most remarkable examples of the work of evolution as applied to mechanical development. The engineer of today may apply his most careful and searching analysis to the structure which uncounted generations of wheelwrights have developed; and when he completes his task he can suggest no improvement on the wheel they have made so long as it is confined to the duty it was designed to do and has done for so many years.

Within recent years, however, a new element has come into the wheel problem, and that is the design of wheels

for self-moving vehicles. Builders of traction engines have struggled with this problem for many years; but their difficulties did not attract much attention; and it was not until the bicycle came to be designed that the new element in the wheel problem came to general notice.

The wood spoke wheel, as ordinarily made for carriages, is wholly unsuited to withstand such strains as would be brought on it by making it fast to its axle and applying a rotating force to the latter. Such a force sets up a bending stress in all the spokes tending to break them off close to the hub. More important even than this in bicycle design, however, was the problem of making a very light wheel of very large diameter, such as was used on the old high wheel bicycle or "ordinary", which was really the first successful vehicle for self-propulsion.

The old wooden wheel was for this for several reasons: First, the "dish" of the wheel had to be sacrificed, and with it a large part of the wheel's strength and stiffness. Second, the very small spokes necessary in so large a wheel became so long and slender that they were very weak as compression members. Third, the size of the felloe and the tire necessary to receive wooden spokes made the wheel too heavy.

It was to meet these conditions that the present, well-known type of bicycle wheel, with its tension spokes

of steel wire, was designed, and it is an admirable adaptation of means to an end. So strong a hold did it take on popular favor, that when the "high-wheel" was displaced by the "safety", our present type of bicycle, the suspension wheel was retained; and it was extensively used on light horse-drawn vehicles. Whenever it has been attempted to place any considerable loads on this type of wheels, however, or to use them on rough roads, or without the protection of shock-absorbing, pneumatic tires, the weakness became at once apparent.

Those who have given the most study to motor-vehicle development acknowledge that one of the most important problems today is what type of wheel should be used. The imperfections of existing types are coming to be recognized, and there are few more inviting problems to the inventor than the question how materials can be fashioned to meet the demands of the present day. It may be of interest, therefore, to consider some of the problems that should be born in mind by those that would solve this problem.

In the first place it should be noted that the material or timber suitable for wood wheel construction, is every year becoming more scarce and hence more expensive. American carriages became noted the world over for their remarkable combination of lightness and strength; but this in general was due to the abundant stores of hickory that was then available. If we are rightly informed the supply

of straight-grained hickory timber in the United States is rapidly dwindling. Vast supplies have been obtained from the forests of Arkansas, and this supply is rapidly becoming exhausted. When our at present dwindling supply is exhausted what will take its place? Even if we grant that other supplies will be found and that other woods will be utilized, it still remains certain that the cost of good wood wheels is bound to increase; and there is more incentive, therefore, for those who would develop a metal construction.

The shock-absorbing qualities of wood wheel over a metal wheel is a point in the formers favor. To make it more fully understood the manner in which a wood wheel absorbs shock, I will explain in the following:

By dish is meant the inclination of the spokes to the exterior plane of the rim or to the normal plane, to the center line of the spindle. The dish (in wheels with simple dish) is practically balanced by the "carrossage", the inclination of the spindle to the center line of the axle. It results from this fact that the lowest spoke of the wheel is very nearly vertical on horizontal ground.

The object of dishing the wheels is to give them more elasticity and strength. The dish has the effect of transforming the spokes into just so many springs rigidly connected to each other, and subjected to bending stresses; it makes of the wheel a conical surface, capable of being slightly deformed in an elastic manner, and which has,

therefore, a certain flexibility which it would not have if the wheel were a plane in form. In the last case the spokes would work solely under compression and successively in such a manner, that all elasticity disappears. For wheels elasticity is one of the most important features; they are continually subjected to violent shocks from the axle and from the ground. If they were of a single piece and devoid of elasticity the shocks would deform them little by little, and would finish by destroying them entirely, while, if the shocks are divided over several pieces, possessing a certain flexibility then the destructive force is greatly reduced. As the points struck may give a certain amount under the influence of the speed impressed by the body causing the shock, the pressure at any moment is made feebler than it would be in the case of a shock against a non-elastic body, and the effects are much lessened. On the contrary, on a non-elastic roller in a single piece, the diameter of the box increases rapidly as a result of these shocks, and the box is rapidly rendered useless. From what I have said, it follows that absolutely rigid wheels are not very suitable for vehicles intended to run at high speeds. Thus it has also been found that wood wheels with double dish (double rows of spokes as in bicycle wheels), good for heavy transport vehicles, which are drawn at a walk on smooth roads, get very rapidly out of shape, if employed on vehicles drawn at a trot, and on slightly rough roads. It

has been found the same of wheels of two rows of spokes all inclined in the same direction, but with a different dish for the two sets, which the english employed in 1900, and which gave them bad results. None of these wheels are applicable to automobiles, except if they are provided with pneumatic tires, or at least elastic tires.

We might make an exception, however, of the metallic wheels constructed and assembled like wooden wheels, and which have, consequently, a certain elasticity, if these wheels did not have other disadvantages from the standpoint of their use on automobiles.

The dish which gives the wheels their elasticity, which is really an indispensable quantity, also gives them the strength necessary for transportation over rough roads. The conical form which the dish gives the assemblage of the spokes, solidarizes them, one with another, and forces them to work together, which they would not do if they were in the same plane. On the other hand, this same conical form is the cause that the different parts always work in the same direction, the same face of a spoke always working on the same face of the hub, and on the same face of the rim, the pressure being always in the same direction. Contrarily, nothing is more unfavorable to the conservation of wheels than to have to undergo strains which come alternately from two opposite directions, which would be the case with a flat wheel. It results from this that if the wheel receives a lateral shock, such as

experienced when skidding or striking a curb, or runs on a ground inclined in the direction of the axles, one of the wheels is working in a direction in which it is impossible for it to give. Under these circumstances, two flat wheels have less strength than the one dished which works in the direction favorable to the strength, as both offer but little resistance to lateral forces which tend to force the wheels outwardly.

As pointed out above, the tension spoke wheel naturally suggests itself when the design of large wheels is attempted; and it may be well to explain the causes of the weakness of tension spoke wheels, to which allusion has already been made. In the ordinary wooden wheel, the spokes are all under compression, and the weight on the axle is carried vertically down to the ground by the spoke which is vertically under the hub. In the tension spoke wheel of which the bicycle wheel is a familiar example, the weight on the axle is carried to the top of the wheel and has to be transmitted all the way around the rim to the point diametrically opposite, where the rim is supported by the ground. The stresses in the rim may be likened to those in two very slender semi-circular arches, which are held from deformation by the pull of the spokes. The weak part of the tension spoke wheel was hardly realized in the early days of bicycle manufacture, and it was not until the failure of the light steel rims used on some of the earlier that the stiffer and heavier wooden rim, with its greater

resilience to absorb shock was submitted in its place.

