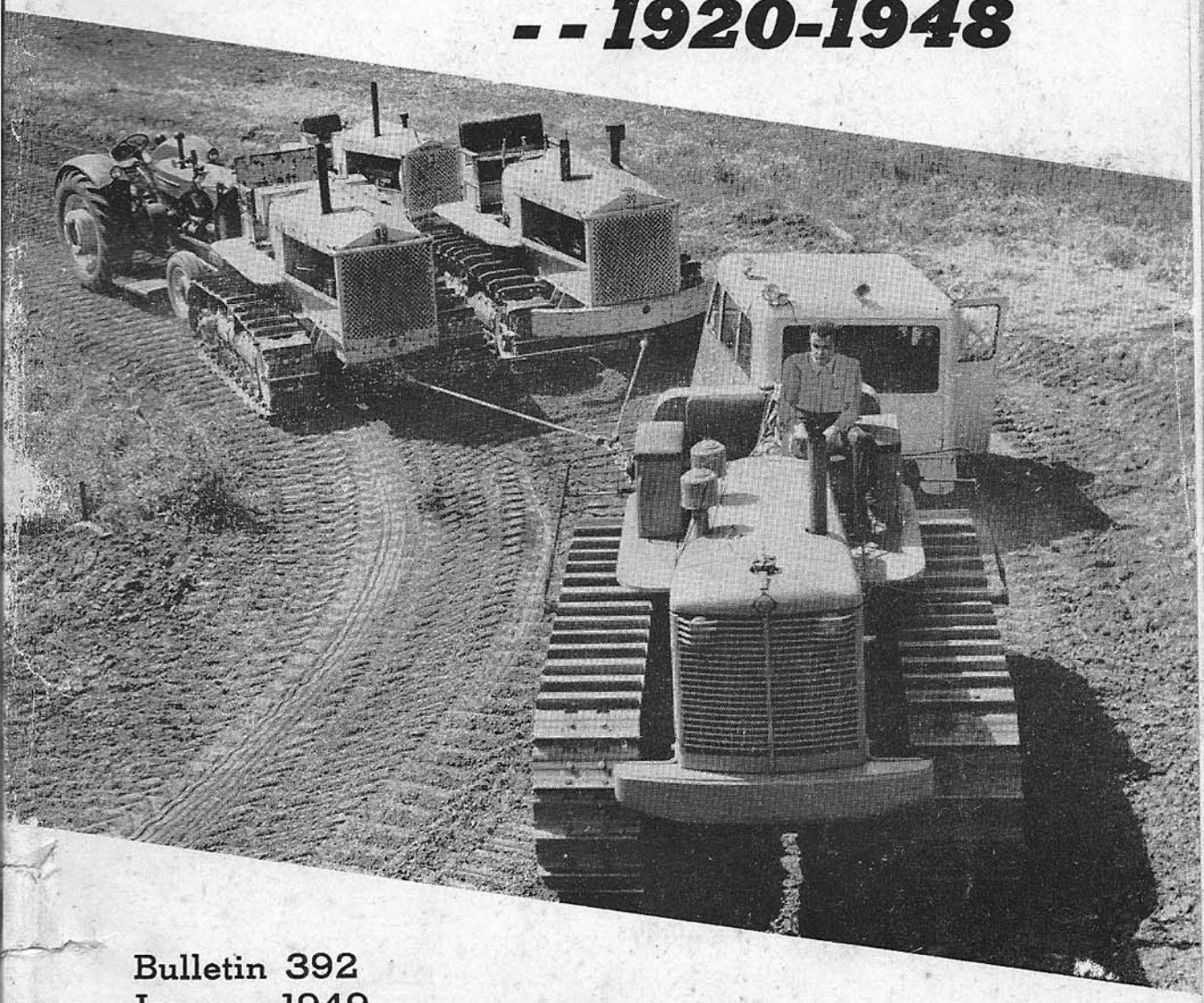
The Nebraska Tractor Tests --1920-1948



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The Experiment Station
University of Nebraska College of Agriculture
W. V. Lambert, Director, Lincoln, Nebraska

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E. E. Brackett, professor emeritus, served as a member of the Tractor Test Board for 28 years, retiring September 1, 1947. He was chairman of the Board for 18 years.

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BOARD OF TRACTOR TEST ENGINEERS
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Nebraska Tractor Tests

With the close of the 1948 testing season came the end of the twenty-ninth year of tractor testing at the University of Nebraska. The numbers of complete tests conducted and reported for these years are as follows:

1920	*1921*	*1922*	*1923*	*1924*	*1925*	*1926*	*1927*	*1928*	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*
65	15	5	12	10	8	12	15	7	16	10	14	12	9	11

1935	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	Total
17	28	19	19	24	27	13	No	tests	during	war	1	10	16	395

This bulletin summarizes the results of 84 of these tests and includes data on all tractors reported by their manufacturers as on the market January 1, 1949. If a tractor has been tested but is not listed in this bulletin, the reader may assume that its manufacture has been discontinued.

All tractors tested are certified by their manufacturers as being stock-model machines, conforming to specifications filed with the application for test. No special or high-test fuels are used except in those cases where the manufacturer states in the application for test that they are necessary to insure satisfactory performance of the engine. Skilled operators employed by the University are in charge of the tractors when all test results are obtained.

In the tests conducted from 1920 to and including the 1927 season, it was permissible to make carburetor settings for each individual load. Beginning with 1928 the "one carburetor setting" was adopted and all results shown on reports of tests made from 1928 to 1934, inclusive, were obtained with the carburetor adjustment remaining unchanged throughout all parts of the complete test. As explained on page 12, it was the practice from 1926 to 1936, inclusive, to determine the highest drawbar and belt rating permissible under the rating code of the American Society of Agricultural Engineers and the Society of Automotive Engineers. The code as revised in 1936 made no provisions for determining horsepower ratings. The same method outlined in the former code, however, is used in arriving at the calculated rating shown on the last page of the individual test report and in column 3 of the bulletin summary sheet. In determining the drawbar and belt ratings, runs are made at a 100 per cent maximum carburetor setting. The results of these runs did not appear in the test reports from 1928 to 1934 except in those cases where the "operating

An individual report of each tractor test at the Nebraska Experiment Station is issued soon after the test is completed, and this bulletin is compiled from these reports. Copies of the original individual reports are available at 10 cents per report (on one tractor) from the Department of Agricultural Engineering, College of Agriculture, Lincoln, Nebraska. Individual reports will be sent to subscribers following each test for an annual subscription rate of $2.00.

setting" was 100 per cent. (See summary sheet column 22 and page 7 of this bulletin.) Test reports issued in 1935-1941 inclusive carried the 100 per cent in addition to the operating maximum test figures. The summary sheet issued with this bulletin (No. 392) has been enlarged to include the results of Test B and Test F (100 per cent maximum belt and drawbar figures) on all current models of tractors tested since March 1, 1930.

GENERAL PROCEDURE AND RULES IN TESTING TRACTORS

WHEN A MANUFACTURER wishes to test a new tractor, application forms are obtained from the Agricultural Engineering Department of the University of Nebraska. These forms call for detailed specifications of the tractor to be tested. They are filled out and returned, together with a request for the assignment of a testing date and check for $500.00 to cover the test fee. Dates for test are tentatively assigned in the order in which the application for tests, specifications, and testing fee are received. The test date depends on the arrival of the tractor and suitable weather conditions. Tractors that are shipped by way of the C. R. I. & P. in Nebraska will be switched to the Agricultural College loading dock with minimum delay.

