--THESIS--

Design of Automobile Testing Plant Including Absorption Dynamometer.

by

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DESIGN OF AUTOMOBILE TESTING PLANT INCLUDING ABSORPTION DYNAMOMETER

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Chapter I.

- INTRODUCTION -

With the present extensive application of the automobile to both our social and industrial welfare, and its promising future, more data and information might be available regarding the actual power developed in the various types of motors, and the maximum economy that can be attained from them.

Various formulae have been used for determining the actual horse power obtainable having given the size of the motor, but considerable comment has been offered as to the correctness of these existing formulae.

A very common method of testing an automobile is to take the car out on the road and see what it can do, and if a high speed is obtained the car is pronounced good. This method of testing was used by the automobile manufacturers in the early stages of development but now where the daily output of some manufacturers runs as high as 1000 cars per day, the problem of giving each car a road test is a serious one; so other means had to be devised to test each engine in order to determine whether it was developing the maximum power allowed before shiping the car to the purchaser.

Numerous methods have been adopted by the manufacturers in testing their cars and at present the socalled electrical method seems to prevail.

In one instance where the electrical method is used the rear end of the automobile is raised up from the ground and special rear wheels with pulleys put on in place of regular ones. These pulleys are belted to the pulleys on the generator shaft and the current generated is sent into the electric mains.

This is one instance where the testing of automobiles can be used to serve two purposes in addition to the regular test, namely, supply electric energy for light and power purposes and utilize the hot water given off by the engines to heat the buildings.

By reading the volt and ampere meters connected to each unit a quick and accurate determination can be made of the power which a particular car is making and developing, after the friction and windage losses have been once determined by previous experiment.

Some manufacturers do not take the time to conduct such an elaborate test, but confine their tests to the engine before placing it in the chassis. This is done by belting the engine to the generator and making a short test in order to determine if the engine developes the minimum power allowable by the manufacturer.

After a motor car has been tested by its manufacturer and placed on the market and used for a year or so, there is no means available at present which the average motorist can submit his car to a short test to determine whether his engine is still developing its maximum power, or, whether the engine is in proper adjustment to give the best economy as well as the maximum power.

- PURPOSE -

The purpose of this thesis is to offer a complete design with working drawings of an automobile testing plant, including absorption dynamometer for giving a quick and accurate test on any motor car or light motor truck without disassembling the car.

The plant is to be so designed that a car can be run on the testing platform and given a test without disturbing any parts of the automobile other than to attach the necessary apparatus for measuring fuel consumed and for determining the speed of the car.

To make the plant complete in its simplest form it must possess, (1) means for measuring the power developed, (2) method for absorbing the power developed, (3) a device for holding the car in position, (4) apparatus for measuring the draw bar pull, (5) means for measuring the amount of the fuel consumed and (6) means for comparing the speed of the pulleys and rear wheels in order to determine if a slip is present.

The plant shall be simple in its operation as well as accurate and made as inexpensive as modern engineering practice will permit.

Chapter II.

- CONDITIONS EXISTING AND SPACE AVAILABLE -

The unit is to be designed to suit the conditions existing in the steam laboratory at Throop College of Technology. Owing to congested conditions in the laboratory considerable thought was given to the selection of a proper place for the building of this Automobile Testing Plant. Several methods were suggested and worked out before the final one was adopted.

The first suggestion was to dig a pit outside of the building next to the north wall, but this form of construction while simple in structure necessitated the digging of a pit large enough to contain two pulley wheels, absorption dynamometer and scales; also to give room enough for one attendant. This construction does not require a platform for the automobile to run upon, other than a few boards placed over the pit preparatory to running the car into place, thus leaves the car on the ground level and not several feet in the air.

This method had several good points, but the one objection was that the apparatus was out in the open, unprotected from the weather and made a distasteful appearance for the north side of the laboratory. So I worked out another possible arrangement by placing the pit inside of the building and allowing the front end of the automobile to project outside. After making measurments I found that there was only one place available on the inside of the north wall, provided the partition between the machine shop and the laboratory was moved two feet westward. In addition to rearranging some plumbing for a nearby washstand this required digging a rather large pit and expense of concreting.

With the above plans in mind I turned my attention to another part of the laboratory not much in use and found possibilities which looked favorable, because sufficient room was available and the means of access to the various measuring apparatuses were better.

The idea of digging a pit was abandoned because this would necessitate a greater expense of tearing up the present reinforced concrete floor; in changing and rearranging the underground piping now used by the hydraulics department, and putting in a concrete pit, than that which would be occured in building a platform out of wood that could be taken apart and stored away some place when not in use.

A large double window in the west wall of the laboratory makes it an easy matter with slight alterations to bring an automobile into the building for testing without making any extensive changes to the general outside appearance of the laboratory.

After a thorough consideration I came to the conclusion that the space in the southwest corner of the laboratory with ample room and access through the window would be the ideal place for the testing plant; so this spot was selected and the platform made to suit the conditions existing there.