From the above analysis, it will be seen at once how the difficulties thicken in the way of securing sufficient strength of rim, as the diameter of the tension wheel is increased.

In fact, the rims soon become so large as to make them unsightly, and even then it is notably deficient in strength and elasticity to resist shocks due to passage over obstacles, and the lateral stresses which every four-wheeled vehicle imparts to its supports but which are entirely absent in the bicycle.

So far as can be seen, the compression spokes must be the feature of a successful wheel for motor vehicles. If they can transmit tension as well, so much the better, or possibly a combination of them with tension spokes may be an advantage. The wheel, with purely tension spokes, however, is so inherently defective that it should be discarded by motor vehicle builders, and in fact already has been in many cases.

I have alluded before to the necessity of making the wheel itself sufficiently resilient itself to absorb without injury the shocks and jars of rough roads and rapid service. It is doubtless here that the designers of metal wheels for motor vehicles will meet their chief difficulty. The quality desired is resilience, the power to absorb shock.

At the present it can only be said that hickory has

probably considerably more elasticity per pound of weight than the best steel. The metal wheel designer, therefore, must seek to compensate for this defect in his material by making the different parts of his wheel work together more perfectly to absorb shock than can be done in the wooden wheel, with more or less imperfect connections.

I don't wish to claim that the metal wheel alone is the wheel of the future. Something may well be accomplished, and indeed has been accomplished, in wheels of composite construction. If hickory fails, other woods, even though less satisfactory, may be made to take its place. Other materials may perhaps be utilized; in fact the whole field is open to the inventive designer.

That it is not entirely an unworked field may be seen by looking over the Patent Office's list of patents issued on wheels.

In comparing the general design of motor wheels of all kinds with that of other wheeled conveyances one of the most striking points is the very small size of the wheels employed in proportion to the weight carried. A bicycle, it is true, has wheels only 28 inches in diameter, but the weight carried on them is generally 100 pounds per wheel or less. Ordinary light two-wheel dog carts as seen in France and other foreign countries, however, have wheels from 3 to 5 feet in diameter, even when the weight on them is only about 300 pounds per wheel, while for heavier weights than this, wheels under four feet are comparatively rare. Trac-

tion engines have wheels as large as 71/2 feet in diameter. On the other hand motor cars carrying several hundred pounds per wheel often have wheels very little, if any, larger in diameter than a bicycle, and motor trucks have wheels about half the diameter that would be considered necessary to carry the same weight at the same speed in horse-drawn vehicles. Nothing is, in fact, so striking in the comparison of a horse-drawn and a motor vehicle as the fact that although the latter weighs twice as much as the former, the newer type of vehicle has wheels little more than half the size of the older form of conveyance. It is, therefore, interesting to examine the size of wheels used in various vehicles, and the effect size of wheels has on their efficiency.

There can be no doubt whatever that, from the design-ers point of view as well as that of the constructors the smaller wheel presents several advantages. They are lighter, cheaper, and put less strain on the axles. In many cases it is a matter of greater simplicity to place the platform of the vehicle at the height required if the wheels are small, and it is always easier to arrange for the necessary lock on the steering-wheels.

I practice the principal points which limit the size to which wheels can be reduced for a given load are the vibrations caused by the small wheels moving over the inequalities of the road, and the destruction of the road from too great a concentration of the load. Both these depend to

a large extent on the surface of the road, and the size of the wheel depends primarily on the latter.

Having taken up the historical developement of the wheel from its earliest mention in history until its present stage of developement I will next take up the manufacture of its parts and their assembly in to the complete product, the wheel itself.

The raw material, which is straight grained hickory is obtained from the natural sources of it that still exist in the forests of Georgia and Arkansas. The trees that are to be used are marked by an inspector. They are then cut down and sent to the saw mill where they are sawed up into the proper lengths. It is again inspected and the inferior specimens are discarded.

After the inspectors have picked out the pieces they are to use they are sent to the shops where they are turned into spokes and others cut into the proper lengths for felloe billets. This is all done right near the saw mill so that none of the waste is shipped up to the factory and thus the loss of freight charges on this waste is saved. The material when it reaches the factory is green, but with the exception of the work that it is necessary to do on it to make it a complete wheel, it resembles the unassembled parts of the wheel. The spokes are all turned and the only further processes that are performed on them are mitreing, cutting to length, cutting the tenon and drying. The felloes are in the form of two inch billets about three feet long when they reach the factory and the only further operation on them outside of cutting them to

size and drilling the tenon holes for the tenons on the spokes is the finishing and drying process.

After the stock reaches the factory it is put into drying kilns where it is seasoned and dried before it is used for the finished product. These drying kilns, as they are called, are rooms of brick construction about 50 x 20 feet and are generally located in the basement of the factory. The system is an air drying system, the warmed air being admitted to the kiln by twelve inlets 10 x 10 inches, there being six of these inlets on either side of the kiln. The floor is of concrete and has a false floor over it to enable the air to circulate freely around the green wood and be in contact with it at all times. The doors are of the rolling type, being hung from above, and making it possible to have the kilns quite tightly sealed as is necessary. The green wood is trucked in to the kilns in the form of billets. The green wood is allowed to remain in the kilns for twenty-one days to completely dry and season it.

After the wood is seasoned and dried in the kilns, the manufacturing of the wheel begins. I will first take up the various processes in the manufacture of the felloe, which is the part of the wheel over which the tire fits.

Upon coming from the drying kilns, the billets from which the felloes are made are put into an oven where they are kept from 25 to 35 minutes depending upon how dry they are. The steam used in these ovens is at about 35 pounds pressure and is exhaust steam from the power plant. When

the felloes have been in this oven for a sufficient length of time they are removed and placed in a machine where they are bent into a semi-circular form around a template by hydraulic power. They are then clamped in this position and taken to the next operation where the clamp is removed and replaced by a half inch board nailed across the end of the felloes radially to keep them in the same position they were set in by the press. From here they are either taken to the drying kilns again where they are seasoned some more or to the store room where they are held until they are taken to the next operation.

In the store room, which is a large size room, the felloes are piled up and kept at an even temperature of 80 degrees Fahrenheit. To facilitate the maintenance of this even temperature swinging doors are provided which prevents air changes from taking place by the doors standing open. Heating coils, which encircle the room, furnish the required heat.

The felloes are taken from the store room as needed into the shop proper. The holes that receive the tenons of the spokes are first drilled and then the felloes are sawed to the proper length. They are then finished up and inspected and this finishes the operations on the felloe and nothing more is done on them until they are assembled into the complete wheel.

The spokes being already turned when they reach the factory are mitred and sawed to length and then the tenon

is turned on. In the former process named the ends of the spoke that fit into the hub are cut at an angle so that they will fit into the hub and tightly together also. This is done on a machine consisting of two knives set so that when the operator of the machine pulls on a little lever these knives come up and cut the required mitre. The spokes are then sawed to the proper length. The tenon on the end that fits into the felloe is then turned and this finishes the operations on the spokes.