It is assumed that the application for test is made by the tractor company with the knowledge that it is not an experiment but an official performance test to be run under the tractor specifications submitted with the application and under the testing rules in force. One of the rules is that there shall be no revision of specifications after the test starts nor any change of parts or equipment except to make replacement for that which may be defective or broken. Experimentation desired by the manufacturer must be deferred until after the official test is completed and is then contingent on available time. All such experimental work is charged to the manufacturer on an hourly basis. Any data and results obtained are for the information of the manufacturer and will not be included in the official report.

A representative of the manufacturer should be present during the test. His duties include unloading the tractor, installing wheel equipment or other accessories, operating the tractor during the "limber-up" run, making such adjustments as he may deem necessary before the test, making repairs when necessary during the test, and at conclusion of the test disposing of the tractor. In addition to these duties, the manufacturer's respresentative makes all decisions involving permissible choices or company policy relative to the current test which are not covered in the application for test.

Before any tests are made the lubricating oil is drained from the crankcase and is replaced with new oil. This new oil is selected by the manufacturer's representative from the brands generally available in Nebraska. It is of the viscosity specified in the application for test and is purchased by the Tractor Testing Laboratory in sealed containers. The oil is weighed and the weight per gallon at 60°F. is determined. All figures in the test report showing consumption of either oil, fuel, or water in gallons are based on the amounts used in pounds and the weight per gallon at 60° F.

The fuel used is the lowest grade recommended by the manufacturer for use in the tractor being tested. For instance, if the application for test states

that the tractor will operate on gasoline, tractor fuel, and distillate, distillate or tractor fuel will be used. The gasoline used is of the lowest commercial grade available and in no case is a premium fuel used in an official test except in those cases where it is specified by the manufacturer as being essential to the successful operation of the engine. Fuels and lubricants are supplied by the University and charged to the manufacturer at current prices.

Test A.—The first run is made on the drawbar and is known as the "limber-up" run. The principal object of this test is to take out the stiffness likely to be found in a new machine and give an opportunity to check the condition of the tractor and ascertain if all the parts are working normally. The tractor is operated at approximately one-third rated load for four hours, two-thirds rated load for four hours, and full rated load for four hours. A reasonable amount of additional time is granted if desired. Each one of the forward gears is used for some portion of this test. The manufacturer's representative is responsible for the operation of the tractor during this test and may make such adjustments as he believes necessary, provided they do not conflict with the specifications in the application for test.

Ten-hour drawbar test (Test No. 391).

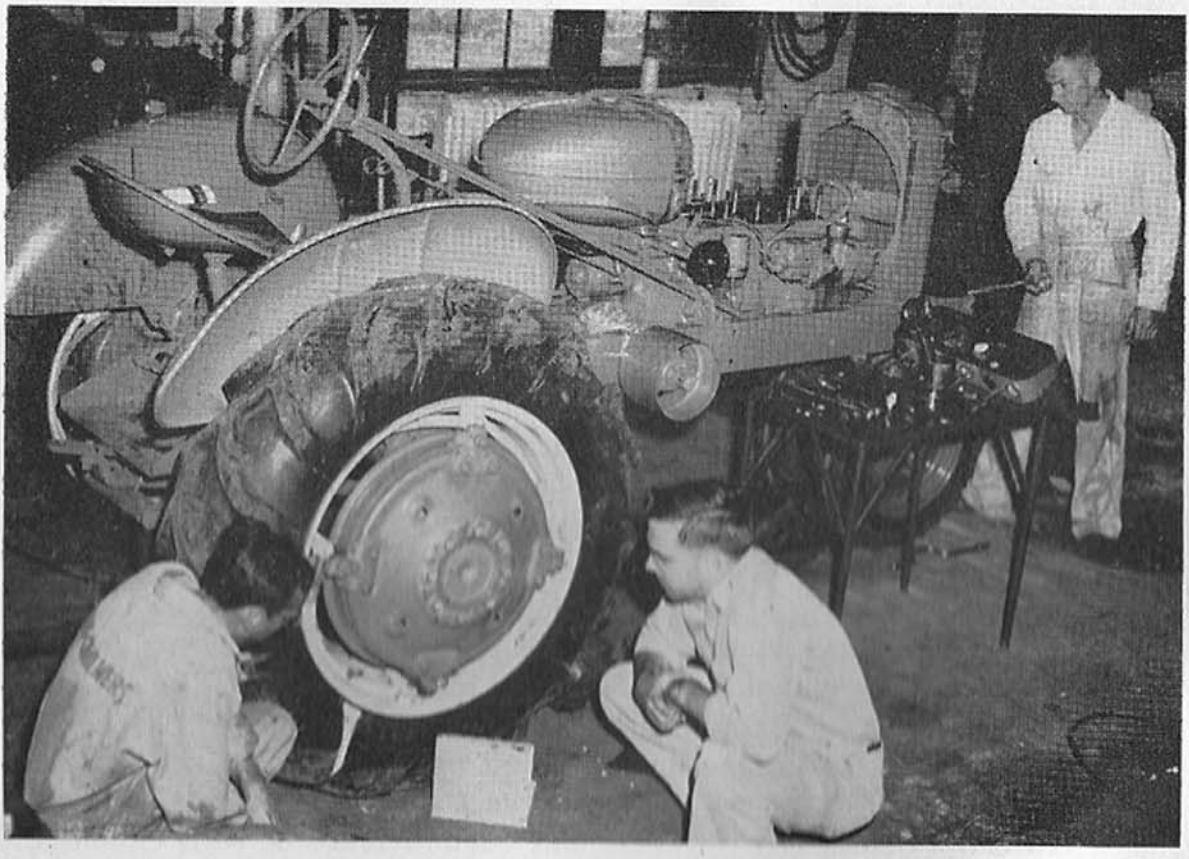
Adjustments that are permissible include setting the valve tappet clearance and the gap of breaker points or spark plug points, adjusting the clutch, and making other adjustments of a similar nature. This shall not be interpreted to permit the installation of new parts or accessories without having the same mentioned in the official report of the test.

BELT TESTS

THE TRACTOR TESTING engineer then takes charge of the tractor and it is belted to the cradle-mounted General Electric dynamometer used in determining the belt horsepower. Before any belt horsepower tests are run, the top radiator tank is drilled to take an indicating thermometer, a fuel line is installed from tractor fuel system to the fuel-weighing equipment, and measurements are taken of the belt thickness and circumference of both engine and dynamometer pulleys. No allowances are made for belt losses.

Test B, 100 per cent Maximum Belt Test.—The engine is then run at full load until it is thoroughly warmed and has reached a condition of constant operating temperatures. All adjustments are made to secure maximum output from the engine at rated rpm. Rated crankshaft speed is that number of revolutions per minute recommended by the manufacturer for normal operation. The governor is set to hold the throttle valve to the extreme open position, the spark is set to give the best results, the manifold heat control, if present, is set at the most favorable position, and the carburetor is carefully adjusted to that point at which an additional amount of fuel gives no increase but less fuel decreases the power output at the rated speed of the engine. After uniform operating conditions are reached, this test, known as the 100 per cent or rating maximum, is continued for two hours. The object of this test is to check or establish belt horsepower ratings.

At ten-minute intervals readings are taken or observations made of engine belt pulley and brake speed, load on scale beam of dynamometer, temperature of water in top tank of radiator, air temperature at a point approximately five feet in front of the center of the radiator, and amount in pounds of fuel used. Barometer readings are taken every hour. The water level in the radiator is measured at the beginning and at the end of the two-hour period, and the necessary amount of water is added to raise it to the same level as at the start of the two-hour test. Water, if used in the fuel mixture, is checked in the same manner.



Checking gear ratio (Test No. 399).

Results of this test are used in arriving at the "calculated" rating appearing on the last page of the individual reports and in column 3 of the bulletin summary sheet. The manner in which this rating is determined is explained on page 12.