A weir three feet wide, two feet above the floor and three feet deep runs along the south and west walls; and as the portion running along the west wall has been of little use to the hydraulics department, it is to be removed, leaving the trough in the floor one foot deep and three feet wide, to be covered over with boards.

The automobile will be run into the building so that when it is in position on the testing platform the rear end will be near the opening allowing the fumes from the exhaust to escape directly into the air outside.

Chapter III.

- VARIOUS TYPES OF BRAKES AND THE ONE ADOPTED -

Having definitely decided upon the location and style of plant to build the next question to decide was what method would be employed to absorb and measure the power developed by the automobile. The maximum power was taken as 70-horse power at a speed of 60 miles per hour.

One of the oldest and simplest methods in use to-day is the prony brake, which in its simplest form consists of a friction band placed around a pulley and cooled by a stream of water running on the band or wheel to carry away the heat generated by the friction; an arm projects out from the band and acts on a pair of scales so that the torque can be measured. This method was considered, and after carrying out some calculations found that it would take a pulley of large proportions to absorb the power efficiently without overheating the friction band, so I turned my attention to some other types of dynamometers.

The electric method of absorbing and measuring the power developed was next taken under consideration. Due to the fact that electric generators are ordinarily designed for speeds of 1000 R.P.M. or higher, a generator capable of absorbing 70 H.P. at 650 R. P. M. would call for an extraordinarily large one and of a special design. This means a greater proportionate cost for the generator as compared with a similar generator of higher speed. Realizing that the cost would be as high as compared to the other methods available, I turned my attention toward some cheaper method.

Various types of hydraulic brakes and dynamometers were investigated in view of finding one that would not be too expensive to construct and would serve the purpose but none was found, for almost every type involved the design of buckets and blading which would lead one into complications in both design and construction. Therefore this type was abandoned.

After considerable searching and investigation I finally decided on the type of brake invented by Geo. I. Alden, a dynamometer that is accurate, reliable, neat and simple in its operation. It has been thoroughly proved by long use and includes a series of tests on the power developed by a locomotive.

The Alden dynamometer in its simplest form consists of:- A smooth, circular, revolving cast iron disc with radial grooves. A disc keyed to the shaft which transmits the power to be absorbed. A non-revolvable housing has its bearings upon the hub of the revolving dish. A pair of thin copper plates fastened to the housing, one face of each copper plate being close and parallel to the sides of the revolving disc, the other face of each plate having back of it a chamber in the housing.- A system of piping and connections by means of which oil is circulated in such a manner as to insure the perfect lubrication of the surfaces of the copper plates which are next to the revolving cast iron disc. A system of piping and connections by means of which water under pressure can be circulated through the chambers between the copper plates and the housing. An arm of proper design fastened to the housing bears down on a pair of scales so that the power absorbed can be readily determined.

- OPERATION -

When the dynamometer is in use, the water flows through the chambers in the housing, and thus over the copper plates. It also by its pressure, tends to force the plates against the sides of the revolving disc. The pressure increases the friction between the revolving disc and the copper plates, which being held by the housing, offer a resistance to the rotation of the disc. This resistance is balanced by the weighing apparatus. The pressure of the water flowing through the chambers in the housing is regulated by a valve. The water flowing through the chambers of the housing performs the double function of supplying the pressure which cause the friction and of carrying off in the form of heat energy absorbed by that friction.

The oil enters the chamber in which the disc revolves near the hub of the disc, and it is carried by centrifugal force along the grooves in the sides of the disc out to its periphery and completes its circuit through tubes external to the housing.

In carrying out the design for the housing and disc, two discs were first decided upon and then the design was changed using only one disc. This was done so that the housing could be used in an old centrifugal pump frame formerly used in the hydraulics laboratory. The design gave a coefficient of friction between the copper plates and disc of 5.42% at a speed of 250 R.P.M. and 70 H.P. as compared with 5.5% used by Alden in the design of his dynamometer.

In carrying out the design of this dynamometer provision was made throughout the design for overload capacity and ability to use the dynamometer for testing any engine which might be added to the laboratory in the near future up to 70 H.P. at a speed of 250 R.P.M. although the maximun load that will ever be developed by a machine on the testing stand will rarely exceed 70 H.P. at 650 R.P.M. on the dynamometer shaft.

Before determining the speed of the dynamometer shaft, the size of pulleys to transmit the power from the rear wheels of the automobile had to be determined. The size of automobile wheels varies from 30 inches to 37 inches in diameter, so two pulleys 32 inches in diameter were selected as about the proper size to suit all conditions. The designs and construction of these wheels will be taken up in detail under Part V.

Having decided upon the size pulleys to use, the speed of the dynamometer shaft was determined to be 650 R.P.M. as previously stated, and at a speed of 10 miles per hour the shaft will only rotate 65 R.P.M. and at proportionate revolutions for speeds in between.