The felloe bands that encircle the wood felloe are made of sheet steel. This steel comes to the factory in the form of large sheets. These sheets are cut up into pieces of the proper length and width and welded into a circular form. They are then run thru a series of rolling mills where they are put into the form to receive the tire or tire mounting as the case may be.

The hubs used on the different types of wheels vary quite a good deal. They are either cast or drop forged and are received at the factory in this form. The only operation performed on them is machining and trueing them up to size.

Having gone thru the manufacture of the different parts of the wheel I will now take up the method of assembling them into the finished wheel.

The first operation in the assembly of the wheel is putting the spokes into the felloes. This is done by means of a small press which is continuous in operation. The operator of the press places the tenon of the spoke into the hole drilled for it in the felloe to receive it and the

ram of the press comes down and presses the spoke tightly into position. The spokes are put into the felloes while the latter are still in halves and then these halves are assembled.

In assembling these halves of the wheel the halves are properly placed around a dummy and placed in a large press. When this press presses the halves firmly together the bolts in the dummy hub are tightened up and the wheel from here goes to the inspectors who inspect the wheel thoroughly and either allow it to continue to its next operation or reject it. These inspectors examine the condition of the spokes and felloes and if they are defective they are so marked and the defective parts are removed. After the defective parts have been replaced by good parts the wheel continues on to the next operation.

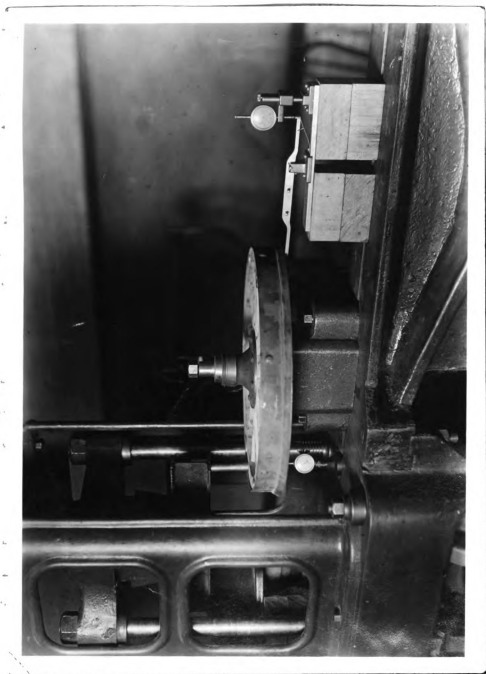
If passed by the inspector the wheels go to the next operation where the outer face of the felloe, over which the felloe-band is pressed is finished and trued up. This is done on a circular planing machine. The planing knives are circular in form and plane the face of the felloe as it is brought up against it.

The steel felloe-band is next pressed onto the felloe. The bands are heated up to about three hundred degrees Fahrenheit and then they are pressed onto the felloe by a large press. It was found in this operation that it was good practice to have the bands at 300 degrees and no

higher. If the temperature is higher the felloe surface is liable to be burned and charred and this would give a defective wheel. At this temperature the rims expand just enough to be forced over the felloes without damaging them. If the rim is not hot enough when it is pressed onto the felloe the band is liable to stretch and the felloe is liable to be checked and the entire wheel ruined so a careful check is kept on the temperature at which these bands are pressed onto the felloes.

After the felloe-bands have been pressed on the holes for securing the tire to the rim and the rivets which secure the rim to the felloe are drilled. The rivets are then put in place and the felloe and spokes are then sand-dand the tire lugs put in place on the felloe.

The dummy hub is removed at this point and the hole in the center of the wheel which receives the hub is cut to the proper size to receive the permanent hub on a vertical boring mill. The hub is then seated and the holes for the bolts which hold it in place drilled and these bolts put in and tightened up. The wheel is then complete and is taken to the freight car on the siding and after being properly packed is shipped to the company who ordered it.



TESTING.

The following tests were made in the M.A.C. Mechanical Testing Laboratory to determine the strength of the various parts of Reo and Olds wheels and to determine what their behavior would be when subjected to these various tests. All of these tests were performed on the large 100,000 pound Riehle Testing Machine. These tests were run by Mrs. Jones, Blades, Davi and the author, two of us at all times being present. One man ran the machine and the other read the gages and recorded the data which will be given here along with the rest of the details of each test.

Before taking up each test a complete discription will be given of the setup, object of the test, the value of the data obtained, how the curves were drawn, and a complete discussion of the results.

The method of set up is shown in the accompanying photograph and will show clearly how the wheels were set up for the tests.

The following test was made Reo wheels with both wood and steel felloes. All of the wheels had pressed steel hubs and were not equipped with rims. This test was run to show the relative strength of spoke tenons in the wood and steel felloe wheels

PROCEDURE: This test was performed on the large, 100,000 pound testing machine in the M.A.C. Testing Laboratory. The wheels were held on an arbor which fitted into the hub the same as the axle does when it is mounted on a car for use. The load was applied at the felloe, directly over a spoke tenon. A strain gage was placed directly under the place where the load was applied and another 180 degrees from this point on a similar point on the felloe. The gage at the point directly under the point where the load was applied gave the deflection down which was read for each increment of load of 200 pounds. The gage placed 180 degrees from this point was read for the same increments of load. The former gave the deflection down for each load and the latter gave the deflection up for each load. At every additional load of 600 pounds or at increments of 600 pounds the entire load was removed from the wheel and the permanent set up and down read on the gages and recorded on the data sheets.

Before the wheel was assembled all of the spokes were weighed to give a uniform weight of 7-3/4 ounces per spoke and an average quality of wood was used. The hub used was the pressed steel hub, with the regular loose flange, as is

now being used on Reo production wheels.

I am including a copy of the original data sheets so that it will be possible to show some of the outstanding points of comparison.

The accompanying curves were drawn from the average results, taken at increments of 600 pounds, and show the relative strength of the tenons of the wood and steel felloe wheels. One set of curves called the "permanent set curves" shows, upon examination, that for the same load the steel felloe wheel takes a greater permanent set than does the wood felloe wheel. This indicates that the wood is the better material for felloes as for the strains put on it due to skidding, spinning and striking the curb when in use on a car would be less liable to produce a permanent disalignment of the wood felloe wheel than in the case of the steel felloe wheel. The average deflection for both wheels seems to run pretty close for both wheels.

Sheet No. 1.

Running Log of:- Reo 23 x 4 steel felloe wheel, with hub.

Observers:- D. Jones, H. Blades, M. Davis, R.F. Gray.

Date:- April 12, 1921.

Load in pounds.	Defl. Down	Defl. Up	Set Down	Set Up
200	.031	.012		
400	.066	.022		
600	.101	.031	.004	.005
800	.140	.040		
1000	.182	.051		
1200	.230	.062	.022	.011
1400	.285	.073		
1600	.344	.083		
1800	.423	.095	.078	.019
2000	.515	.106		
2200	.612	.117		
2400	.738	.132	.179	.021
2600	.891	.147	.244	.036

Max. Load 3229#

Evidence of Failure in the Following Order:

#1- Cracking noise

#2- Tenons rolled in bubble slightly where pressure was applied.