The observed maximum horsepower as determined in this initial belt test did not appear in the published report of each test nor on the summary sheet of the annual tractor test bulletin from 1928 to and including 1934, except in those cases where the manufacturer elected to use the 100 per cent maximum power setting throughout the complete test. Test B has appeared on all of the individual test reports in 1935-1941 inclusive. The summary sheet of this bulletin (No. 392) has been revised to include Test B figures on all current models of tractors tested since March 1, 1930. On either the first or last page of the report and in column 22 of the summary sheet are figures indicating whether the carburetor setting used was 100 per cent or some lesser value.

Test C, Operating Maximum Belt Test.—In case the manufacturer wishes to use a carburetor adjustment leaner than the 100 per cent setting, a series of trial runs of 20 to 30 minutes at leaner settings are made and the manufacturer's representative is permitted to choose from these an "operating setting." This operating setting of the carburetor is used throughout the remainder of the test with the exception of the 100 per cent maximum drawbar test in rated gear (to determine the drawbar rating) when the adjustment used is the 100 per cent maximum power setting as obtained on the belt.

The first run on this operating setting is a one-hour maximum power test known as the "operating maximum belt test." The object of this test is to determine the maximum power developed and the fuel consumption at a carburetor setting that is practical for field operations. The radiator cover or shutters, manifold heat control, and spark are set at the most favorable positions, the engine is run until operating conditions have become stabilized, and then readings are taken at ten-minute intervals over a one-hour period.

Test D, Rated Load Belt Test.—The next belt test is of one-hour duration and is known as the rated-load belt test. The object of this test is to determine whether the tractor will carry its rated load on the belt and to secure a record of fuel consumption and other operating data. The tractor is given, as nearly as possible, its rated load. The carburetor remains set at the operating setting. The governor is adjusted to maintain rated engine speed at rated load. Rated load is determined in one of two ways. If the tractor is rated by the manufacturer, sufficient load is applied to develop rated horse power at rated engine speed. In case the manufacturer either does not specify the rating of the tractor or elects to accept the "calculated" rating, then rated load becomes 85 per cent of the corrected maximum as calculated from the results of the 100 per cent maximum belt test.

Test E, Varying Load Belt Test.—The last run on the belt is known as the varying-load test. The carburetor setting and ignition timing are the same as in the rated-load test. The object of this test is to show the governor control of the speed and also fuel consumption when the load varies. It is composed of six 20-minute runs made in the following order: The first is rated load, which is the same load as the one-hour rated load test just completed; in fact, if conditions are favorable, the rated and varying load tests are continuous

and the last 20 minutes of the rated-load run are used for the first 20 of the varying-load test. This is followed by 20 minutes at no load. The minimum load is applied and the power developed is approximately one horsepower. The next load applied is one-half of the rated-load torque and this is followed by a maximum horsepower test in which enough load is applied on the dynamometer to pull the engine far enough under rated speed to insure an extreme throttle opening. The last two runs are made at one-fourth and three-fourths rated-load torque, respectively.

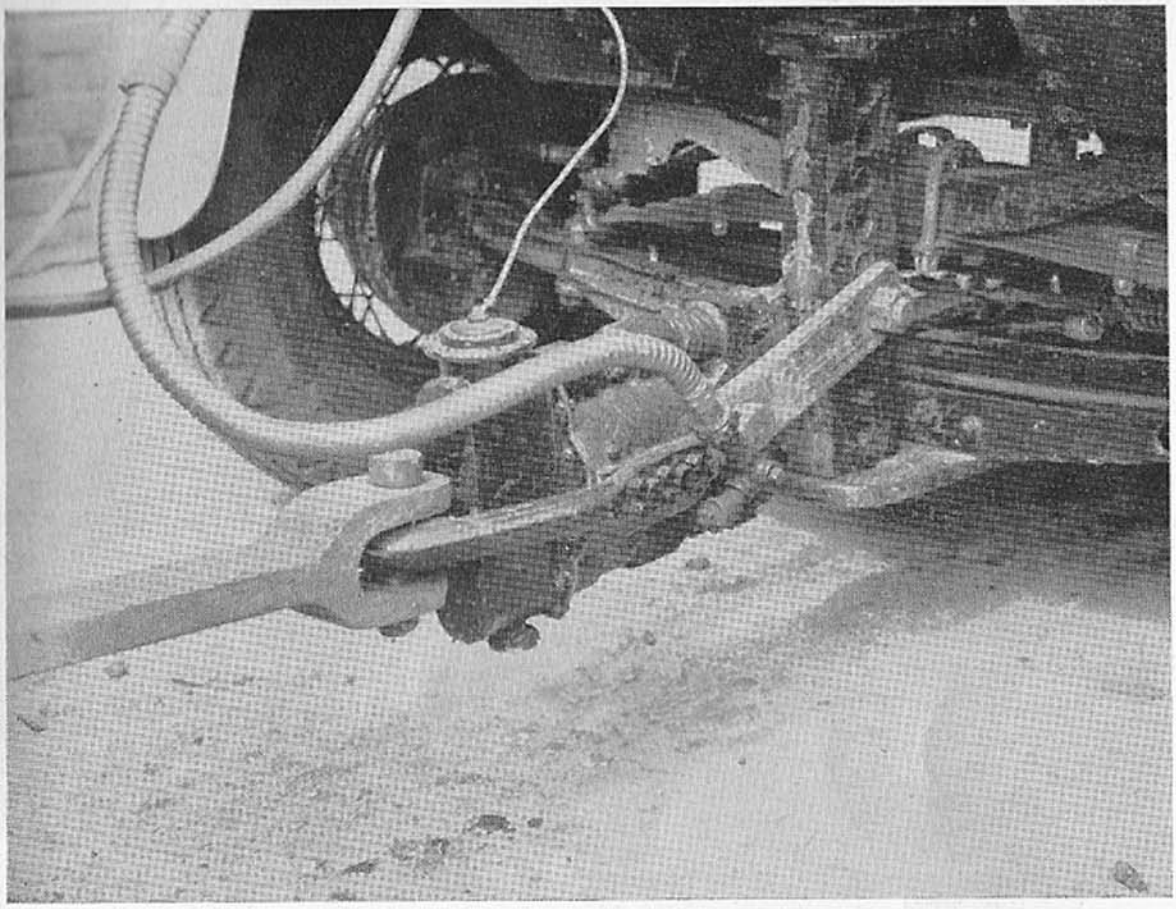
During the varying-load test the amount of heat applied to the intake manifold may be changed according to the load if an easily controlled manual adjustment, such as a lever operating from the driver's seat, is provided. An effort is made to maintain the recommended temperature of the cooling medium when possible, by regulating the amount of covering on the radiator in those cases where an adjustable cover is provided. These adjustments, it is believed, require no more attention than may reasonably be expected from a careful operator.

DRAWBAR TESTS

Test F, 100 per cent Maximum Drawbar Test.—The first drawbar tests made are maximum horsepower runs at two carburetor settings, "operating" and "100 per cent." The 100 per cent maximum test is made in one gear only, that designated by the manufacturer as most suitable for plowing or ordinary farm work. It is commonly known as "plow gear," "working gear" or "rated gear." The results of a test in this gear, with the carburetor adjusted at 100 per cent as found on the belt, are used to determine the "calculated" drawbar rating. The observed 100 per cent maximum drawbar horsepower is corrected to standard conditions, multiplied by 0.75, and the result is the "calculated" rating. This is explained in detail on page 12. The results of this rating maximum test have not appeared in the published report of each test nor in the summary sheet of the annual tractor test bulletin from 1928 to and including 1934 except in those cases where the manufacturer elected to use the 100 per cent or maximum power setting throughout the complete test. The summary sheet of this bulletin (No. 392) has been revised to include Test F figures on all current models of tractors tested since March 1, 1930.