The diameter of the disk selected was 28 inches so that a safe peripheral speed would be obtained at the maximum speed of 650 R.P.M. with a sufficient factor of safety. This gives sufficient area for friction with the copper plates to enable the dynamometer to absorb 70 H.P. efficiently at 650 R.P.M.

Considerable discussion arose regarding the amount of friction between the disk and copper plates with a film of oil between, but from previous design and experiment the Alden type of brake gave very satisfactory results, producing sufficient friction to carry the loads placed upon them.

From experiments performed in the fuel laboratory the fact was brought out that by increasing the pressure between two smooth surfaces with an oil film between, did not increase the friction in direct proportion until a pressure was reached where the oil film was broken down. In this case two surfaces were used which were perfect, but in the case of the disk and copper plate surfaces in the above dynamometer it is a question whether such a perfect surface will be had. If not, the total friction produced will not remain constant during change in pressure, but will vary accordingly.

The coefficient of friction between the disk and copper plates assumed is not more than the coefficient of friction one will find in ordinary journal bearings. The value assumed was .0542 at the maximum load and the value found in the average bearing is about .033.

The capacity of the dynamometer approximately estimated will be from 2 to 12 H.P. per 100 R.P.M. The maximum horsepower that may be absorbed at a given speed by a dynamometer of given size, depends upon three factors, viz; the kind of oil used, the temperature at which the oil is maintained, and the water pressure by which the copper plates are held against the revolving disk.

To carry the maximum load, the oil used should be heavy and of high viscosity, and a large quantity of cold water should be supplied so that the oil may be kept comparatively cool. The source of water supply should have a steady pressure up to 50 pounds per square inch.

The data and formulae used, together with drawings of dynamometer assembled and details will be found in the appendix to this thesis.

- DIRECTIONS FOR RUNNING DYNAMOMETER -

When the dynamometer has been mounted on the shaft make necessary connections for water and oil. Pour oil into the oil cup until the oil spaces are filled. Light oil may be used in starting the machine, but heavy cylinder oil is recommended when the maximum capacity of the dynamometer is required. Open wide the valve in the pipe through which the cooling water is discharged from the dynamometer. Open the valve which supplies the cooling water, so that water at low pressure, will be flowing through the dynamometer when the motor is started. Start the motor to be tested. Gradually throttle the inlet water until the scale beam balances, and maintain this condition throughout the test.

Chapter IV.

- APPARATUS FOR MEASURING DRAW BAR PULL -

When the car is under test on the platform, some means must be provided to hold the car in place or counterbalance the draw bar pull exerted by the automobile. This force varies inversely as the speed of the car and ranges in value from 450 pounds at 60 miles per hour with a 70 horsepower engine to 1500 pounds at 10 miles per hour with a 40 horsepower engine. If a car develops 70 horsepower at 10 miles per hour the draw bar pull will be 2600 pounds, but in the average car, few engines develop their maximum power at such a slow speed as 10 miles per hour. So the maximum draw bar pull was taken as 1500 pounds in designing the draw bar pull apparatus.

The essentials of this apparatus are rigidity, accuracy, and ability to measure in the simplest manner possible, the draw bar pull exerted by the automobile.

Various forms were considered, including the hydraulic cylinder using oil for the working substance and gages to record the pressure; the compression of a steel spring measuring the force by the amount of deflection produced, and the lever method of transferring the force to a pair of scales placed on the floor.

The latter method was the one adopted because this form of construction as carried out in the design offered a means of holding the car in place on the stand and gave a fairly accurate method for measuring the pull developed. The design for this apparatus consists of a right-angle frame section built up with I beams, pivoting at the corner on Hess Bright ball bearings securely fastened to the bearing plate. This bearing plate is fastened to a steel channel securely anchored in the concrete floor and braced with a one inch rod extending outside and anchored in the ground. To one end of this frame is fastened the removable arm fastened to the car by means of straps, while the other end will bear down transversely upon an I beam one end of which is pivoted while the other end bears down upon the scale platform placed out in front of the testing platform. This system of leversfor transmitting the force was the only method found that could be used to suil the conditions existing to do the work with a fair degree of accuracy.

Further details of the design and construction of this apparatus will be found in the appendix.

Chapter V.

- PLATFORM FOR THE AUTOMOBILE -

Having decided, owing to conditions existing, to have the apparatus above the floor level, a suitable platform must be built to carry the automobile while undergoing a test. The height of this platform is determined by two factors, the size of the pulleys used to transmit the power from the auto and the height of the dynamometer shaft from the floor. The minimum height allowable in this case was three feet, so this was selected as the height to build the platform. The platform proper will be of two runways braced together; each runway consisting of a 4"x10" timber on the top and a 2"x 12" plank on the bottom with 4"x6" and 2"x10" studs placed between as per drawing. These two units are thoroughly braced and fastened together at the proper distance so that the center of one runway is parallel to the other at a distance of 56 inches, this being the standard motor car tread. All timber in this platform construction is to be surfaced on all sides and of No. 1 quality Oregon Pine. This form of construction will carry a load from 6000 to 9000 pounds safely. For dimensions, and list of material required see the appendix.

