IDEAL TRACTION *from* STEAM ENGINE

REPLYING TO CERTAIN STATEMENTS
ON THE STANLEY CAR IN A. LUDLOW
CLAYDEN'S ARTICLE, "HORSEPOWER
FACTS AND FALLACIES"

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THE STANLEY MOTOR CARRIAGE COMPANY
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Mr. A. Ludlow Clayden, the author of "Horsepower Facts and Fallacies," is the technical editor of The Automobile. *He has furnished many very valuable contributions to automobile engineering literature, and is one of the leading figures in that branch of the industry.*

Space prevents our reprinting the whole of this very valuable paper, but the accompanying passages give the points referred to by Mr. Nies.

This article—"Horsepower Facts and Fallacies"—was published in The Automobile *of April 26, 1917.*

Extracts from

Horsepower Facts and Fallacies

By A. Ludlow Clayden

Horsepower in an automobile engine is only a means to an end. This seems sufficiently obvious, yet it is a fact that often is not appreciated fully. The end for which we require horsepower is the provision of driving effort at the contact between tire and road. A car with a 100 brake hp. engine may be less good a performer than one with 30 hp. Horsepower alone without any qualification does not mean much.

Limit of Power Usable

There is a limit for the power which it is possible to use, this being the amount of driving effort that can be exerted without causing the wheels to slip. This is limited in turn by the weight on the driving wheels and the coefficient of friction between the tire and road. Probably the maximum effort that any rubber tire can exert in a tractive direction upon any road is half the weight resting on the tire..

Now, it follows that maximum "ability" will result when we have the maximum transmittible power available at all speeds. It is very instructive to check up some well-known cars and compare their actual power with the power that could be used in them. One, a car (*internal-explosive*) that is well-known as a particularly good performer, has the characteristics following:

Miles per Hour	Developed hp.	Maximum hp. transmittible	Difference
10	10	27	17
20	26	53	27
30	41	81	40
40	57	108	51
50	72	135	63
60	80	162	82

A. P. Brush once stated that the steam engine was nearer the ideal for automobile use than the gas engine, because it could produce the highest torque when there was the least speed. In an internal combustion engine we usually find that the mean effective pressure, and consequently the torque, reaches a maximum somewhere between 20 and 30 m.p.h. on high gear..................

At low speeds the torque falls off rapidly..........

Now, with a steam engine we can have a constant power output, because the product of pressure and speed can be kept constant within limits, but a constant power *is not* what is wanted for maximum performance. What we desire is a constant *tractive effort,* unaffected by speed, and this is no more easily obtainable with steam than with gasoline. With a two-wheel drive and a 0.5 coefficient of friction between tire and road the maximum tractive effort we can handle is 25 lb. per 100 lb. of car weight.........

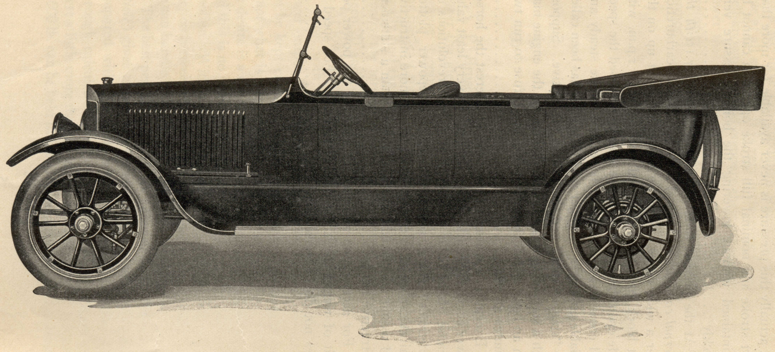
The best performance of any (*plotted in Mr. Clayden's article*) gives an effort of under 16 lb. at the best speed, compared with the 25 lb. which is theoretically possible. A rough calculation shows that the Stanley steamer can exert a little more than 25 lb. for as long as a full pressure of 600 lb. can be held in the cylinder throughout the stroke,

but actually this pressure is never available for more than part stroke and nominal full stroke operation cannot be maintained without lowering the boiler pressure very quickly ....

At the present time the greatest difficulty (*with the internal combustion engine*) is to get efficient carburetion over a wide range. Suppose an engine is set up on the test block and adjusted to pull well at 1,000 r.p.m. with wide open throttle; then if the load is increased the speed will come down till a point is reached where steady and reliable pulling is no longer possible. This has been called the "stagger spot," and the term is descriptive. Suppose such a stagger spot is found at 600 r.p.m., the engine may run an hour at full throttle at 650 and refuse to run two minutes at 580...................................