The manufacturer's representative is permitted to select the tire, wheel, lug, and extension-rim equipment from that supplied on stock tractors or that regularly offered to the trade in Nebraska but at extra cost. The same tire or wheel and lug equipment must be used on all the drawbar tests except Tests J and K. When drawbar tests are made on rubber tires, additional weight may be placed on the rear wheels or rear of the tractor. The total weight on the rear wheels is not to be in excess of the tire recommendations furnished by the Tire and Rim Association. In the case of the crawler tractors, a choice may be made in the type and width of track and the type and size of cleats, subject to the same restriction as obtained for wheel tractors. The drawbar specifications as to dimensions and adjustments for height and point of attachment must be the same for all of the drawbar tests. They must also conform to the specifications in the application for test.

Test G, Operating Maximum Drawbar Test.—Operating maximum drawbar tests are made in the forward gears, using the operating carburetor setting selected and used on the operating belt tests. The object of these tests is to determine the maximum horsepower the tractor will develop in each forward gear with the carburetor adjusted at the operating setting with engine running at rated speed under the prevailing temperature and barometric conditions.



All of the pull exerted by the tractor is applied to the hydraulic draft unit.

After the tractor is thoroughly warmed and brought to a condition of constant operating temperature, at least two suitable drawbar runs are obtained over a measured distance of 500 feet on the testing track. A suitable run is one in which the operating temperatures are normal, the throttle is open to the extreme position, the load is relatively constant, and the average engine speed is at or very close to that specified by the manufacturer. Very seldom is a pull used in which the variation from rated speed is more than one per cent and in each test in each gear an attempt is made to obtain an average number of revolutions per minute, which does not deviate from rated speed more than one-half of one per cent. Occasionally there is not sufficient traction with steel wheels to hold the engine speed down to the rated figure at wide open throttle without producing slippage of approximately 20 per cent or more. In such cases the throttle is closed to the point where the slippage is a reasonable amount or something less than 20 per cent. The method used in making maximum drawbar tests on rubber tires is explained in detail on pages 18 and 19.

Test H, Rated Load Drawbar Test.—The last run made on the drawbar is the rated-load test. The duration of the test is ten hours' actual running time (as nearly continuous as possible) with constant load. A record is made of the time and reason for each stop, and also of any adjustments or repairs made on the tractor. The object of this test is to determine whether the tractor can pull its rated load continuously and to secure a record of fuel consumption on drawbar work. The governor is adjusted to give rated speed of the engine with the tractor pulling rated load and in the gear recommended for plowing or ordinary farm work. The carburetor remains at the operating setting. Rated load is determined in one of two ways. If the tractor is rated by the manufacturer, sufficient load is applied to develop rated horsepower at rated engine speed in rated gear. In case the manufacturer either does not specify the rating of the tractor or elects to accept the "calculated" rating, then rated load becomes 75 per cent of the corrected maximum as calculated from the results of the 100 per cent maximum drawbar test in rated gear.

Once each hour during the rated-load drawbar tests a chart is taken, by means of the graphic recording drawbar dynamometer, of the drawbar pull; observations are made of the time required to travel 500 feet, the revolutions of the drive wheels over this same measured course, and the temperature of the air and cooling medium. From the chart and observations, calculations are made for the drawbar pull in pounds, the rate of travel in feet per minute and miles per hour, the drawbar horsepower, the engine revolutions per minute, and the drive-wheel slippage in percentage. The testing operator maintains the load as nearly constant as possible and by following the progress of the test applies such a load as will be sufficient to develop horsepower equal to or slightly in excess of rated horsepower.

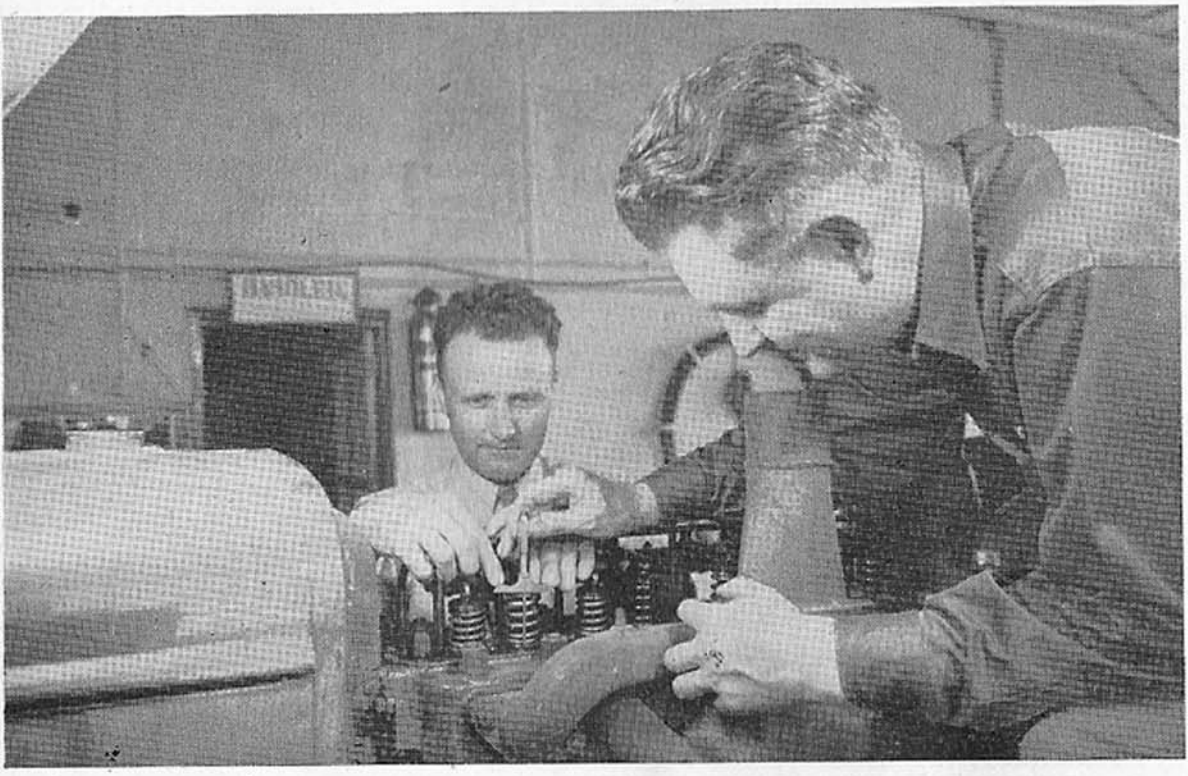
Test J is made in rated gear only, using the operating carburetor setting. The principal object of Test J is to show the effect of the removal of added weight on the performance of the tractor. In Test J, the wheel and the tire equipment used is the same as in Tests F, G and H except that all added weight, either liquid, cast iron or any other form, is removed. Test J may be compared directly with the rated gear run in Test G.

Test K is made in rated gear only, using the operating carburetor setting. The principal object of Test K is to show the effect of using smaller tires and wheels on the performance of the tractor. In Test K the smallest wheels and tires furnished as optional equipment by the manufacturer are used. This test can be compared with Test J. All added weight, either liquid, cast iron, or any other form, is removed.

END OF TESTS

AT THE CONCLUSION of the rated-load drawbar test the lubricating oil is drained from the crankcase and weighed, the specific gravity at 60° F. is determined, and the number of gallons drained is calculated. A record is kept throughout the test of all oil added or drained. The test report shows the total number of gallons of new oil put in the crankcase and the gallons of used oil drained.