- POWER TRANSMITTING APPARATUS -

When the automobile is in place on the platform the rear wheels will be directly over and resting upon the 32"x12"pulleys previously mentioned. These pulleys must be of such strength as to withstand the weight of the rear end of the automobile in addition to transmitting the power to the dynamometer. The surface of these pulleys must be such as to correspond to the actual road surface as near as possible. After considereble research I decided on the pulleys as made by the Dodge Manufacturing Company, namely, with iron center and wooden rim. I wrote to the above firm for the cost of a pair of pulleys under loading as follows; weight of car (maximum) on two pulleys 4500 pounds, maximum speed of 650 R.P.M. corresponding to rim speed of one mile per minute and maximum power to be transmitted from rear wheels of automobile 70 horsepower at maximum speed. They referred me to Harron, Rickard & Mc Cone of Los Angeles, California, who are their sales agents there, and on inquiry they furnished me an estimated cost for the two pulleys of approximately $30.00, this including the freight to the coast. After I inquired I decided to widen the face of the pulleys from 8" to 12" and this will thereby add a slight additional cost.

- SHAFT -

The size of shaft to adopt to carry the weight of the pulleys with the automobile resting upon them, and transmit the maximum power of 650 R.P.M. was next decided upon. The maximum bending and twisting moments were found, and applied in a formula given in Jone's machine design. Allowing for a reasonable factor of safety the diameter of shaft obtained was 2 and 5/16 inches for shafting steel. The formula and data are given in the appendix. A flexible coupling is to be fastened on the shaft toward the dynamometer end and connected to the dynamometer shaft.

- BEARINGS FOR SHAFT -

Two bearings were selected for carrying the shaft and pulleys, the pulleys to be placed on the shaft 56 inches apart from center to center and the bearings placed next to the pulleys on the inside mounted on wooden timber as shown in assembled drawing. The bearings selected are for a 2 and 5/16 inch shaft of the Standard Box Type, manufactured by Dodge Manufacturing Company and listed at $8.80 each less 50 and 10.

Chapter VI.

- SPEED AND GASOLINE MEASURING APPARATUS -

In order to determine the power the engine is developing it is necessary to know the rate of travel. Considerable difficulty was experienced in obtaining a device that was simple and self indicating. At first it was suggested to use the ordinary type of speedometer that is used on automobiles, but owing to the various sizes of wheels that are found on automobiles the speedometer will be too expensive, because one compleat set of gears will have to be obtained for every size tire made.

The size of automobile tires varies from 28 inches in diameter on the smaller cars up to 36 inches in diameter on the larger cars. Each size will require a complete set of gears in order to work on the same speedometer. This would add greatly to the cost of the plant and would not be as simple in operation as by using a tachometer and a revolution counter.

Two tachometers can be used; one on the dynamometer shaft and the other on the rear axle of the automobile and the two readings compared to see if any slip occured and if so, what percentage.

To determine the fuel economy it will be necessary to discount the carbureter from the fuel tank and to connect the carbureter to a vessel calibrated so that the amount of fuel consumed can be determined at a glance. A vessel with a glass gage calibrated to parts of a gallon is recommended, same to be connected to the carbureter by means of a rubber hose and suspended from some object not connected with the automobile so that the vibrations will not interfere with the accuracy of the readings taken from the gage glass.

The power developed by the automobile can be calculated by two methods: by knowing the draw bar pull and speed, and by the amount of power absorbed by the dynamometer which can be calculated as follows:

The lever arm on the dynamometer was made 31.512 inches long; now the downward force exerted at the end of this lever is measured by the scales, and determining the speed of the dynamometer shaft in R.P.M. the horsepower can be readily calculated by using the following formula.

$$H.P. = \frac{2\pi R F N}{33000 \times 12}$$

$$H.P. = \frac{2\pi \times 31.512 \times F N}{33000 \times 12}$$

$$(1) \quad H.P. = .0005 F N$$

R = Lever arm in inches.

N = R.P.M.

F = Force at end of arm in pounds.

H.P.= Horsepower.

The scales on the draw bar levers will read $\frac{39 \times 42}{54 \times 91} =$ .3335 of the force actually exerted by the automobile and in order to get the correct value the scale reading must be multiplied by $\frac{1}{.3335}$ or 3. Having determined the force and speed of the car in miles per hour, the horsepower developed can be calculated by the formula

(2) $$H.P. = \frac{5280 \times S \times F}{33000 \times 60}$$

S = Speed in miles per hour.

F = Draw bar pull in pounds.

The value obtained should check very close to that obtained in formula (1), the discrepancy being due to friction in the dynamometer shaft bearings and in the bearings on the pulley shaft.

Chapter VII.