Except as a matter of engineering interest the horsepower curve is of little value. It is of the very least value because of the habit of plotting it against revolutions or sometimes against piston speed. Horsepower plotted against car speed in m.p.h. would be far more instructive and would tell the car user much more than a statement of tractive effort...................................

For acceleration and for hill climbing the power per unit of weight gives the true perspective. For speed it does not do so above 30 m.p.h......................



SPECIFICATIONS

Body Aluminum; smooth-line, with flush sides. Front seat, 42 inches wide, 18 inches deep; rear, 48 inches wide, 20 inches deep.

Upholstery Soft genuine leather, straight grain; filled with curled horse-hair. Wide, deep cushions in both front and rear, tilted for comfort.

Top Improved one-man type, locking to windshield.

Windshield Slanting special Troy design, ventilating and rain vision; black enamel and nickel.

Color Royal green with running gear and fenders black. Valentine's colors and varnishes used exclusively.

Lights Electric throughout, with Willard battery and Apple Electric Generator; combined headlights and dimmers with separate bulbs and Controlite Lenses. Electric dash and tail lights.

Horn Klaxon electric, under hood; button under driver's left foot.

Steering Gear Warner, with 18-inch wheel; left side; worm and gear type.

Wheelbase 130-inch with standard 56-inch tread.

Wheels 34 x 4, with Firestone Light Demountable Rims. Wire wheels optional at $100 for black and $110 for white per set of five.

Tires Straight groove, black tread, cord. 35 x 4½ straight side.

Springs Semi-elliptical front; full-elliptical rear.

Frame Channel section pressed steel.

Front Axle Complete Timken installation.

Rear Axle New design Stanley with Timken inside bearings. S. K. F. outside bearings.

Brakes On rear whee's with 14-inch drum and 2-inch face. Hand emergency brake of expanding type and pedal service brake of contracting type.

Pumps Driven from rear axle at one-quarter engine speed.

Water Tank 24-gallon capacity, tank hung under frame, giving water mileage of 150 to 250 miles.

Radiator Standard Mayo, V-shaped, cellular type.

Fuel Tank Main fuel tank for kerosene at rear, 20-gallon capacity; pilot tank and cylinder oil tanks under front seat.

Boiler Standard Stanley fire-tube type, welded construction, 23-inch diameter.

Burner Drilled type; can burn kerosene or gasoline or any mixture of the two. Pilot burns gasoline from miniature tank of 4-gallon capacity.

Engine Two cylinders, 4 x 5, slide valve type; double acting; bolted to rear axle and geared direct into differential ring gear. The entire differential and engine assembly enclosed in a dust-proof, oil-tight housing and running in a bath of oil.

Instrument Board with steam gauge, duplex fuel gauge, oil sight feed, Warner speedometer and lighting switch.

Pilot Electrically heated from Willard Storage Battery.

Prices (Subject to change) f. o. b. Newton. (War tax additional)

Model 735, seven-passenger touring car	$3,100
Model 736, four-passenger touring car	3,050
Chassis only	2,725

Ideal Traction from Steam Engine

By J. D. Nies
Lewis Institute, Chicago

In A. Ludlow Clayden's excellent paper in The Automobile, April 26, certain statements that appear to be in error are made concerning the performance of the Stanley car. The tractive effort of the car is given by Mr. Clayden as a little over 25 lb. per 100 lb. of car weight when the full steam pressure of 600 lb. is held throughout the stroke. This is really about half the true value. as shown in the calculation following.

The Stanley engine has 4-in. bore and 5-in. stroke, the gear ratio is 1.5 to 1, and the rear wheel diameter is 34 in. Assume that 600 lb. steam pressure is taken for the full stroke. During one revolution of the rear wheels, the car advances $34 \times 3.1416 = 106.8$ in. The engine makes 1.5 revolutions, or 3 working strokes per cylinder, or 6 working strokes for both cylinders. The total piston travel $= 5 \times 6 = 30$ in. Therefore, during one revolution of the rear wheels the travel of the car is $106.8 \div 30 = 3.56$ times the piston travel, and the force acting to drive the car must be $1/3.56$ of the force applied to the piston.