At this time the tractor is inspected. The manufacturer's representative, when so directed by the engineer in charge, disassembles any part of the tractor or its accessories in order to facilitate inspection. Particular attention is centered on such specifications as clearance volume, valve and port dimensions, bore and stroke, transmission, differential and belt-pulley reduction ratios, and the conditions of such parts as valve heads and seats, spark plugs, magneto or distributor breaker points and fuel, oil, and water connections.



The valve lift is measured to check manufacturer's specifications.

During the drawbar tests, or on their completion, the tractor is driven to a government-inspected farm scale on the Agricultural College campus and weighed. The weight which appears in the test report is the observed weight plus the weight of the operator and the amount of fuel necessary to completely fill the fuel tank.

When all of the tests have been completed and the inspection made, the engineer in charge may release the tractor to the manufacturer's representative or at his discretion may withhold the release until the test report is issued.

INTERPRETATION OF SUMMARY SHEET

Name, Col. 1.—The tractor name as it appears in the body of the summary report is the name by which it was known when the machine was tested. If it has been changed, the same has been noted below.

Horsepower Rating by Manufacturer, Col. 2.—This is a figure determined by the manufacturer as being a reasonable output for the engine. The figure appearing first is the drawbar rating and the second is the belt rating.

Horsepower Rating, Calculated, Col. 3.—For several years A.S.A.E. and S.A.E. codes were quite generally accepted as the standard for tractor rating. These two groups, the American Society of Agricultural Engineers and Society of Automotive Engineers, revised their Tractor Test Code in 1936 and it no longer makes any provision for determining either belt or drawbar horsepower ratings.

The Nebraska Tractor Testing Laboratory, however, has continued to use the same method of determining belt and drawbar ratings as was formerly embodied in the A.S.A.E. and S.A.E. codes. These ratings are somewhat less than the maximum horsepower output of the tractor, in order that the operator may be sure of having a certain amount of reserve for emergencies. The belt horsepower rating is 85 per cent of the maximum corrected horsepower obtained by correcting the observed horsepower in Test B to standard conditions (60° F. and 29.92″ Hg).

The drawbar horsepower rating is 75 per cent of the maximum corrected horsepower obtained by correcting the observed horsepower in Test F to standard conditions (60 °F. and 29.92″ Hg).

The correction formula used is as follows:

$$BHPc = BHPo \times (Ps \div Po) \times \sqrt{To \div Ts}$$

where BHPc = corrected brake horsepower
BHPo = observed brake horsepower
Po = observed barometric pressure in inches of mercury
Ps = standard barometric pressure in inches of mercury
To = observed absolute temperature in ° F.
Ts = standard absolute temperature in ° F.

The following is a typical application of the correction formula: Let us use the model D Case, Test 349, as an example. Looking at Test B on page 1 of the individual report, we find that the

BHPo = 35.36
Po = 28.855
Ps = 29.920″ of mercury
To = 82° F. + 460° F. = 542° F.
Ts = 60° F. + 460° F. = 520° F.

Then $BHPc = 35.36 \times (29.920 \div 28.855) \times \sqrt{542/520}$
$29.920/28.855 = 1.0369$
$542/520 = 1.0423$
$\sqrt{1.0423} = 1.0209$
The correction factor is $1.0369 \times 1.0209 = 1.059$
Then $BHPc = 35.36 \times 1.059 = 37.45$

The corrected brake horsepower is sometimes known as "sea level" horsepower or the amount of horsepower developed under "standard conditions."

The "calculated" belt rating is obtained by multiplying the corrected horsepower by 0.85. In this case the rating would be $37.45 \times 0.85 = 31.83$.

Test 349, Test F, shows a maximum observed drawbar horsepower of 30.67, air temperature of 89° F., and barometer reading of 28.550″. The correction factor is 1.077 and that multiplied by 30.67 = 33.03, the maximum corrected drawbar horsepower. The "calculated" drawbar rating is 33.03 × 0.75 = 24.77.

Weight as Tested, Col. 4.—This is the weight of the tractor and full fuel tank, full radiator, operator, and such attachments as are necessary in the testing procedure. The total weight of these attachments varies from 30 to 40 pounds.

Rated R. P. M., Col. 7.—In this column appears the speed recommended by the manufacturer as the rated engine speed. In some instances a range of speeds may be recommended but for the purpose of this test it is necessary that some one rated speed be selected by the manufacturer. The manufacturer's specifications as to drawbar pull, rate of ground travel, pulley speed, and belt horsepower are all based on the rated engine speed.

Fuel Used, Col. 9.—The manufacturer specifies the grade of fuel that may be used in a tractor. In the event that machines are sold to burn several grades of fuel, the lowest grade is used. High-test or special fuels are used only when specified by the manufacturer as being necessary to the successful operation of the engine.

Oil, Cols. 10, 11, 12.—The viscosity of the lubricating oil used conforms to the manufacturer's specifications and the brand is one selected by the manufacturer's representative from those available in Nebraska. The gallons of oil placed in and drained from the motor are calculated figures obtained from observations of weight and the specific gravity of the new and used oil.

Belt Horsepower, Cols. 14, 23, 31.—In these columns are figures indicating the horsepower delivered at the end of the belt under the conditions existing at the time of the test. See page 15 for detailed explanation of horsepower.

Average Engine Revolutions per Minute, Cols. 15, 24, 32, 74.—An attempt is made to maintain such loads and such governor adjustments on rated runs as will result in a deviation of not more than one per cent from rated speed.

Fuel Economy Figures, Cols. 16, 17, 18, 25, 26, 27, 33, 34, 35, 76, 77, 78.—The amount of fuel used is expressed in three ways. The first term is gallons per hour. Comparisons with other tractors as to relative economy are not readily made with this expression of fuel consumption because the amount of power developed is not included in the term.

Two other expressions of fuel economy, horsepower hours per gallon and pounds per horsepower hour, both allow direct comparison to be made between two machines. A horsepower hour is the term applied to the arithmetical result of horsepower multiplied by time in hours. Ten horsepower hours might come from the development of ten horsepower for one hour, from one horsepower for ten hours, from two and one-half horsepower for four hours, or from any other combination of horsepower and hours which, when multiplied together, would equal ten.

Then, if by the burning of a gallon of fuel one engine is able to develop eight horsepower hours and another burning the same amount of the same fuel will develop twelve horsepower hours, obviously the second engine has the

better fuel economy. In other words, the larger the number of horsepower hours per gallon, the better the fuel economy.

The third term, pounds per horsepower hour, expresses the amount of fuel used to develop one horsepower for one hour. The smaller this value, the better is the fuel economy. Pounds per horsepower hour may be readily converted into horsepower hours per gallon by dividing the weight of a gallon of the fuel used by the consumption in pounds per horsepower hour; or, conversely, dividing pounds per gallon by horsepower hours per gallon gives pounds per horsepower hour.

Water Used, Cols. 19, 28, 36, 79.—These figures indicate the amount of water used in the cooling system and, where water is used with the fuel mixture, include that also.

Temperatures, Cols. 20, 21, 29, 30, 37, 38, 80, 81.—The atmospheric temperature as recorded is the average for the test. There may be considerable variation of temperature from the beginning to the end of the run, particularly on the ten-hour rated-load drawbar test. The cooling medium is maintained as nearly as possible at the temperature recommended by the manufacturer. Only such accessories as are standard equipment are used to maintain this regulation.

Carburetor Adjustment for Percentage of Maximum, Col. 22.—A tractor is not ordinarily required to develop its maximum horsepower. There is a point in the range of the carburetor adjustment where the tractor will develop nearly its maximum horsepower and still use considerably less fuel than it does at the point of maximum output. This point is determined by running a series of belt tests at various carburetor settings. The manufacturer's representative then selects some carburetor adjustment as the operating setting. It is identified by dividing the corrected horsepower obtained at this point—the point of operating setting—by the corrected horsepower at the 100 per cent setting and multiplying the result by 100. This percentage figure appears in column 22.