#3- Spoke pulled loose from on pressure side about 1/8"

#4- Two spokes split on the pressure side at 3240#, spokes split in throat.

* Note:- The evidence of failure did not appear until after the 2600# load was applied.

Sheet No. 2.

Running Log of:- Reo wheel having steel felloe and hub.Observers:- Jones, Blades and Gray.Date:- April 12, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up	
200	.032	.006			
400	.062	.012			
600	.096	.019	.005	.003	
800	.130	.026			
1000	.164	.033			
1200	.208	.041	.021	.007	
1400	.267	.052			Max. Load 3000#
1600	.335	.064			
1800	.417	.078	.089	.021	
2000	.531	.093			
2200	.653	.110			
2400	.810	.129	.254	.045	
2600	1.073	.162	.402	.061	
2800	2.027	.224			
3000	3.067	.305	1.817		

Evidence of Failure in the Following Order:

#1- Cracking noise

#2- Tenon of no. 2 spoke rocked in felloe, opened $1/32"$ @ 2600#

#3- Spokes pulled loose from flange and mitres opened on pressure side. Opening caused from tenon rocking increased from $1/32"$ to $1/16"$ @ 2800#.

*Note:- No split spokes.

Sheet No. 3.

Running Log of:- Reo wheels- 33 x 4 - wood felloe with hub.Observers: Jones, Blades, Davis, Gray.Date:- April 19, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.040	.015		
400	.072	.026		
600	.110	.038	.006	.005
800	.143	.049		
1000	.183	.061		
1200	.223	.072	.027	.012
1400	.281	.088		
1600	.342	.104		
1800	.409	.104	.091	.026
2000	.475	.137		
2200	.565	.158	.176	.044
2400	.653	.177		
2600	.775	.204		
2800	.923	.235	.193	.071
3000	1.018	.288		
3200	1.318	.340		
3400	1.828	.363	1.018	
3580 Max. Load.				

Evidence of Failure in the Following Order:

#1- Cracking Noise.

#2- Spokes pulled out of felloe, opening about 3/16"

Tenons rocked in bubble at nos.1 and 2 spokes

Nos. 1 and 12 spokes split in throat : 3400#

Sheet No. 4.

Running Log of: Reo wheels - wood felloe - pressed steel hub

Observers: Jones, Davis, Gray.

Date: April 15, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.051	.021		
400	.101	.041		
600	.127	.050	.007	.003
800	.159	.061		
1000	.197	.074		
1200	.246	.089	.034	.011
1400	.302	.105		
1600	.360	.121		
1800	.435	.141	.092	.035
2000	.506	.163		
2200	.611	.193		
2400	.702	.216	.183	.060
2600	.832	.259		
2800	.995	.314		
3000	1.308	.379	.443	.060
3200	2.306			

Evidence of Failure in the Following Order:

- #1- Cracking noise at 2600#
- #2- Mitres opened and no. 1 spoke split at 2800# load.
- #3- No. 2 spoke split at 3000# load
- #4- Nos. 12 and 3 spokes broke and felloe split on the pressure side at Max. Load 3106#

Sheet No. 5.

Running Log of: Reo 33 x 4, wood felloe, pressed steel hub

Observers: Jones, Davis, Gray.

Date: April 15, 1921.

Load in Pounds	Defl. Upwn	Defl. Up	Set Down	Set Up
2000	.045	.014		
400	.085	.029		
600	.120	.043	.007	.004
800	.149	.053		
1000	.185	.062		
1200	.212	.070	.024	.008
1400	.265	.086		
1600	.307	.096		
1800	.368	.113	.072	.020
2000	.447	.137		
2200	.511	.151		
2400	.596	.174	.151	.040
2600	.687	.201		
2800	.797	.225		
3000	.934	.257	.331	.086
3200	1.081	.299		
3400	1.331	.358		
3600	2.331	.555	.893	.770

Evidence of Failure in the Following Order:

#1- No. 2 spoke broke at 3000#

#2- No. 1 spoke broke at 3200#

#3- No. 12 spoke broke, flange bent and sheared bolt at

Max. Load 3600#

Sheet No. 6.

Running Log of: Reo 33 x 4, steel fellow, pressed steel hub.

Observers: Jones, Davis, Gray.

Date: April 15, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.050	.009		
400	.105	.020		
600	.135	.026	.007	.003
800	.184	.035		
1000	.272	.042		
1200	.296	.051	.056	.010
1400	.369	.061		
1600	.460	.073		
1800	.565	.087	.120	.023
2000	.675	.101		
2200	.795	.117		
2400	.923	.132	.267	.043
2600	1.028	.146		
2800	1.395	.173		
2826	1.903	.195	.841	.082

Evidence of Failure in the following Order:

#1- Tenons of Nos. 3 and 9 spokes opened about 1/32" at

2800#

#2- Nos. 1, 2, and 3 spokes broke at Max. load of 2826#

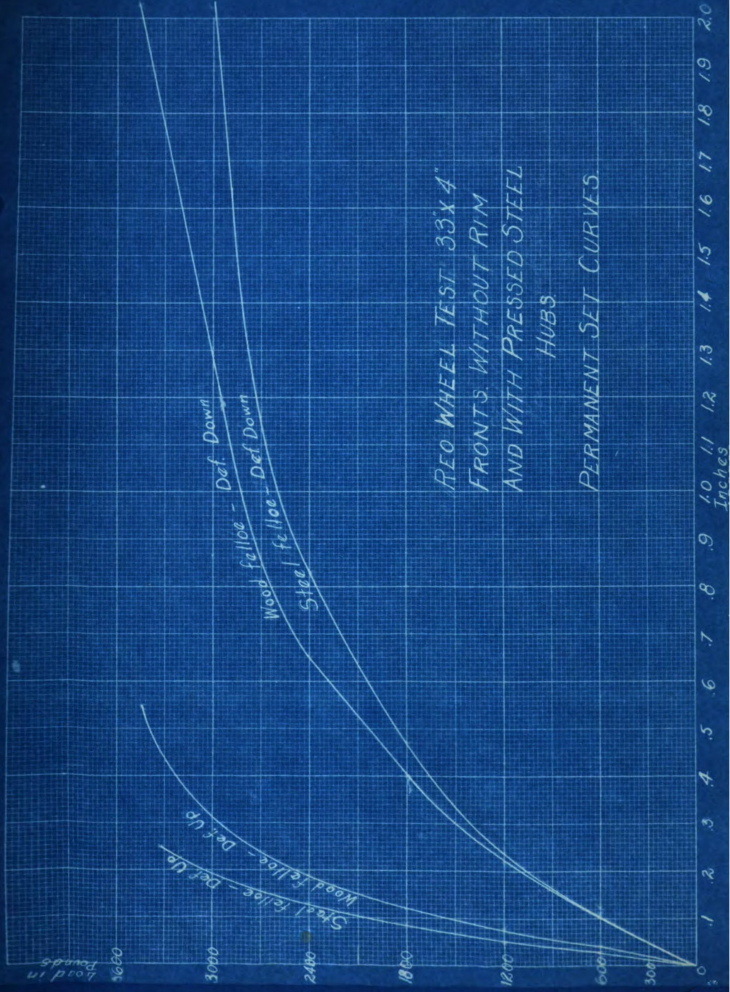
The following is the data from which the curves were plotted . The load increments were taken every 600 pounds and the curves plotted thru these points. The average deflection and set was found for the three wood and three steel felloe wheels and is given on this data sheet and the average deflection and set was used in plotting the curves.