Piston area $= 4 \times 4 \times 0.7854 = 12.56$ sq. in.
Pressure on piston $= 600 \times 12.56 = 7536$ lb.
Force driving car $= 7536 \div 3.56 = 2118$ lb.
Weight of car $= 3650$ lb.
Tractive effort per 100 lb. $= 2118 \div 36.50 = 58.1$ lb.
Allowance for losses $= 12.5$ per cent.
Net tractive effort per 100 lb. of car weight $= 58.1 \times 0.875 = 51$ lb.

This is about twice the value as given by Mr. Clayden. The value as given by Mr. Clayden for full stroke admis-

sion is really correct for a cut-off at about one-third stroke. Auchicloss (Link and Valve Motions, page 16) says that the mean effective pressure with one-third stroke cut-off is equal to one-half the boiler pressure, making the tractive effort for this cut-off

$$0.5 \times 51 = 25.5 \text{ per 100 lb. of car weight.}$$

The same authority gives the mean effective pressure for one-fourth stroke cut-off as four-tenths of the boiler pressure, making the tractive effort for this cut-off

$$0.4 \times 51 = 20.4 \text{ per 100 lb. of car weight.}$$

This tractive effort is close to the limit of traction on ordinary road, and can be maintained at a fairly high car speed without lowering the boiler pressure.

Mr. Clayden's under-estimation of the performance of the Stanley car has naturally given him an improper basis of comparison of the ability of steam and gasoline engines, as disclosed particularly in the second of these sentences: "Constant power is not what is wanted for maximum ability. What is wanted is constant tractive effort unaffected by speed, *and this is no more easily obtainable with steam than with gasoline.*" (The italics are mine.) Reading these sentences in the light of the remainder of Mr. Clayden's paper, it is clear that he has in mind a value of tractive effort up to the slipping point of the tires at all speeds, since it could not possibly be argued that any value of tractive effort will answer so long as it is constant and no matter how small it is. Waiving any question as to whether this ideal of performance is a proper one or not, we may consider the assertion that it is attained as easily with gasoline as with steam.

In the first place the tractive effort developed by the gasoline engine is not constant: *at low speeds it disappears.* In the second place, the tractive effort is too small to satisfy the above requirement; there is no gasoline touring car in existence that can slip its drivers on high gear at any speed. It is simply not commercially practicable to provide an engine of sufficient size to do that, since to develop that amount of tractive effort at say 10 miles per hour would require an engine actually big enough to develop some 162 hp. at 60 m.p.h. That is the trouble with the gasoline engine: either you must have several times as much power as you want for speeds that you rarely or never use, or else you must get along with only a fraction of the power that you want for speeds that you do use. The latter condition must always obtain, so that standard cars can develop on direct drive only half or less than half of the permissible tractive effort.

The steam car can do so continuously at any speed up to or somewhat over 20 m.p.h., and can do so for a short time at any car speed, and an analysis will show that nothing more than this is ever needed.

In making this analysis we may assume two extreme road conditions, one a deep sand road, the other a hard, smooth, level road. A consideration of what is required from the power plant to propel the car over these roads will enable a sound opinion to be formed as to whether the greater ability can be obtained from a steam engine or a gasoline engine.

On a deep sand road it is not safe to operate a car at more than a moderate speed; the car cannot be steered at high speed. What is wanted for this work is an engine that can maintain a tractive effort up to the slipping point continuously at any speed from standstill up to as high speed as is safe to use on such a road. The steam engine can do this, and the gasoline engine cannot approach doing it.

On hard, smooth, level roads the maximum tractive effort is not needed continuously, because if applied continuously it would carry the car speed up to values unattained as yet by any automobile. Either the steam or the gasoline engine can maintain as much tractive effort as can be used *continuously* on hard, level roads.

Maximum Power at all Times

On the hard, level road, however, the maximum tractive effort may be wanted for a short time for accelerating; for instance, the maximum tractive effort, up to the slipping point, may be wanted momentarily at a speed of

50 m.p.h. It can be done with a steam engine; it cannot be done, with or without any possible gear shifting, with a gasoline engine.

Now, since the steam engine can develop the maximum transmissible tractive effort under all conditions where it is possible for the operator to use it, and the gasoline engine cannot do so under any conditions, it is clearly an error to state that the desired performance can be obtained as easily with gasoline as with steam.