Varying-Load Revolutions per Minute (High and Low), Cols. 39, 40.—These are the extremes of the crankshaft revolutions per minute for the varying load, Test E, as obtained with the variation of load applied to the tractor. The figures are an indication of the governor control of the motor speed.

Drawbar Horsepower, Cols. 42, 46, 50, 54, 58, 62, 66, 71, 82, 86.—In these columns are figures indicating the amount of horsepower delivered at the drawbar under the conditions existing at the time of test. See page 15 for detailed explanation of horsepower.

Drawbar Pull, Cols. 43, 47, 51, 55, 59, 63, 67, 72, 83, 87.—These figures are the average pull exerted by the tractor under the described conditions.

Miles per Hour, Cols. 44, 48, 52, 56, 60, 64, 68, 73, 84, 88.—These speeds are calculated from observations of the time required to travel, while pulling the described load a distance of 500 feet.

Slip of Drivers, per cent, Cols. 45, 49, 53, 57, 61, 65, 69, 75, 89.—These are average slippage figures. The manner in which they are obtained is discussed under "Drawbar Testing Equipment," page 16.

HORSEPOWER

HORSEPOWER is a rate of doing work, and work is a force acting through a distance. For instance, a force of 150 pounds acting through a distance of 10 feet would do 1,500 foot pounds of work. However, unless we know the length of the time in which the work is done, we do not know how much power is developed. If, in one case, the work is done in two minutes and in another only one minute is required then the amount of power developed is twice as great in the second instance as in the first. To develop one horsepower it would be necessary to do 33,000 foot pounds of work in one minute or 550 foot pounds in one second.

Drawbar Horsepower.—Suppose we wish to determine the drawbar horsepower required to pull a three-bottom plow three miles per hour. First, we shall have to assume that the draft per bottom is some value, let us say 600 pounds. This, of course, will vary with the type and condition of soil, the depth and rate of plowing, and the condition and adjustment of the plow. If each bottom has a draft of 600 pounds, then the total pull required is 1,800 pounds. One mile per hour equals 88 feet per minute and three miles per hour equals 264 feet per minute. Then 1,800 pounds acting through a distance of 264 feet in one minute equals 475,000 foot pounds of work done per minute, and 475,000 divided by 33,000 equals 14.40 horsepower. If it were desired to pull the same number of pounds half as fast as before, then only 7.20 horsepower would be needed. If the rate of travel were twice as fast, or six miles per hour, then 28.80 horsepower would be required to pull the 1,800-pound load.

The work done at the drawbar or on the belt is known as useful work. Non-useful work is done in moving the tractor, in flexing the belt about the pulleys, in slippage both of the drive wheels and of the belt, and in overcoming friction in gears and bearings. Improved gear and bearing design and materials, as well as reduction of tractor weight, have brought the useful drawbar horsepower of the modern tractor much closer to the belt horsepower than was true in the early models. Work also is done in overcoming the internal friction of the engine caused by piston-cylinder contact, connecting rod and main bearing friction, and the resistance of other moving parts.

The use of rubber tires reduces the rolling resistance of a tractor, or in other words, less power is required to move the tractor over the ground than when steel wheels and lugs are used. This leaves more engine power available for useful work at the drawbar and accounts for the superior fuel economy of rubber over steel, particularly in the higher gears.

Belt Horsepower.—The point of maximum available horsepower of an engine is at the flywheel. Few current tractors are designed, however, so that the belt pulley may be attached directly to the flywheel. The belt horsepower must pass through one set of gears and sometimes more before it is delivered to the belt. The belt horsepower figures shown in our reports are obtained after the power has been transmitted through the belt and the driven pulley and they represent the amount of power available for useful belt work.

In an analysis of belt horsepower, there are the same factors—force, distance, and time—as in drawbar horsepower. Force is represented by the

number of pounds of effective tension in the belt and the other two, distance and time, are the number of feet of belt travel per minute. The rate of belt travel will be controlled by the size and speed of the tractor belt pulley. For each revolution of the pulley the belt will be advanced a distance equal to the circumference of the pulley. Then, the revolutions per minute of the tractor belt pulley multiplied by the pulley circumference will equal the belt travel in feet per minute. This is assuming there will be no belt slippage. Actually the slippage will vary from 1 per cent to 5 per cent and with any given load will depend on the tightness of the belt as well as the size and condition of both pulleys and belt. With few exceptions the belt slippage on the official tests is held to 1 per cent or less.

DRAWBAR TESTING EQUIPMENT

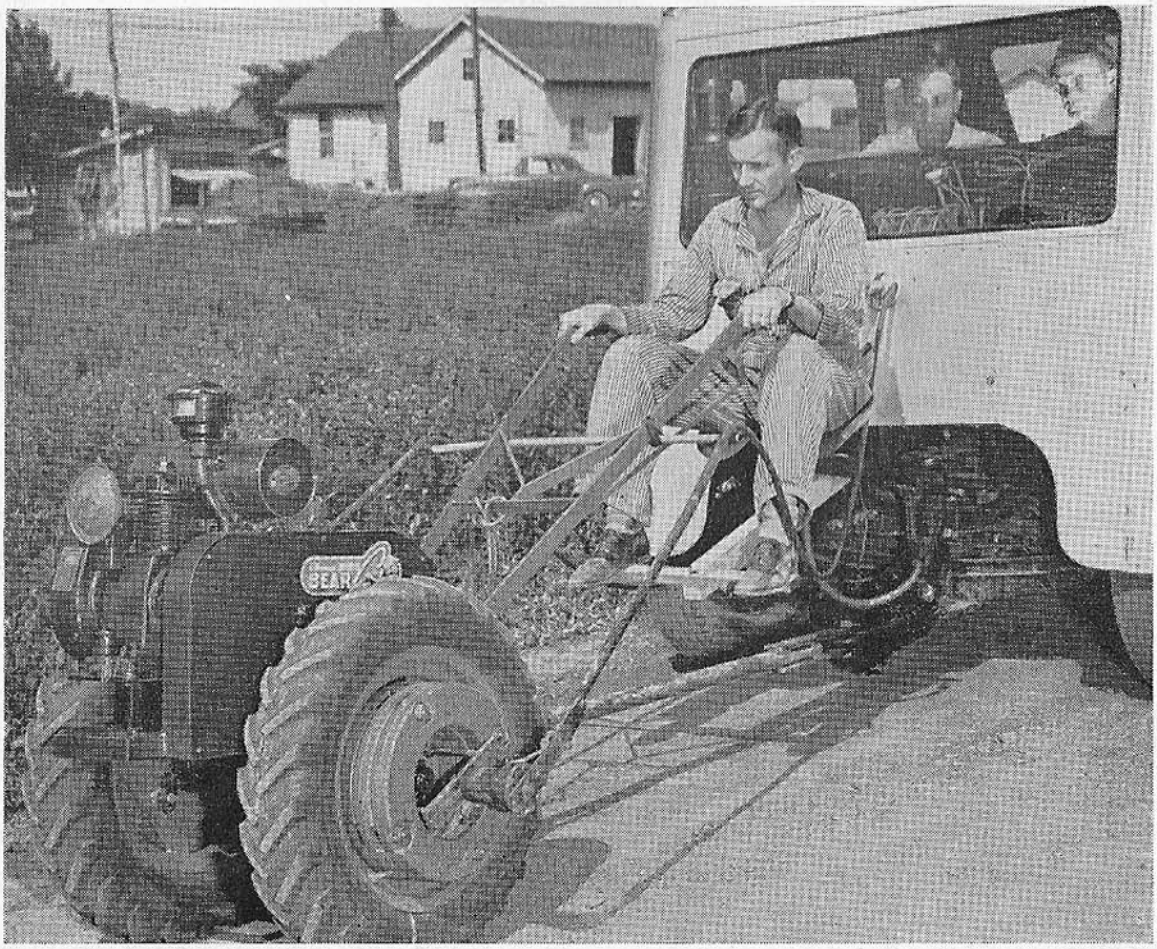
Comments.—All of the drawbar pull exerted by the tractor being tested is transmitted, by suitable equalizers and a hydraulic piston-cylinder mechanism called a draft unit, to the drawbar load. The pressure in the draft unit is carried through flexible metal tubing to the draft-recording instrument. The essential mechanism of this draft-recording unit is a gas-engine pressure indicator which has been so adapted to the requirements that it leaves on a special chart a continuous record of the drawbar pull of the tractor. From this chart, showing the pull in pounds, and from stop-watch readings showing the time of travel over a measured course, the horsepower developed is calculated. Rotary switches having ten contact points are attached to each drive wheel and connected to magnetic counters which record to one-tenth of one revolution the number of revolutions made over a measured distance. From these same readings are calculated the engine speed and the drive wheel or track slippage. In determining the slippage the tractor is driven without any drawbar load for a distance sufficient to give at least 20 revolutions of the drive wheels or crawler tracks. This distance is then accurately measured and is used as a basis for computing wheel slippage. The computations are as follows:

The distance covered at no load is divided by the number of drive-wheel revolutions to obtain the number of feet advanced per revolution. The number of revolutions made in advancing 500 feet is recorded by the electric counters. This number multiplied by the feet of advance per revolution at no load gives the distance the tractor would have travelled had there been no loss due to slippage. However, the tractor actually advances only 500 feet. The difference between these two distances is divided by the former, and the answer multiplied by 100 is the percentage of slippage. (When speaking of rubber tire tests, some prefer to use the term, "travel reduction.")

Drawbar Loading Machines.—In determining the drawbar horsepower of a tractor, it is necessary to provide a source of load which may be readily varied. One loading machine which has been used in a large number of tests since 1931, is built about a McCormick-Deering 15-30 tractor. A gear-type pump is mounted on the platform and driven by a roller chain from a special sprocket which replaces the brake pulley. The discharge line of the pump is carried up and forward to valves mounted on the top of the radiator. These valves may be closed or opened to increase or decrease the amount of

power absorbed by the pump. A return line from the lower radiator connection to the inlet openings of the pump completes the system. Additional load may be obtained by placing the tractor in gear and operating the engine against compression without fuel or ignition. If a light load is desired, the tractor may be placed in gear, the fuel and ignition turned on, and the throttle set to give such assistance as will result in the desired load.

Another loading machine built about a pneumatic-tired 15-30 McCormick-Deering tractor was first used in the 1936 testing season. The rear wheel equipment was changed to dual zero-pressure tires for the 1937 and 1938 seasons and back again to more heavily weighted pneumatic tires for the 1939, 1940 and 1941 seasons. A four-speed transmission mounted in the power line from the tractor rear wheels to the gear-type pump permits the use of this machine at travel speeds up to approximately 25 miles per hour. Still another machine, a smaller one, has a range of load from about 200 pounds to 1,600 pounds and a possible top speed of 40 miles per hour. The essential parts of this machine are the rear axle assembly and transmission from a heavy-type passenger car, a gear-type pump, a radiator and fan, a supply tank, and suitable controls. Three Cletracs, two large and one medium sized, together with two additional rubber-tired McCormick-Deerings, a 15-30 and an I-20, are used as supplementary loading units when the occasion demands.



One of the small tractors tested in recent years (Test No. 379).

A new instrument car, designed and built here at the Tractor Testing Laboratory, was placed in service at the start of the 1940 testing season. It provides protection for both the recording instruments and the operator from the weather and dust. Two small gear pumps, mounted in the car and driven by the rear wheels through two transmissions, provide drawbar load for the very small tractors.

TRACTORS USING RUBBER TIRES

STARTING WITH the 1934 season, supplementary tests on rubber tires, at no extra charge, were offered to manufacturers making drawbar tests on steel wheels and lugs. The first manufacturer to take advantage of this offer was Allis-Chalmers in Test 223 on their model "WC" tractor.

The routine drawbar tests were made on steel wheels and lugs. Then a four-hour fuel-economy run was made in third gear, after which the steel wheels were removed and rubber-tired wheels were mounted. For all rubber tire tests, the added weight per rear wheel has been such that the total weight on each rear tire did not exceed the tire manufacturer's recommendations.

These supplementary tests on rubber tires have consisted of operating maximum drawbar horsepower tests for each of the forward gears and fuel-economy runs of four hours each in second and third gears.

In the lower gears the traction developed by rubber tires and wheel weights, as ordinarily used, is not sufficient to transmit maximum engine horsepower. To determine the maximum horsepower in each gear, a series of runs was made, starting with the throttle partly closed so that the governor controlled the engine speed and with sufficient load applied to produce a drive-wheel slippage of 5 to 6 per cent. Other runs were made with increased load, but with the throttle opened wider to give rated engine speed which, of course, gave increased slippage. This balancing of throttle opening, engine speed, load, and slippage was carried to the point where either the engine was developing maximum power or the slippage was so great that the horsepower was appreciably reduced, usually a slippage of 25 to 30 per cent. The horsepower was calculated for each of the 500-foot tests, and such runs as produced the largest amount of power (and at the same time keeping within one per cent of rated engine speed) were selected as representative of the operating maximum drawbar horsepower in that gear.

The following arbitrary method was used in arriving at a suitable horsepower to develop in the fuel tests. The relationship between the rated and operating maximum horsepower on steel wheels in rated gear was determined. In Test 223 this was 12.14 divided by 14.36 and multiplied by 100 which equals 84.5 per cent.

Carrying along the illustration in Test 223, the amount of power that was desirable to develop in the second-gear fuel-economy run on rubber tires was obtained by multiplying the operating maximum horsepower in second gear on rubber, 14.19, by 84.5 per cent, which equals 11.99. An examination of the test results shows that 12.08 horsepower was the average developed over the four-hour period. In the same manner, the desired horsepower figures for third gear on rubber ($17.59 \times 0.845 = 14.86$) and for the third gear on steel ($13.34 \times 0.845 = 11.27$) were calculated for the fuel-economy tests.

This method just outlined applies to Tests 223, 237, 238, 249, 250, 282, 291, 292, 293, 294, 299, 303, 304 and 305. Tests 274, 275, 296, 297, 302, 308, 310, 311, 312, and 313, were conducted on rubber tires only. The drawbar tests made on these rubber-tired tractors were the same as normally would be made on the steel-wheel equipment.

In Tests 306, 307 and 309 the drawbar ratings were determined on rubber tires and then supplementary tests were made on steel wheels and lugs. The same procedure as outlined for Test 223 was used except that the steel wheels and rubber tires were interchanged.

At the end of the 1939 season it was felt that there was no longer any particular need for supplementary tests either on rubber if steel was used, or on steel if rubber was used in determining the drawbar rating. All of the wheel tractors submitted for test in 1939, 1940, and 1941 were tested on rubber tires.

Since 1941 two additional drawbar tests on rubber tires have been made. The present procedure for testing rubber tires includes Tests F, G, H, J, and K.

THE LAW

Purpose of the Law.—The Nebraska Tractor Law as stated in the Revised Statutes of Nebraska, 1943, Chapter 75, Article 9, Sections 75-901 to 75-911, inclusive, was enacted to encourage the manufacture and sale of improved tractors and to contribute to a more successful use of the tractor for farming.