- CONCLUSIONS.-

I have incorporated in the following part all the data and formulae used in carrying out the design and drawings for the testing plant.

The number of board feet and sizes of timber used to construct the platform are tabulated in this section together with the necessary number of bolts and screws to carry out the construction.

Blue print working drawings for the dynamometer and testing plant will be found in the appendix.

With the above brief description together with the data and working drawings I have endeavored to present for your approval a design of an Automobile Testing Plant simple and accurate in operation.

Henry B. Gerckens

CHAPTER VIII APPENDIX
DATA AND FORMULAE

Size of shaft for dynamometer

data:- 70 H.P. at 650 R.P.M & 75 H.P. at 250 R.P.M.

Moment in in. lbs $= \frac{33000 \cdot 75 \times 12}{2\pi \cdot 250} = 18,900.$ (Maximum)

$Dia. = 1.71\sqrt[3]{\frac{M}{S}}$

M = Moment in in. lbs.
S = Stress in fibre.
D = dia. in inches.

$D. = 1.71\sqrt[3]{\frac{18900}{12000}} = 2.00$ in.

Min. dia. of $2\frac{1}{8}$" was used.

Thickness of casing to withstand pressure of 70 lbs per sq. in.

$T = .00439\, D\sqrt{P}$ (From Kent)

D = dia of casing in in.
P = Press. lbs per sq. in.
T = Thickness in in. for Cast iron.

$T = .00439 \times 24\sqrt{70}$

T = .883 inches.

By reenforcing with ribs or stress members the thickness was reduced to $\frac{9}{16}$ in.

Bolts to hold casings together.

Net area of casing subjected to pressure = 408 sq. in.

Total outward pressure = 408 × 70 = 28,560 lbs.

Assume tensile stress of 8000 lbs per sq. in. and 18 bolts. stress per bolt $= \frac{28560}{18} = 1590$ lbs.

Net area of bolt $= \frac{1590}{8000} = .199$ sq. in.

The bolt having an area of .199 sq. in. or more at the root of the thread was found to be a $\frac{5}{8}$ in. bolt with area of .202 sq. in.

DATA AND FORMULAE CONTINUED

Thickness of disk

Maximum shearing force will occur next to the hub at a distance of 2.6 in. from center.

Shearing force $= \frac{\text{Moment}}{\text{radius}} = \frac{18900}{2.6} = 7{,}260$ lbs.

Circumference $= 2\pi \times 2.6 = 16.33$ in.

Allowable shear for cast iron 1000 lbs sq. in.

Length × thickness × 1000 = 7260 lbs.

Thickness $= \frac{7260}{1000 \times 1633} = .0445$ in.

This value is too small so a thickness of 1" was used.

Size of pipe to supply required amount of water to carry away the heat generated.

1 H.P. = 42.42 B.T.U. per min.

75 H.P. $= \frac{75 \times 42.42}{60}$ B.T.U. per sec. = 53.

Temp. of incoming water 80° of outgoing water about 200°

Heat absorbed per lb. of water = 200 − 80 = 120 B.T.U.

$\frac{53}{120} = .44$ lbs. of cooling water per sec.

Approximate velocity of water = 44 ft/sec.

Area of pipe in ft. $= \frac{Q}{V}$ Q = cu. ft. per sec
V = vel. ft. per sec

$Q = \frac{.44}{62.5} = .007$ cu. ft.

Area $= \frac{.007}{44} = .00016$ sq. ft.

A $\frac{1}{2}$" pipe with area of .0021 sq. ft was used

DATA AND FORMULAE CONTINUED

Friction disk

Outside dia. 24" Area 452.39 sq. in.

Inside dia 8" Area 50.26 sq. in.

Net area per side = 402.13 sq. in.

Center of pressure $= \frac{2}{3}\frac{(R^3 - r^3)}{(R^2 - r^2)}$

R = outter radius in in.

r = inner " " ".

$C.P. = \frac{2}{3}\frac{12^3 - 4^3}{12^2 - 4^2} = \frac{2 \times 1664}{3 \times 128} = 8.67$ in.

Tangential Force at C.P. $= \frac{\text{Moment}}{8.67}$

$= \frac{18,900}{8.67} = 2,180$ lbs for 75 H.P.

Coefficient of friction $= \frac{\text{Tangential force}}{\text{Normal force}}$

Normal force $= 50 \times 402.1 = 20105.$ per side

C. of F. $= \frac{2180}{20105 \times 2} = .0542$ for maximum case.

C. of F. for 70 H.P. and 650 R.P.M.

C. of F. $= \frac{782}{50 \times 402 \times 2} = .01945$

Thickness of ring

Outward pressure = 70 lbs per sq. in.

$24.5 \times 70 = 1720.$ lbs per linear inch.

$\frac{1720}{2} = 860$ lbs. per side.

Area per side $= 1 \times 1\frac{3}{4} = 1.75$ sq. in.

Bolt area $= 1 \times \frac{5}{8} = .68$ sq. in.

