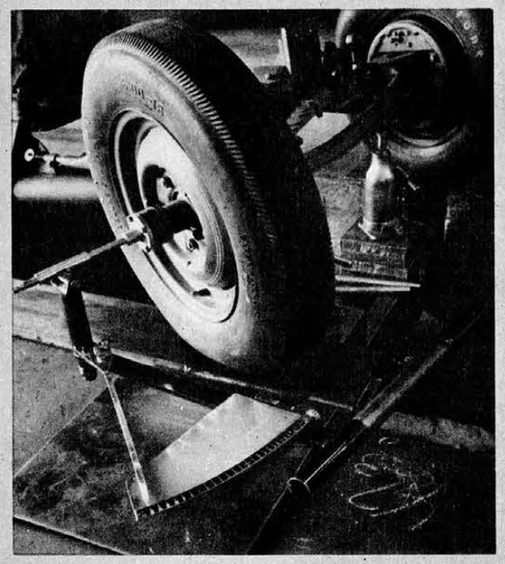
Wheel Alignment

Drawings in this article are reproduced, through courtesy of the Elliott Addressing Machine Co., from the booklet "The Story of a Father and Son."

Streamliner chassis is being measured for "square" while wheels are aligned.

"Tram" mounted on front spindles of streamliner used for setting toe in



Part Two of This Informative Article on Steering.

by George Hill

IN LAST month's issue I attempted to impress you with two facts: the importance of having correct wheel alignment in the chassis of your automobile, and with the obvious superiority of the Bagge Wheel Alignment system over any other type in use today. We also covered part of the actual alignment operations on a lakes roadster being converted back to street use. You will remember the amount of caster was reduced from 9 degrees to a setting of 4 degrees.

At high speeds (this car had been driven at speeds in excess of 130 mph in dry lakes competition) more positive caster is needed to hold the front wheels in a straight line.

The weight of the car acting as a lever, through the rearward tilt of the spindles (caster), actually forces the wheels to hold a position pointing straight forward. This creates a condition in the steering leverage whereby much more pressure is needed to turn the steering wheel. Therefore, when converting a lakes machine back to street use, the amount of caster is usually reduced in order to obtain easier steering.

The camber was checked again and reset at the same angle, 1¼ degrees, as used for lakes straight-away time trials. (The front end set up for a drag race job could be the same as a lakes job.) With caster and camber now taken care of, we go to the next operation.

TOE-IN is the bringing together of the front wheels at the front. Purpose: to prevent tire wear and insure proper steering on the straightaway. Remember the front wheels are actually being pushed forward over the road surface by the forward momentum of the automobile and where the two surfaces meet (the tire and the road), a certain amount of friction is created. This friction induces a rearward pressure on the wheel assembly which is greatly accentuated as speed increases. Therefore the wheels must be set with toe-in condition while stationary, in order to maintain a straight forward position while at speed. Toe-in is adjusted by lengthening or shortening the tie rods.

Comparing the alignment settings of this roadster with those of the City of Burbank streamliner you must remember that a great difference in speeds was anticipated, that the weight distribution was also different but the suspension assemblies were similar. Both cars used the early model Ford axle.

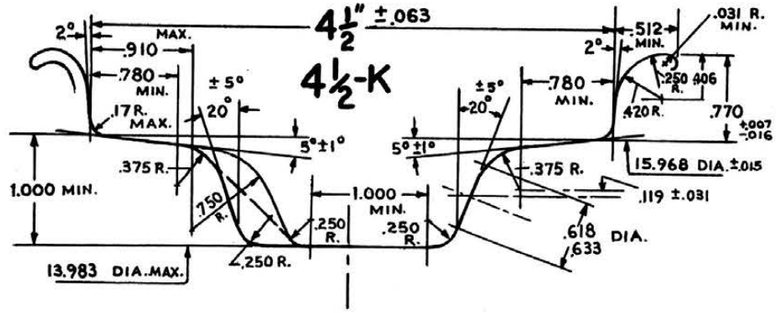
Caster on the streamliner was set at 10 degrees, only one degree more than that of the roadster, while the camber setting was reduced to ¾ of one degree. Less camber was used on the streamliner for two reasons. The stock roller bearings (front wheel) had been replaced with ball bearings fitted in a sleeve inside the hub. The direct pressure of the car's weight transmitted through the spindle to the bearing race creates end thrust on stock bearings. Therefore, as mentioned last month, a negative camber condition places the weight on the outside bearing which in reality is a pilot bearing for the hub.