The objection may be raised that no credit is here given to the gasoline engine for the considerably increased tractive effort that can be obtained from it by shifting to a different gear ratio. The objection is not valid; drivers do not shift gears because they want to, but because they must, and only after the engine has failed or shows signs of failing; since failure occurred, credit should not be given the engine for doing something that it failed to do. Gasoline cars are advertised, sold, and afterward judged in service, on their high-gear performance. "From a crawl to 60 m.p.h. on high gear," "Practically complete freedom from gear shifting," are common advertising phrases; surely it is fair to pass judgment upon anything on the basis of its own claims of superiority. No owner has yet been known to brag up his car because he has to shift to second speed on a hill that the other man's car climbs in high gear. Besides, to shift gears is to abandon constant tractive effort in favor of constant power, the presence of gear boxes on gasoline cars being the best of evidence that the latter characteristic is preferable. For without the gear box the car would have constant tractive effort at least in some degree, the gear box being nothing more than a device provided at considerable cost to convert the characteristic, however clumsily and incompletely, from constant tractive effort to constant power, thus enabling the engine to develop the same power on first speed at 20 m.p.h. as on high gear at 60 m.p.h. This desired result is not accomplished perfectly by any means, but the intention is there. The same idea is embodied in the Owen-Magnetic transmission, which may be said to give twice the tractive effort at half the speed; in other words, the same power at half speed as at full speed. In fact, no commercial gasoline vehicle has ever been built in which the builder did not attempt to secure the characteristic of constant power which is possessed by the steam plant in ideal form.

Comparing the Two Forms of Motive Power

The two forms of motive power may be compared in another way. Assuming steam and gasoline power plants of the same continuous rating applied to cars of equal weight, from which will the better performance be obtained? Let the assumed rating be 50 hp., the gasoline engine developing this power at 50 m.p.h., and the steam engine developing the same power as an overload condition, its normal rating being 20 hp. The usable power at different speeds may be tabulated thus:

Miles per Hour	Steam hp.	Gasoline hp.	Advantage of Steam
50	50	50	1 to 1
40	50	40	1.25 to 1
30	50	30	1.67 to 1
20	50	20	2.5 to 1
10	27	10	2.7 to 1
5	13.5	3(?)	4.5 to 1
0	full torque	no torque	unlimited

It should be noted that the steam plant can develop more than the tabulated amount of power at 5 and 10 m.p.h., but the available traction does not permit the use of more. These figures are approximate, of course, but it is clear that the steam plant gives vastly more power than the gasoline plant at all speeds under 50 m.p.h., that is, at the speeds that are used. At the average speed of operation, say 15 to 20 m.p.h., the steam plant is at least 2.5 times as powerful as the gasoline plant.

It is undeniable that the steam car is incomparably more active on the road than the gasoline car, and it is so simply because the steam plant has a power charac-

teristic enabling the employment of the full power of the plant at almost any car speed.

Mr. Clayden himself supplies a ready instance of this. On page 821 of his paper a certain gasoline car, there referred to as "a particularly good performer," is tabulated as developing 10 hp. at 10 m.p.h., the maximum transmissible power at that speed being put down at 27 hp. Now, since a steam car can develop that maximum transmissible power of 27 hp., it is exactly 2.7 times as powerful as the given gasoline car at that speed.

Although a comparison on the basis of continuous duty is extremely favorable to steam, a comparison on the basis of intermittent duty is much more so. The steam plant can develop power at a rate greatly exceeding its continuous maximum, provided the period of extreme use is followed by a period of moderate use during which the steam pressure can be recovered; the gasoline engine has no such flexibility. In going down a hill, with either type of plant the throttle is closed; closure in the throttle in the gasoline plant shuts off the combustion of fuel, but closure of the throttle in the steam plant merely shuts off the steam without affecting the combustion which goes on, accumulating energy in the boiler up to the limit of storage, which energy can be drawn upon in climbing the next hill.

Gasoline Engine Versus Steam Engine

The gasoline engine will never be the equal in performance of the steam engine until it is provided with a gear box having an infinite number of speeds; until the gears in this box change themselves without attention on the part of the driver and, in fact, without his knowledge, and in such a way as always to give the ratio best suited to the work at hand, until the changes of gear are made without noise and without interruption of the tractive effort; until the engine secures overload capacity and starting torque; until it ceases to have the "stagger point" described by Mr. Clayden; until it has some reserve of power, in some degree at least resembling the tremendous storage of energy provided by the hot water in the steam car's boiler; until it runs with the mathematical steadiness and consistency of the steam engine. This list might be extended to cover many other points, but it seems unnecessary. Faults may be found with the steam car, but absolutely not with the characteristic of the steam engine, which propulsion approaches the ideal for automobile work.

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