Net area of metal = 1.07 sq. in.

Tension = 860 lbs per 1.07 sq. in.

or 804 lbs per sq. in. a safe stress for cast iron.

DATA AND FORMULAE CONTINUED

Size of Key

Maximum torque 18,900 in. lbs.

Force at 1.5 in. radius = $\frac{18900}{1.5}$ = 12,600 lbs.

Allow 8000 lbs per sq. in for shear.

$\frac{12600}{8000}$ = 1.57 sq. in. of metal needed.

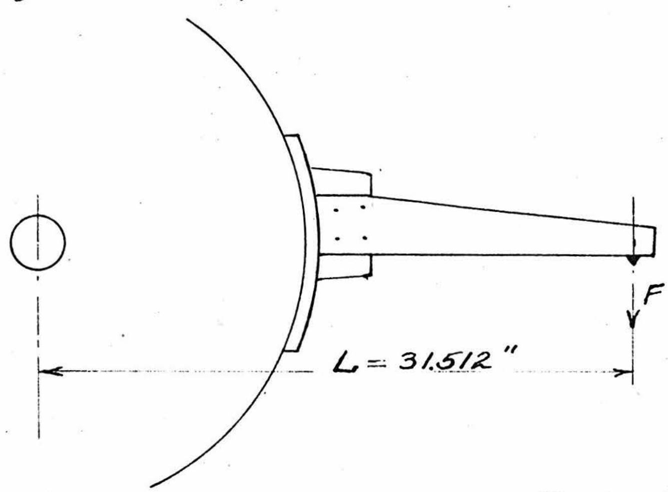
Length × width = 1.57 sq. in.

Length = 10 in.

Width = $\frac{1.57}{10}$ = .157 in. or $\frac{3}{16}$ in.

A key $\frac{3}{4}$ in. × $\frac{9}{16}$ in. was recommended.

Length of torque arm.



$$H.P. = \frac{2\pi RNF}{33000 \cdot 12}$$

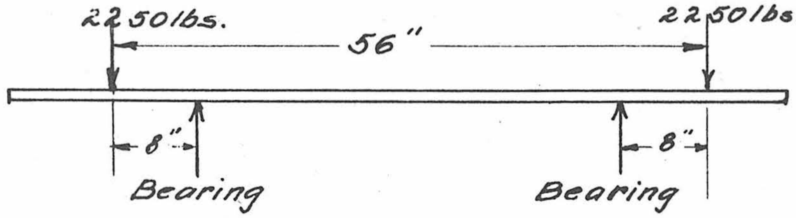
R = Radius in in. = L.
F = Force in lbs.
N = R.P.M.

$$H.P. = \frac{2\pi \cdot 31.512 \cdot F.N}{33000 \cdot 12}$$

H.P. = .0005 FN

DATA AND FORMULAE CONTINUED

Size of shaft necessary to transmit 70 H.P. at 650 R.P.M. and carry wt. of rear end of automobile assumed at 4500 lbs.



$$D^3 = \frac{6.366}{f}\left[.6\,M_b + \sqrt{M_b^2 + M_t^2}\right]$$

f = Bending fibre stress = 10,000

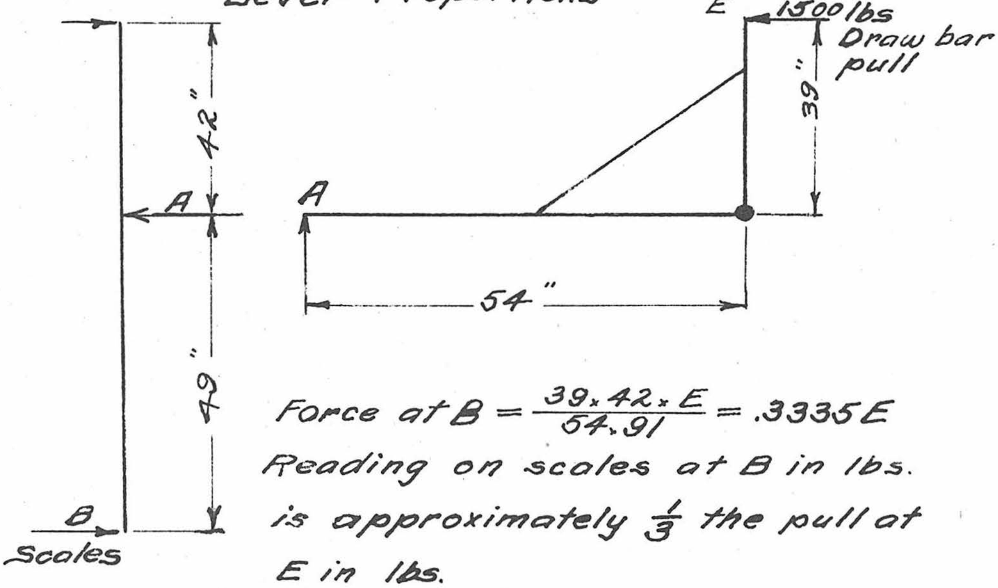
M_b = Bending moment in. lbs. = 2250.8 = 18,000 in. lb.