This condition is automatically eliminated when ball bearings are used so it was decided to set the wheels with only ¾ of one degree positive camber. No sharp turning of the wheels was anticipated so this lesser amount of camber would not greatly affect the steering of the streamliner.

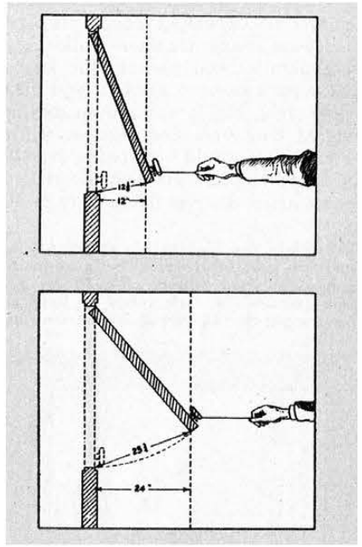
The caster setting of ten degrees, only one degree more than the roadster, was arrived at after considering many factors. The weight distribution of the streamliner chassis placed 56 percent of the weight, or about 1288 pounds on the front wheels. We figured with this amount of weight the leverage on the spindles set at 10 degrees would be more than enough to hold the wheels in a straight forward position. The majority of streamliners built to date with the engines located in the rear, need more caster in the front end. The So-Cal Spl. had 12 degrees caster and we have heard of some running as high as 15 degrees.

No toe-in was set into the front end alignment. They were set at 0 having neither toe-in or toe-out for this reason: All but a thin skin of rubber had been turned from the tires so that an area of only about 12 square inches was in contact with the ground. The soft passenger car tire has from 56 to 70 square inches of rubber per tire in contact with the road. This cut the ground friction to a minimum.

The wheels were also completely enclosed in the body and therefore had no wind friction to force them back. At this point we assumed the wheels would retain practically the same setting at any speed and a toe-in condition at



These are The Tire & Rim Association standard measurements for U.S. passenger cars and other similar vehicles.



These two drawings illustrate the method, explained in the text, whereby Sterling Elliott discovered the principle of modern front end geometry. In this case the door represents the spindle arm and the string representing the tie rod.

over 200 mph could create tremendous friction. Added rolling resistance of any type would be detrimental to the overall function of the car and in the case of tire friction, an unsafe heating problem would be encountered.

The turning radius was checked at this point and found to be 100% true. Bagge was astounded and thought we must indeed be chassis engineers to have altered the front end so much and still retained true turning radius. Little did he know that it was only by accident that this condition existed in our car. We had cut 10 inches from the center of the axle (to narrow the tread) reshaped the spindle steering arms so that the tie rod would clear the radius rods and main frame tubes of the chassis and only by chance arrived at a completed assembly condition that registered true turning radius on the Bagge instruments.

Had we missed, I would have felt badly but George Bagge explained that the only car on the market today that has retained this important function of the front end assembly is Ford.

It seems odd that with the millions of dollars spent each year by the new car manufacturers in experimentation, research and road testing, they allow themselves to get further and further from the basic safety and operational functions of the front end assembly. Striving for a softer, spongier, floating ride they are forced to sacrifice the principles discovered, or rather invented by Sterling Elliott in the year 1888.

Elliott, at that time a manufacturer of bicycles, built a four wheeled, rubber tired quadricycle. Just prior to this in 1887, Elliott had built a large hall with a hardwood floor on which people could learn to ride his bicycles.

One night the Elliott employees had a party in this hall and waxed the floor for dancing. The next day when his quadricycle made turns on this waxed floor a loud screeching noise was caused by its hard rubber tires.

Sterling Elliott's study of this noise, coupled with his wife's statement that the wheels seemed to be sliding around the turns and not rolling smoothly resulted in an invention so simple and yet so perfect that it will live forever.

To understand this better you must first visualize the difference between a horse drawn vehicle and the front axle of an automobile. With a horse drawn vehicle the shafts and front axle turn with the horse, but Sterling Elliott's Quadricycle had a *non turning* axle, and he discovered the necessity of making one wheel turn more than the other. Explanation — One was traveling in a tighter circle than the other. When turning to the left, the left front wheel must turn more than the right wheel. But when turning to the right, the right front wheel must turn more than the left front wheel because the problem is now reversed and it is the right front wheel that must travel in the smaller circle. Other bicycle manufacturers said this problem could not be solved so they manufactured three-wheeled Velocipedes with only one front wheel