Steel Felloe

Sheet No.						#1	#2	#3	Ave.
600	Pounds	gave	a	deflection	down	.101	.096	.135	.111
1200	"	"	"	"	"	.230	.208	.296	.245
1800	"	"	"	"	"	.423	.417	.565	.468
2400	"	"	"	"	"	.738	.810	.923	.650
Max.	"	"	"	"	"	---	3.067	1.903	2.485
600	Pounds	gave	a	deflection	up	.031	.019	.026	.025
1200	"	"	"	"	"	.062	.041	.051	.051
1800	"	"	"	"	"	.095	.078	.087	.087
2400	"	"	"	"	"	.132	.129	.132	.131
Max.	"	"	"	"	"	----	.305	.195	.250
600	Pounds	gave	a	permanent	set	.004	.005	.007	.005
1200	"	"	"	"	"	.022	.021	.050	.031
1800	"	"	"	"	"	.078	.089	.120	.096
2400	"	"	"	"	"	.179	.254	.267	.250
Max.	"	"	"	"	"	---	1.817	.841	1.329
600	Pounds	gave	a	permanent	set up	.005	.003	.003	.004
1200	"	"	"	"	"	.011	.007	.010	.009
1800	"	"	"	"	"	.019	.021	.023	.021
2400	"	"	"	"	"	.031	.045	.048	.041
Max.	"	"	"	"	"	----	----	.082	.082
Max. Load	-----					3294	3000	2826	3040

Wood Felloe

Sheet No.	#3	#4	#5	Ave.
600 Pounds gave a deflection down	.110	.127	.120	.119
1200 " " " " "	.223	.246	.212	.227
1800 " " " " "	.409	.435	.368	.404
2400 " " " " "	.653	.702	.596	.650
Max. " " " " "	----	2.308	2.331	2.313
600 Pounds gave a deflection up	.038	.050	.043	.044
1200 " " " " "	.072	.089	.070	.077
1800 " " " " "	.104	.141	.133	.126
2400 " " " " "	.177	.216	.174	.189
Max. " " " " "	---	---	.555	.555
600 Pounds gave a per. set down	.006	.007	.007	.007
1200 " " " " "	.027	.034	.024	.028
1800 " " " " "	.091	.092	.072	.085
2400 " " " " "	.176	.183	.151	.170
Max. " " " " "	---	---	.893	.893
600 Pounds gave a per. set up	.005	.003	.004	.004
1200 " " " " "	.012	.011	.008	.010
1800 " " " " "	.026	.035	.020	.027
2400 " " " " "	.044	.060	.040	.048
Max. " " " " "	---	---	.270	.270
Max. Load -----	3580	3106	3600	3429



RGO WHEEL TEST 33x4"
FRONTS WITHOUT RIM
AND WITH PRESSED STEEL
HUBS
PERMANENT SET CURVES

Load in Pounds

3600

3000

2400

1800

1200

600

0

Steel felloe - Set Up

Wood felloe - Set Up

Wood felloe - Set Down

Steel felloe - Set Down

REO WHEEL TEST 33"x4"
FRONTS WITHOUT RIM AND
WITH PRESSED STEEL HUBS.
PERMANENT SET CURVES.

.2

.4

.6

.8

1.0

1.2

Inches

Conclusions:- From the above test data, it was decided that the tenon was sufficiently strong in both the Steel and Wood Felloe Wheels since no failures were noted at this point. The first failure occurring in most cases by breaking in the mitre or the barrel of the spokes. From the permanent set curves it was found that the steel felloe wheel takes a greater permanent set, for the same load, than does the wood felloe wheel. This indicates that the wood wheel gives more and has more spring than the steel felloe wheel and therefore the wood felloe wheel is the better wheel in consideration of the resistance to the strains of skidding, spinning wheels and striking the curb. From a study of the curves it was found that the average deflection for both wheels ran just about the same. This can also be seen by a study of the data on page 37.

This test was run on Olds wood wheels with standard hubs and various sizes of bolts and thicknesses of flange stock.

Object:- The object of this test was to find the variation in the strength of wheels relative to the size of bolts and the thickness of flanges.

Procedure: The set up was the same as for the Rec Test just discussed.

Before the wheels were assembled all the spokes used in them were weighed approximately 8 ounces each and were of the same gauge. Each half of the felloe weighed 2-1/4 pounds, and the hubs weighed 7 pounds each. An average of spokes and rims were used.

I am including a copy of the original data sheets so that it will be possible to show some of the outstanding as well as a summary data sheet from which the curves were plotted the same as in the Rec Tests.

Sheet No. 1.

Running Log of: Olds wheel, wood felloe, 5/32" flange stock,
3/8" bolts, and standard hubs.

Observers: Jones, Davis, Gray.

Date: April 21, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.041	.028		
400	.085	.049		
600	.118	.065	.016	.010
800	.160	.085		
1000	.210	.106		
1200	.254	.120	.049	.019
1400	.308	.141		
1600	.361	.159		
1800	.460	.175	.091	.023
2000	.577	.197		
2200	.641	.216		
2400	.742	.247	.267	.047
2600	.867	.270		
2800	.992	.299		
3000	1.117	.337	.367	.073
3200	1.492	.396		
3400	2.055	.505		
3640	3.085	.651	.1.420	.128

Evidence of Failure in the following Order:

- #1- Spokes pulled down about 1/16" from flange on pressure side at 3200#
- #2- Cracking noise. No. 1 spoke split in head thru bolt hole at 3400#; Lower part of flange bent down at same load about 3/8".
- #3- Max. Load 3640#

Sheet No. 2

Running Log of: Olds wheel 32 x 4, wood felloe, 5/32"

flange stock, 7/16" bolts and standard hub.

Observers: Jones, Davis, Gray.

Date: April 21, 1921.