M_t = Twisting moment in. lbs. = 18,900 in. lb.

$$D^3 = \frac{6.366}{10000}\left[.6 \times 18000 + \sqrt{18000^2 + 18900^2}\right]$$

$D^3 = 23.5$ $D = 2.86$ in. $2\frac{15}{16}$" was adopted

Lever Proportions

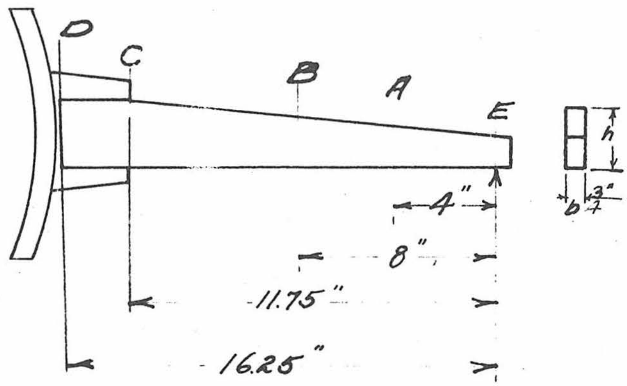


$$\text{Force at } B = \frac{39 \times 42 \times E}{54 \times 91} = .3335E$$

Reading on scales at B in lbs. is approximately $\frac{1}{3}$ the pull at E in lbs.

DATA AND FORMULAE CONTINUED.

Design of torque arm.



Maximum force at E = 600 lbs

Allow 8000 lbs per sq. in. for wrought iron in tension

$\text{Moment} = \frac{PI}{e}$ $\qquad P = 8000$; Moment = in. lbs.

$I = \frac{bh^3}{12} \qquad \frac{I}{e} = \frac{bh^2}{6} \qquad b = .75"$

Section at "A." $\quad 4 \times 600 = \frac{8000 \times .75 \times h^2}{6}$

$h^2 = 2.4 \qquad h = 1.55$ in.

Section at "B" $\quad 8 \times 600 = \frac{8000 \times .75 \times h^2}{6}$

$h^2 = 4.8 \qquad h = 2.2$ in.

Section at "C" $\quad 11.75 \times 600 = \frac{8000 \times .75 \times h^2}{6}$

$h^2 = 7.05 \qquad h = 2.65$ in.

Section at "D" $\quad 16.25 \times 600 = \frac{8000 \times .75 \times h^2}{6}$

$h^2 = 11.25 \qquad h = 3.36$ in.

Casting at "D" $\quad 16.25 \times 600 = \frac{1500 \times 25 \times b}{6} \qquad \begin{cases} P = 1500 \\ h = 5 \end{cases}$

$b = 1.56$ in.

Casting at "C" $\quad 11.75 \times 600 = \frac{1500 \times 3.5^2 b}{6}$

$b = 2.3$ in.

DATA AND FORMULAE CONTINUED

Draw bar pull in lbs. for various speeds in miles per hour and H.P.

	SPEED IN MILES PER HOUR							
H.P.	10	20	30	40	50	60	70	80
5	187.6	93.8	62.5	46.9	37.5	31.3	26.8	23.4
10	375.1	187.6	125	93.8	75.	62.5	53.6	47.
15	562.8	281.4	187.6	140	112.	94	80	70
20	750.4	375.2	250.	187	150	125	107	94
25	938.0	469.0	312	244	187	156	134	117
30	1125.6	562.8	375	281	225	187	160	140
35	1313.2	656.6	437	328	262	219	187	164
40	1500.	750.2	500	375	300	250	214	187
45	1688.	844.	562	422	337	281	241	211
50	1875.	937	625	469	375	312	268	244
55	2063	1031	687	516	412	344	294	258
60	2250	1125	750	562	450	375	321	281
65	2438	1219	813	609	487	406	348	305
70	2625	1312	875	656	525	437	375	328
75	2814	1407	938	703	562	469	402	352
80	3000	1500	1000	750	600	500	429	375.

$$\text{Force in lbs} = \frac{33000 \times 60 \times H.P.}{5280 \times M.P.H.}$$

H.P. = Horse power.

M.P.H. = Speed in miles per hr.

LIST OF MATERIAL
PLATFORM GROUP
Lumber

Nº Req.	Size	Length	Bd. ft.	Material	Remarks
2	4"x10"	12'-0"	80	O. P.	Surfaced on all sides
2	2"x10"	11'-0"	37	" "	" " "
1	4"x6"	11'-0"	22	" "	" " "
2	2"x10"	8'-0"	27	" "	" " "
2	2"x8"	22'-0"	58	" "	" " " one side half round.
8	2"x4"	12'-0"	64	" "	Surfaced on all sides
4	2"x4"	11'-0"	30	" "	" " " "
1	8"x10"	3'-6"	24	" "	" " " "
1	8"x8"	10'-0"	54	" "	" " " "
2	3"x12"	12'-0"	72	" "	" " " "
1	3"x12"	6'-0"	18	" "	" " " "
1	2"x3"	4'-0"	2	" "	" " " "
1	2"x12"	16'-0"	32	" "	" " " "
	Total Bd. ft. =		520		

All lumber specified above to be straight grain Oregon Pine of best quality.