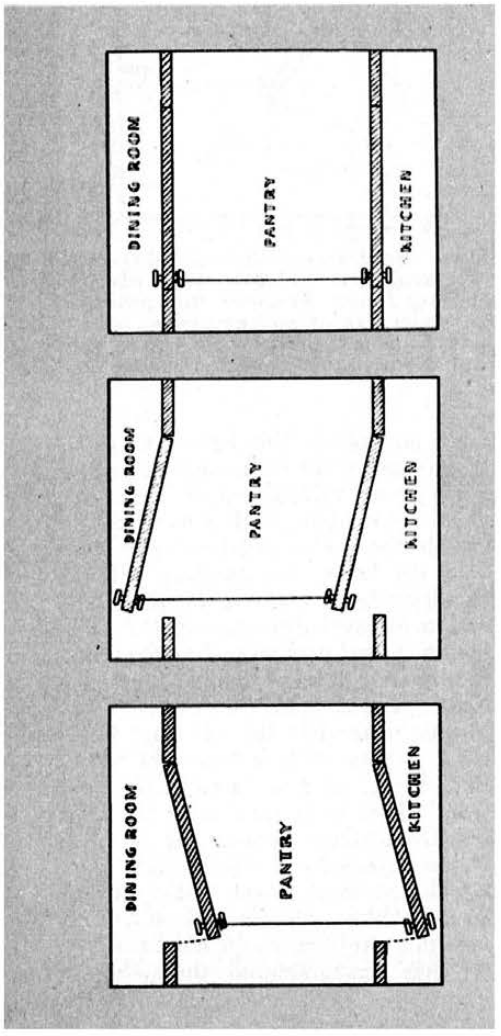
(Continued on Next Page)

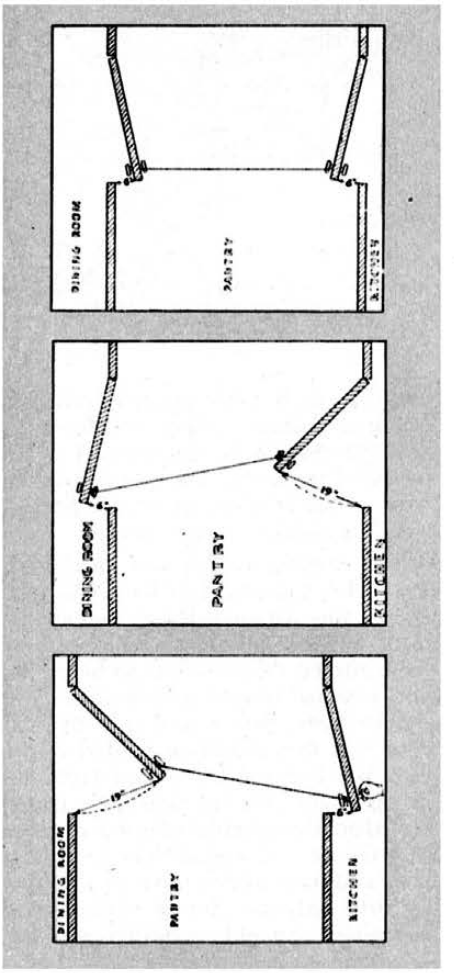
to be steered. The problem was a challenge to Elliott and this is the way he solved it.

He tied a string to the door knob of a swinging door and pulled the string exactly 12 inches, at right angles to the wall, and noticed that the edge of the door had traveled 12⅛ inches. Then still pulling the string at right angles to the wall, he pulled it another 12 inches and noticed that the door had opened another 13⅝ inches. The fact that the door opened 13⅝ inches on the second 12 inch pull and only 12⅛ inches on the first 12 inch pull revealed a solution of the problem to Elliott's keen mind.

To explain his idea to his associates he used two swinging doors. He first tied these doors together while they were parallel and keeping the string tight swung them to the left, and then to the right, and it was proven that as long as they were tied together while parallel they would both swing exactly the same amount. He then shortened the string so that the doors were at an

To explain his idea to his associates he used two parallel doors directly opposite each other in a hallway. The doors remain parallel to each other as long as they are parallel at start of demonstration.





Sterling Elliott then shortened the string between the doors. The doors represent the spindle steering arms and the string the tie rod. By pulling the doors one way, and then the other, it was obvious that they did not open the same amount as before.

angle to each other. Then he pulled the left door to the left and it was noticed that the string pulled the right door further to the left than he had pulled the left door. When he pulled the right door to the right and the string pulled the left door further to the right than he had moved the right door, all were convinced that he had found the solution.