Load in pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.022	.017		
400	.081	.041		
600	.109	.068	.008	.005
800	.155	.095		
1000	.176	.105		
1200	.216	.124	.017	---
1400	.257	.142		
1600	.306	.161		
1800	.406	.195	.050	.012
2000	.406	.195		
2200	.463	.213		
2400	.533	.233	.099	.019
2600	.617	.253		
2800	.687	.271		
3000	.790	.296	.185	.034
3200	.960	.336		
3400	1.397	.407		
3526	2.522	.590	1.272	---

Evidence of Failure in the Following Order:

#1- No. spoke pulled down from flange about 1/32" on the pressure side.

#2- Cracking noise at 3400#.

#3- No. 1 spoke split in head thru bolt hole and lower part of flange bent down about 3/8" at 3526#.

#4- Max. Load 3526#.

Sheet No. 3.

Running Log of: Olds 32 x 4, wood fellow, 5/16" flange
stock, 7/162 bolts, standard hub.

Observers: Jones, Davis, Gray.

Date: April 21, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.			
400				
600	.137	.074	.031	.012
800				
1000				
1200	.249	.---	.045	.016
1400	.335	.162		
1600	.365	.175		
1800	.397	.187	.075	.023
2000	.448	.205		
2200	.500	.222		
2400	.562	.240	.115	.032
2600	.665	.268		
2800	.759	.296		
3000	.884	.329	.237	.059
3200	1.040	.367		
3324	2.352	.421	.977	.023

Evidence of Failure in the Following order:

- #1- Cracking noise at 3200#.
- #2- Spokes nos. 3 and 12 split in head thru bolt hole,
lower part of flange bent down about 3/32" at 3334#.
- #3- Max. Load 3334#.

Sheet No. 4.

Running Log of: Olds 32 x 4, wood felloe, 3/16" flange
stock, 7/16" bolts, standard hub.

Observers: Jones, Davis, Gray.

Date: April 21, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.039	.024		
400	.076	.043		
600	.112	.062	.008	.005
800	.150	.080		
1000	.183	.095		
1200	.236	.117	.028	.010
1400	.271	.133		
1600	.320	.151		
1800	.366	.169	.065	.019
2000	.417	.184		
2200	.477	.203		
2400	.532	.217	.112	.021
2600	.598	.236		
2800	.723	.255		
3000	.848	.276	.235	.035
3200	.973	.296		
3400	1.098	.321		
3600	1.848	.405		
3702	2.098	.500	.848	.045

Evidence of Failure in the Following Order:

- #1- Spokes pulled down from flange about 1/32" at 3400#.
- #2- Cracking noise. No. 1 spoke split in head thru bolt hole.
- #3- Max. Load 3702#.

Sheet No. 7.

Running Log of: Olds 32 x 4, wood felloe, 1/4" flange
stock, 3/8" bolts, standard hub.

Observers: Jones, Blades, Gray.

Date: April 26, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.095	.041		
400	.136	.051		
700	---	---		
800	.157	.063		
1000	.171	.070		
1200	.225	.089	.043	.013
1400	.253	.103		
1600	.298	.117		
1800	.345	.131	.184	.024
2000	.521	.146		
2200	.558	.162		
2400	.615	.175	.247	.035
2600	.708	.199		
2800	.770	.214		
3000	.833	.234	.270	.041
3200	.923	.260		
3400	1.195	.302		
3600	1.518	.370		
3770	3.583	.621	---	.066

Evidence of Failure in the Following Order:

#1- Cracking noise at 3600#. Lower flange bent down about 1/8".

Spokes out at flange 1/8".

Felloe split at no. 3 tenon, no. 3 spoke pulled out about 3/32".

#2- No. 1 spoke pulled out of flange 1/2" and split in head thru bolt hole at Max. Load of 3770#.

Sheet No. 8.

Running Log of: Olds 32 x 4, wood felloe, 1/4" flange stock,
7/16" bolts,, standard hub.

Observers: Jones, Blades, Gray.

Date: April 26, 1921.

Load in Pounds	Defl. Down	Defl. Up	Set Down	Set Up
200	.028	.015		
400	.053	.034		
600	.082	.048	.007	.003
800	.112	.062		
1000	.153	.084		
1200	.184	.094	.027	.015
1400	.221	.108		
1600	.264	.124	.063	.021
1800	.311	.139		
2000	.360	.154		
2400	.474	.183	.117	.029
2600	.535	.199		
2800	.625	.219		
3000	.707	.256	.193	.037
3200	.800	.278		
3400	1.015	.281		
3600	1.203	.315		
3800	1.828	.393		
3850	2.078	.566	----	.258

Evidence of Failure in the Following Order:

- #1- Cracking noise at 3200#; no. 1 spoke split in head.
- #2- No. 3 spoke pulled out at tenon 1/8"; No. 11 spoke pulled out at tenon 1/8", nos. 4 and 2 spokes split, felloe split at nos. 1, 2, 9, 10, and 11; spoke pulled out of flange 1/2"; Nos. 11 and 4 spokes split in head, all at Max. Load 3850#.

The following is a summary of the foregoing data from which the curves were drawn:

Defl. & Prem. Set on Down & Up Sides	3/8" bolts 1/4" flange stock	7/16" bolts 1/4" flange .stock	3/8" bolts 3/16" flange stock
--	------------------------------------	--------------------------------------	-------------------------------------

Down Side

Defl. at 1200#	.244	.216	.249
" " 2400#	.742	.533	.562
" " 3000#	1.117	.790	.884
" " Max. #	3.055	2.520	2.350

Per Set at 1200#	.049	.017	.045
" " " 2400#	.267	.099	.115
" " " 3000#	.368	.185	.237
" " " Max. #	1.420	1.27	.977

Up Side

Defl. at 1200#	.120	.124	.129
" " 2400#	.247	.233	.240
" " 3000#	.337	.296	.329
" " Max. #	.651	.590	.421

Per. Set at 1200#	.019	.009	.016
" " " 2400	.047	.019	.032
" " " 3000#	.073	.034	.059
" " " Max. #	.138	.---	.093

Max. Load in #	3640	3526	3334
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Defl. & Per. Set on Down & Up Sides.	7/16" bolts 3/16" flange stock	3/8" bolts 7/32" flange stock	7/16" bolts 7/32" flange stock
--	--------------------------------------	-------------------------------------	--------------------------------------

Down Side

Defl. at 1200#	.236	.211	.220
" " 2400#	.532	.519	.521
" " 3000#	.848	.739	.783
" " Max. #	2.098	2.426	2.383

Per. Set at 1200#	.049	.017	.035
" " " 2400#	.233	.177	.134
" " " 3000#	.369	.185	.158
" " " Max. #	0.848	.989	.752

Up Side

Defl. at 1200#	.117	.049	.101
" " 2400#	.217	.183	.091
" " 3000#	.276	.236	.153
" " Max. #	.500	.421	.578

Per. Set at 1200#	.010	.012	.015
" " " 2400	.021	.019	.031
" " " 3000#	.035	.035	.043
" " " Max. #	.045	.205	.245

Max. Load in #	3702	3580	3672
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Defl. & Perm. Set on Down & Up Sides.	3/8" bolts 1/4" flange stock	7/16" bolts 1/4" flange stock
---	------------------------------------	-------------------------------------