Hardware

4 - 6" Strap hinges with screws.

24 - ½"x6½" Bolts with nuts and washers.

48 - ½"x5" Lag screws with washers.

8 - ¾"x1'-6" Bolts with nuts and washers.

4 - 1½"x2'-0" " " " " "

1 - 1"x12'-0" Iron rod threaded at both ends with two nuts to fit same.

2 - cu. ft. concrete for anchor.

LIST OF MATERIAL
DRAW BAR APPARATUS

Nº Required	Description	Drawing Nº.
1	Bearing assembly	#10
2	H.&B. Ball bearings #307 dia 3.149" bore 1.3779"	
1	7.5 lb. I-beam 4" deep $57\frac{1}{4}$" Long.	#11
1	7.5 lb. " " " " 30" " .	#11
1	13.25 lb. 9" Channel 4'-0" " .	
1	5.5 lb. I-beam 3" deep $33\frac{1}{4}$" Long.	#11
1	5.5 lb. " " " " $93\frac{1}{2}$" " .	#11
2	$2\frac{1}{4}$" x $\frac{1}{2}$" x 8" steel plate	#11
2	Doz. $\frac{1}{4}$" rivets.	#11
3	Doz. $\frac{1}{2}$" rivets	#11
2	$7\frac{3}{4}$" x $7\frac{3}{4}$" x $\frac{1}{2}$" steel plate	#11
2	4" dia. x $\frac{1}{2}$" " "	#11
4	Hard steel plates as per drawing #11	
2	4" x $\frac{1}{2}$" x 36" steel bar	#12
2	2" x $\frac{1}{2}$" x 20" W.I. bar	#12
1	$3\frac{3}{4}$" x $\frac{3}{4}$" x 41" steel bar	#12
4	$\frac{1}{2}$" x 3" W.I. Bolts.	#12.
2	$\frac{5}{8}$" x 4" lag screws	#12
1	8" x 8" x 8" wood block	#12
1	$\frac{3}{4}$" x $2\frac{1}{2}$" steel bolts	#12

LIST OF MATERIAL
DYNAMOMETER GROUP

No. Req.	Description	Material	Drawing No.	Approx. wt.
1	Shaft	Steel	1	68 lbs
1	Disk	Cast iron	2	160 "
1	Ring	" "	3	38 "
2	Casing	" "	4	400 "
1	Shoe	" "	5	31 "
1	Torque Arm	Steel	5	10 "
2	Friction plates	#10 Copper	28" dia.	38 "
18	$\frac{5}{8}$" x $5\frac{1}{2}$" Bolts + nuts	Steel	1	
1	Ring	W. I.	1	
1	$\frac{9}{16}$" x $\frac{3}{4}$" x $8\frac{1}{2}$" Key	Steel	1	
6	$\frac{5}{8}$" x $2\frac{3}{4}$" Cap screws	"	5	
4	$\frac{1}{2}$" x 3" Bolt and nut	Iron	5	
1	Fulcrum	Steel	5	
2	Pedestal bearing	Al-ready on hand		
1	Base frame			
	Piping for oil and water connections.			
1	1-ft. $\frac{1}{2}$" wrought iron pipe			
2	$\frac{1}{2}$" Valves	Brass		
1	$\frac{1}{2}$" Street el	Iron		
1	3-ft. $\frac{1}{4}$" wrought iron pipe			
2	$\frac{1}{4}$" - Stop cocks	Brass		
2	$\frac{1}{4}$" - Pet cocks	"		
2	$\frac{1}{4}$" - Unions	Iron		
1	$\frac{1}{4}$" Tee	"		
1	$\frac{1}{4}$" El			
1	2 ft. Brass or copper tubing $\frac{1}{4}$" outside dia.			

LIST OF MATERIAL
POWER TRANSMISSION APPARATUS

Nº Required	Description	Drawing Nº.
1	$2\frac{15}{16}$" dia. steel shaft of good quality 7'-0" long.	
2	Bearing base castings	#9
4	$\frac{3}{4}$" x $2\frac{1}{2}$" steel bolts	
8	$\frac{1}{2}$" x 4" steel set screws	#9
2	Standard Box Type Bearings as M'f'g. by Dodge Mfg. Co. for $2\frac{15}{16}$" dia. shaft.	
2	12" face, 32" dia. pulleys, wooden face with iron center as Mfg. by Dodge Mfg. Co.	

List of Drawings