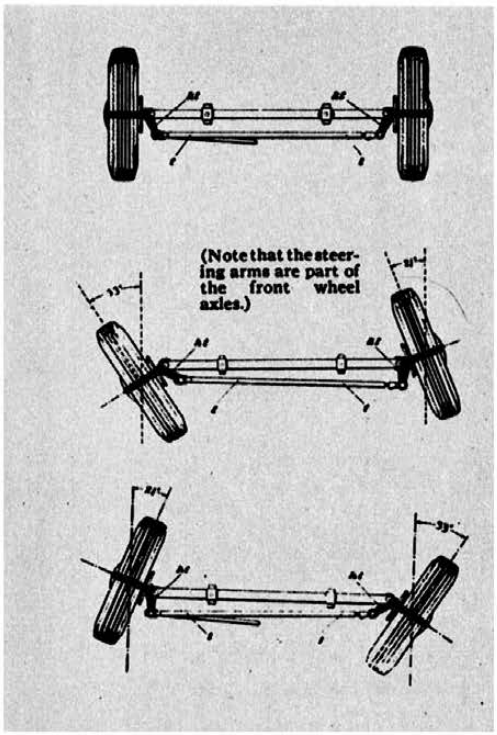
His next step was to set the steering arms of his Quadricycle front wheels at an angle to each other (like the two doors with the shortened string) and fasten them together with a metal tie-rod in place of the string. After many experiments he worked out the exact angle and length of the steering arms and found that not only had the screeching noise disappeared but that the front wheels could be turned with much less effort by the operator. He applied for, and was granted, United States Patent No. 442,663 as the inventor of these principles and was paid a royalty by automobile manufacturers for many years.

Why do I expend all this time and space in explaining Elliott's invention? So that you the reader will realize that at one time the automobile manufacturers respected this man's principles to the extent that they were incorporated in the construction of all automobiles and that you and you and you, Mr. Average Motorist, have demanded the type suspension used in your car today. *You* wanted a *softer* ride. *You* wanted a *roomier* car. Mr. Detroit's answer was *independent suspension.* Here he could spring each side separately and also move the engine up between the front wheels giving more space for *passenger comfort.* The only thing Mr. Detroit lacked was Mr. Elliott to figure a new way of preserving the *true turning radius* which was lost when all the new type steering linkage was *engineered.*

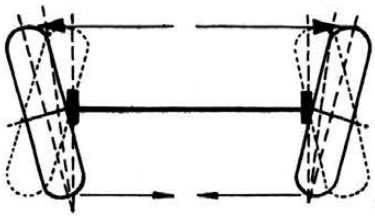
So many mistakes have been made in the *Engineering* of steering and front-end suspension assemblies, sometimes I wonder what has happened to all the cool heads that have until the last few years guided Detroit along the right paths in suspension and steering geometry. It would not be too bad if the adjusting mechanisms in the suspension units could allow shops such as Bagges' to make the necessary corrections. Two of the highest priced cars built in our country are sold to you with up to 3½ degrees negative caster in the front end. *Negative Caster. And Why?* Because with the type of suspension used along with the huge heavy low pressure tire, the heavy duty brakes it takes to stop this 2 to 2½ ton automobile, the system is so flexible that the only way *front wheel shimmy* can be eliminated is by the application of negative caster to reduce road shock.

Before I get carried away with the obvious mistakes made in the automobile chassis of today let us use a few lines for the explanation of *King pin inclination.*

King pin inclination is best described as the outward tilt of the king pins at the bottom. Why must they be tilted? Elementary, yet for a few years cars were manufactured with the king pins in a vertical plane as viewed from the front. The first Model "T" was manufactured with the king-pins installed in a straight up and down position and it was noticed that when turning the steering wheel the spindle swung the wheel around an arc, the center of which was located at a point directly below the center of the king-pin. This meant that while parking or attempting to turn the wheels while the car was not moving, the wheels were actually rolling around in a small circle instead of pivoting in place as they do when the king-pins are inclined. A straight line drawn through the king-pin and extended to the ground should coincide at that point with a line drawn



Elliott's next step was to apply what he had learned to his quadricycle. He then adapted the invention for use on a car as shown in these drawings. The wheels of the car do just as his doors had done.



Camber is seen when car is viewed from front. Outward tilt at top of wheel is positive camber, tilting in, negative.

Kingpin inclination is the relation between the kingpin and a line drawn through the center of tire to ground.

vertically through the center of the tire. Then and only then can the direction of the wheel be changed without forcing it to roll or be dragged into its proper place.