Down Side

Defl. at 1200#	.225	.184
" " 2400#	.615	.474
" " 3000#	.833	.707
"B " Max. Load	3.583	3.078

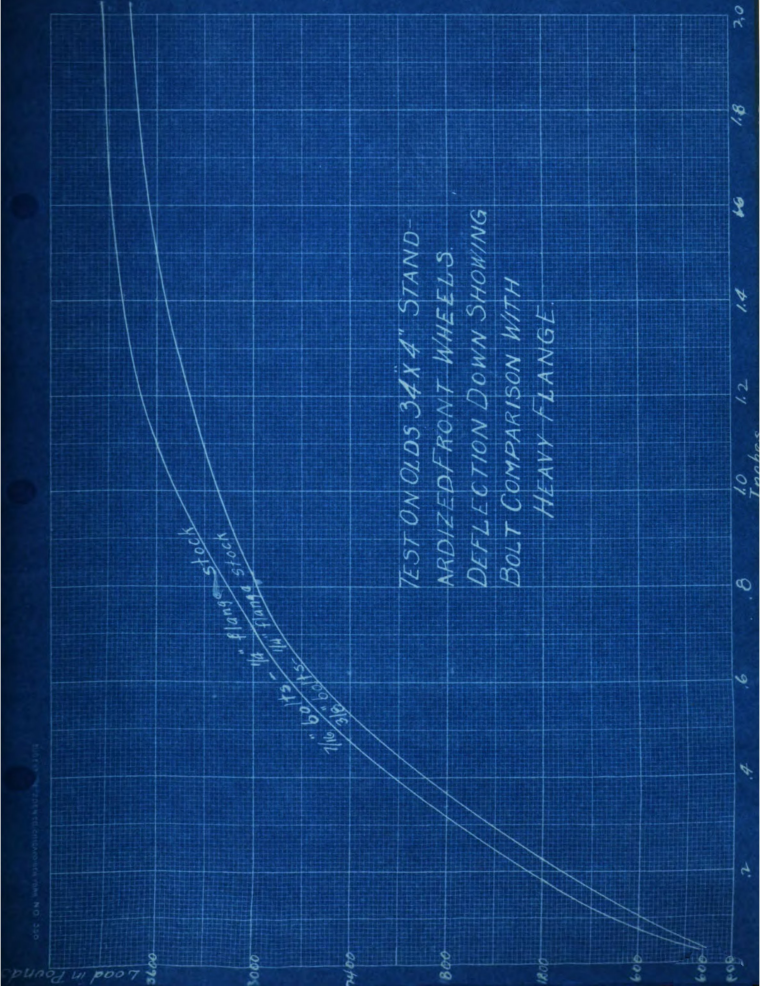
Per. Set at 1200#	.043	.027
" " " 2400#	.247	.117
" " " 3000#	.270	.193
" " " Max. Load	----	----

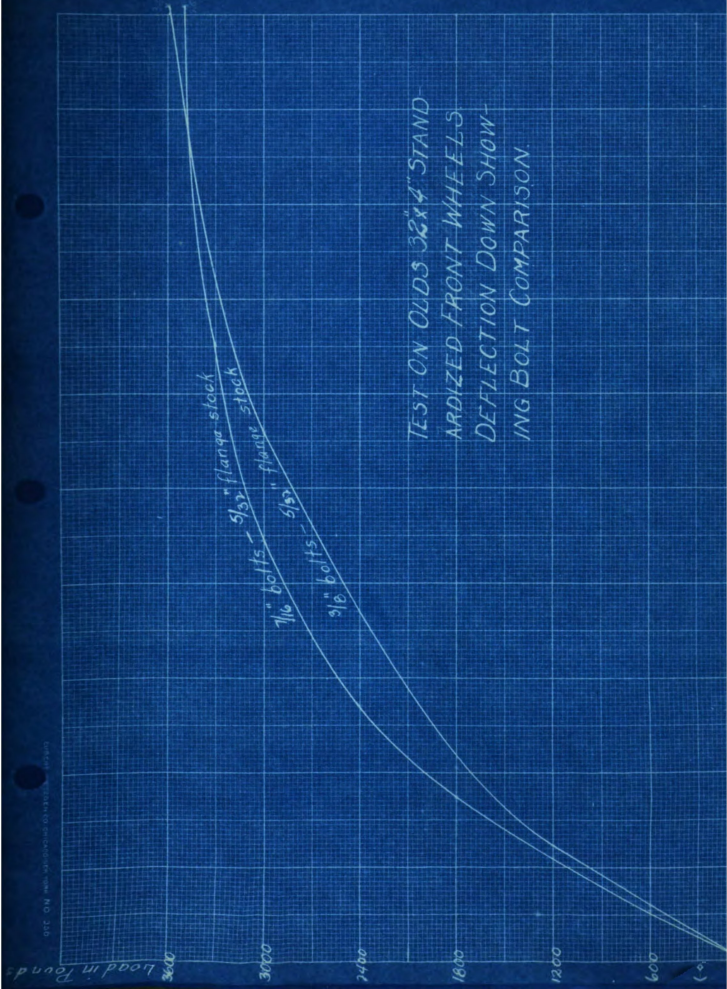
Up Side

Defl. at 1200#	.089	.094
" " 2400#	.175	.183
" " 3000#	.234	.236
" " Max. Load	.621	.566

Per. Set at 1200#	.013	.015
" " " 2400#	.035	.029
" " " 3000#	.041	.037
" " " Max. Load	.066	.258

Max. Load in #	3770	3850
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Load in Pounds

3600

3000

2400

1800

1200

600

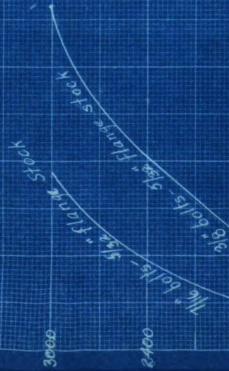
0

$\frac{1}{16}$ " bolts - $\frac{1}{4}$ " flange stock

$\frac{3}{16}$ " bolts - $\frac{1}{4}$ " flange stock

TEST ON OLDS 32"x4" STAND-
ARDIZED FRONT WHEELS.
SET DOWN SHOWING BOLT
COMPARISON

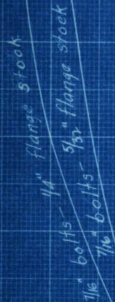
Load in Pounds



TEST ON OLDS 32"x4" STAND -
 ARDIZED FRONT WHEELS SET
 DOWN SHOWING BOLT COMPAR-
 150A.

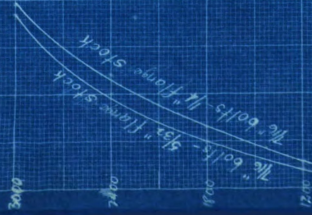
TEST ON OLDS 32"x4" STANDARDIZED FRONT WHEELS SET DOWN SHOWING FLANGE COMPARISON





TEST ON OLDS 32x4" STANDARDIZED FRONT WHEELS
DEFLECTION DOWN SHOWING FLANGE COMPARISON.