It was thought that the best method of accomplishing these objects would be to require a tractor of each model sold in the state to be tested at the University of Nebraska and to have the results of these tests made public.

Provisions of the Law.—Stated briefly the provisions of the law are:

That a stock tractor of each model sold in the State shall be tested and passed upon by a board of three engineers under State University management.

That each company, dealer or individual offering a tractor for sale in Nebraska shall have a permit issued by the State Railway Commission. The permit for any model of tractor will be issued after a stock tractor of that model has been tested at the University and the performance of the tractor compared with the claims made for it by the manufacturer.

That a service station with full supply of replacement parts for each model of tractor shall be maintained within the confines of the State and within reasonable shipping distance of customers.

Nebraska Tractor Law.—The full text of the law is as follows:

ARTICLE 9

PERMITS TO LIQUID FUEL TRACTOR COMPANIES

75–901. Tractor engines; testing required. No tractor or traction company shall be permitted to sell or dispose of any model or type of gas, gasoline, kerosene, distillate or other liquid fuel tractor engine in the State of Nebraska without first having said model tested and passed upon by a board of three competent engineers who are or shall be under the control of the University of Nebraska. Each and every tractor presented for testing, shall be a stock model and shall not be equipped with any special appliance or apparatus not regularly supplied to the trade. Any tractor not complying with the provisions of this section shall not be tested under sections 75–901 to 75–911,

nor the result certified; Provided, no official tractor tests shall be conducted during the months of December, January and February. Applications for the test of a tractor shall be made to the testing board of engineers and shall be accompanied by specifications of the tractor required by the board of engineers, and by the fee specified in section 75–905. If the application with specifications and fee is submitted during December, January, February, or at any other time when the test cannot be started at once, the State Railway Commission, with the approval of the board of engineers, may issue a temporary permit for the sale of tractors of the model specified in the application for test, the date on which the temporary permit shall terminate to be fixed by the board of engineers. All temporary permits shall be conditioned upon such tractor as is covered thereby being tested at the earliest available date, and the tractor company to which a temporary permit has been issued shall submit a tractor for test which conforms to the specifications filed with the application, which tractor shall be delivered for test at any time specified by the board of engineers. Upon failure so to do, all such fees deposited by said companies shall be forfeited to the State of Nebraska, and in addition such companies shall be liable to the penalties prescribed by section 75–910 and shall never thereafter be issued any temporary permit whatever; Provided, however, that all sales of tractors upon which a temporary permit has been issued, shall be made subject to the final official test and approval of the model.

75–902. Tractor engine tests; nature. Such tests shall consist of endurance, official rating of horsepower for continuous load, and consumption of fuel per hour or per acre of farm operations. The results of such tests shall be open at all times to public inspection.

75–903. Tractor engine tests; certification; permit; grounds for denial. The University of Nebraska, after having duly tested any model of liquid fuel traction engine, shall certify the results to the State Railway Commission. Prior to the issuing of a permit by the commission to any liquid fuel traction engine company to do business in the State of Nebraska, the official tests of the university shall be compared with the representations of the tractor company as to horsepower rating for not less than ten consecutive hours of continuous load, fuel used for developing such horsepower, and any other representation such company shall make, and in case any such representations shall be found false, the commission shall deny the company manufacturing or assembling such tractor the right to do business in the State of Nebraska, except as provided in section 75–906.

75–904. Tractor companies; service stations; duty to maintain. The State Railway Commission shall deny to any liquid fuel tractor company the right to do business in the State of Nebraska which shall be found, on complaint of two of more bona fide customers residing within the state, to fail to maintain an adequate service station, with full supply of replacement parts, within the confines of the state and within reasonable shipping distance of such customers.

75–905. Tractor engine tests; fees. Application to the University of Nebraska for test of a tractor shall be accompanied by a fee of five hundred dollars as a partial reimbursement for the cost of such test. Payment shall also be

made upon presentation of the proper statement for costs of all fuel and oil consumed in making the test.

75–906. Tractor engines; retesting permitted. The failure of any model of tractor to come up to the representations of the company manufacturing or assembling it, shall not prevent the company from placing on the market other models of tractors that do comply with the specifications and ratings. Any model of tractor that fails, in the official test, to come up to the company's own specifications may be retested after alteration and remodeling. Each and every permit issued under sections 75–901 to 75–911 shall specify the model or models included in such permit to sell.

75–907. Tractor engine tests; report; publication. The report of the official tests required by section 75–901 shall be posted in the Agricultural Engineering Department of the University of Nebraska and in such other places as may be designated by the university. The same shall be incorporated in the annual report of the State Railway Commission.

75–908. Tractor engine tests; report; use in advertising prohibited; penalty. No tractor company shall use the results of such tests in such manner as would cause it to appear that the University of Nebraska intended to recommend the use of any given type or model of tractor in preference to any other type or model. It shall be unlawful for any tractor company operating in the State of Nebraska to publish extracts from such official tests for advertising purposes without publishing the entire report. For any violation of the foregoing provision the State Railway Commission may, in its discretion, suspend or deny the right of any such company to do business in the state.

75–909. Tractor engine tests; order; discrimination prohibited. Tractors shall be tested by the University of Nebraska in the order in which they are presented for such tests, and no discrimination shall be made for or against any tractor company in any manner whatsoever. Complaints against the violation of this provision shall be heard and adjudicated by the State Railway Commission.

75–910. Tractor companies; sales without permit; penalty. Any gas, gasoline, kerosene, distillate or other liquid fuel tractor or traction company selling or offering for sale in the State of Nebraska, or any automobile, implement or other company or individual operating in behalf of such tractor company or on their own behalf, who shall sell or offer for sale in the state any model of liquid fuel tractor engine, without having in his possession a permit from the State Railway Commission to sell such model of tractor as he is offering for sale, shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine of not less than one hundred dollars nor more than five hundred dollars for each offense, in the discretion of the court.

75–911. Tractor test law; enforcement; duty of commission. The State Railway Commission shall have full authority to enforce the provisions of sections 75–901 to 75–910, both by denial of a permit to do business in the state and by due process of law to compel compliance therewith.

The Tractor Test Board. Left to right are F. D. Yung, L. F. Larsen, C. W. Smith and L. W. Hurlbut.

Manufacturer's representatives are present during test.

Test No. 385. FORD 8N. Ford Motor Company, Detroit, Michigan; September 8 to September 19, 1947.

Chassis: standard, enclosed gear drive.

Tread width: rear 48"–76", front 48"–76".

Advertised speeds, mph: first 2.75, second 3.54, third 4.87, fourth 10.16, reverse 4.52.

Belt pulley: diameter 9", face 6½", rated rpm 1358, 3199 fpm.

Clutch: Long, dry plate, operated by foot pedal.

Rear tires (F, G, & H): 2, 10–28, 4-ply, air pressure 14 lbs.

Test J: Same size tires as above, no added weight of any kind.

Added weight per rear wheel: 247 lbs. liquid, 670 lbs. cast iron.

Front tires: 2, 4:00–19, 4-ply, air pressure 28 lbs.

Engine: Ford, 4-cylinder vertical, "L" head.

Battery and ignition system: Ford.

Carburetor: Marvel-Schebler, TSK-33, ⅞".

Governor: Novi, variable speed, centrifugal.

Air cleaner: Oakes, oil washed wire screen.

Oil filter: Fram, removable cartridge.

Cooling-medium temperature control: thermostat.

Comments: The original six-blade fan was replaced with a four-blade fan. The transmission slipped out of mesh three times while operating in first gear. Belt pulley shaft bearing was adjusted during the belt run. Clearance in the bearing on the belt pulley shaft was adjusted during the belt run.