Now you should be able to see how important it is to have the combination of correct king-pin inclination and the right amount of toe-out on turns. With spindle steering arms of the right length and angle the two front wheels will each have its correct turning radius and if the king-pins are inclined at the right angle they will be allowed to follow smoothly and easily the paths prescribed for them by Sterling Elliott's discovery.

A word now to those planning a custom, roadster or lakes chassis. If you are using the Ford straight front axle do not bend the spindle steering arms up or down, for by bending them you shorten them and thereby lose the correct toe-out on turns. If you have obstructions in the way of the tie-rod fabricate a new tie-rod to fit the chassis.* If you reverse the spindles to locate the tie-rod in front of the axle you must then bend the spindle arms outward and install a longer tie-rod. The correct position for center of the tie-rod mounting hole in the spindle steering arm will be found by extending a straight line from the center of the differential through the top center of the kin-pin.

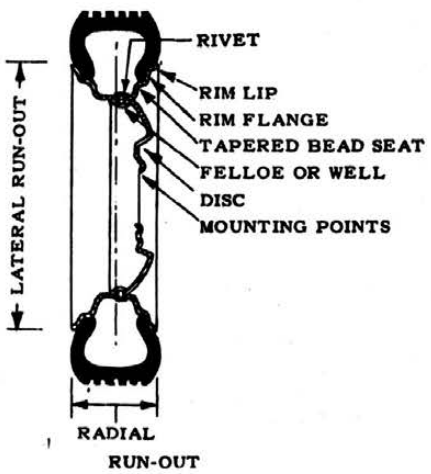
Another point stressed by Bagge is the importance of normalizing and baking front end assembly parts that have been stressed or are to be chrome plated. An axle that has been subjected to any great amount of stress or welding becomes hard and brittle. Worse yet is an axle that has been stressed or welded and then chrome plated without the benefit of being normalized before plating and baked immediately afterwards. To get a little more information on this I called Modern Plating Co. of Inglewood, Calif., and Leo Atimion explained it this way.

The chemicals supplied to plating plants are not 100% pure. Steel parts put into the vats containing these chemicals are subjected to a migration of hydrogen, an atomic hydrogen that saturates the part as completely as does imitation coloring poured into a pitcher of water. This hydrogen enters the part in a diffused state and can be released easily if the part is baked immediately afterwards. If the baking process is omitted the hydrogen gradually enters into the grain boundaries and the structure of the steel submits to fatigue and embrittlement. Zinc plated parts should be baked at 275 degrees from 4 to 6 hours. Cad. and chrome parts need 375 degrees from 2 to 3 hours to release the hydrogen.

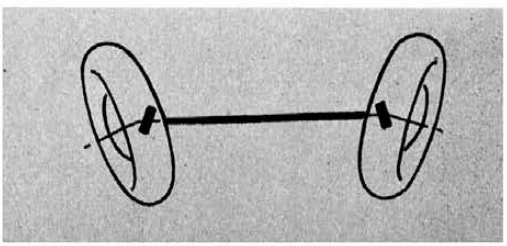
We recommend then that when having steering linkage or axle assembly parts plated, you take the work to a shop equipped to handle the stress relieving and baking. If they are not familiar with these processes make arrangements with a nearby heat treating plant. It may seem like a lot of extra trouble but it is important. I know, and you know, that Ford used a good grade of steel in his axles and spindles but then Mr. Atimion assures me that the higher the grade of steel the more susceptible it is to the hydrogen and its damaging action.

We feel that in the past, too much space in automotive journals has been devoted to praise of horsepower and to the efforts to beautify the body and accessories of the American automobile and not enough on the safety aspects of the chassis. We hope that you, Mr. Motorist, have realized some benefit from this article and in learning a little more about your automobile can see that a good front-end alignment job is one of the safety precautions you can ill afford to neglect. Mr. Bagge's personal observations and many experiences with all types of automobiles and their owners could fill a library of many volumes and I regret that space here does not permit us to include them in this article.

Nomenclature of present day wheel and rim as used by Tire & Rim Association.



Toe-in of front wheels as viewed from the front with an exaggerated camber and toe condition for this illustration.



* Previously in this article I had mentioned bending the spindle arms on the City of Burbank to enable the tie rod to clear the radius rods, and now I say don't do it to a street roadster or custom. The reason for us being able to bend the arms on the streamliner and still retain correct turning radius is as follows: The Ford Motor Company determined the length of the spindle arms partially by the length of the axle (determining the front tread) and partially by the wheelbase of the car. Our car had the front axle shortened 10 inches, so when the spindle arms were bent (which shortened them) they now are still in proportion to the shortened length of the front axle.