Load in Pounds



TEST ON OLDS 32" X 4" STAND-
 ARDIZED FRONT WHEELS
 SET DOWN SHOWING FLANGE
 COMPARISON.

Conclusions: Due to the variation in timber the results are not as uniform as they would be if a large number of wheels of each type were broken. From an inspection of the curves for the bolt comparison it is seen that the same wheel with heavier bolts gives a stronger wheel to resist strains from skidding, and striking the curb, as the wheels with the heavier bolts seem to give a less deflection and a less permanent set than those with the smaller bolts and the same size flange. In creasing the size of the flange stock does not seem to have a very great effect on the strength of the wheel although in each case the wheel with the heavier flange seems to give a little less deflection and permanent set for the same load. For this reason it was decided to use the same sized flange stock and heavier bolts in the wheels.

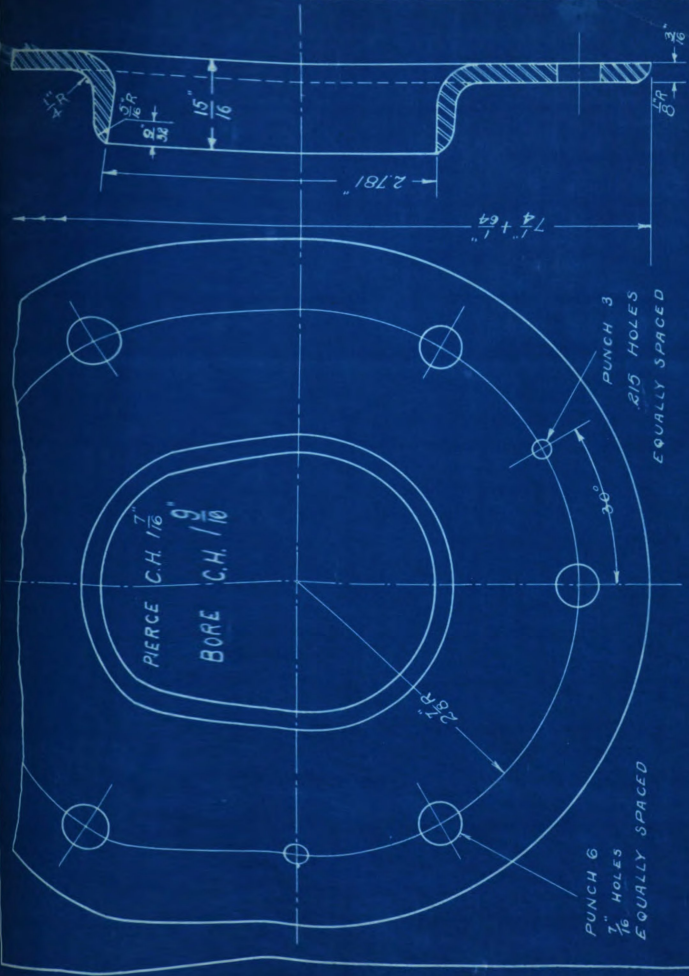
* Note:-

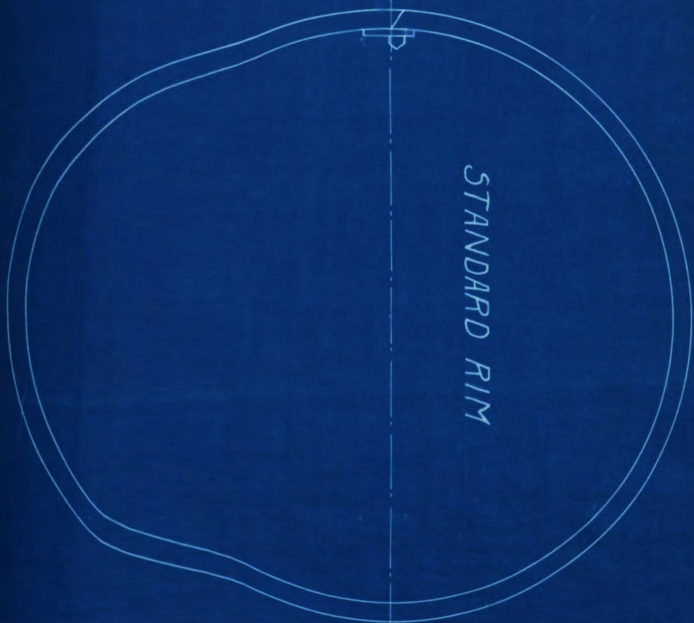
None of the bolts broke during these tests, altho the 3/8" bolts stretched slightly more than the 7/16" bolts did. The lighter flange bent down more than the lighter one did, the heavier flange being the more rigid. This was especially noticeable on the wheel with the 7/16" bolts and the spokes directly under the load, which broke at 3200# while the maximum load was carried on the two spokes on each side of the broken spoke.

I am including a number of drawings of all the parts of the wheel so that the reader may become familiar with each part in detail and then I have included an assembly drawing of the wheel itself so that the relation they bear to each other may be plainly seen when assembled into the complete wheel. This should illustrate the thesis more fully and make it more interesting to the reader.

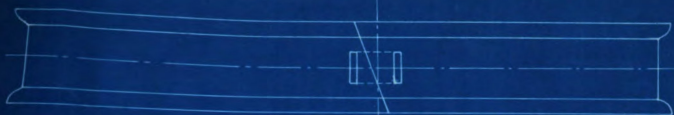
A comparison of the wood and steel wheels at the present time indicates, that the wood wheel is far superior to the steel wheel.

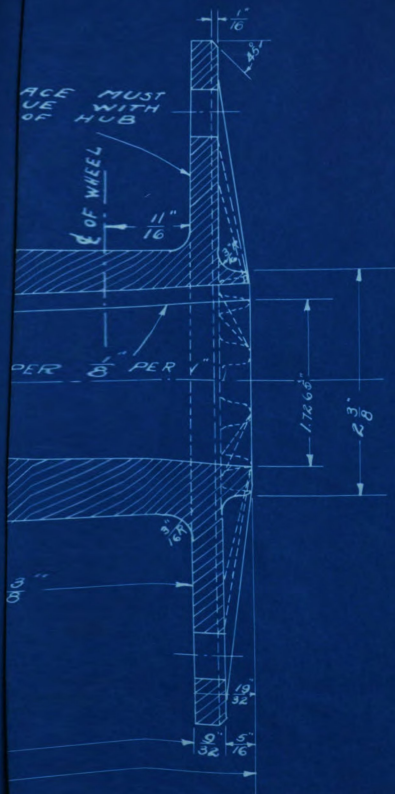
FLANGE

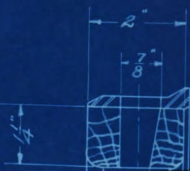




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