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4-H Tractor Club : Extension Circular 7-51-2

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1943

Extension Service, College of Agr., Univ. of Nebr.
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Acts of May 8 and June 30, 1914

4H TRACTOR CLUB
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It is the purpose of this project to better acquaint 4-H Club Members with the principles of tractor operation and with preventive maintenance through study of tractor stability, air cleaners, lubrication, fuels and cooling systems.

In the Tractor Club we have the 4 "C's" - Clean Air, Clean Oil, Clean Water, and Clean Fuel.

The material in this circular approved by the Department of Agricultural Engineering, University of Nebraska.

Prepared by: Carlton L. Zink, Extension Agricultural Engineer
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PROBLEM I

RUBBER TIRES

During the past few years, rubber tires have become common equipment on farm tractors. These tires represent a piece of valuable property and care should be taken of them.

Inflation is very important in tire maintenance. Under-inflated tires are soft and the striking of an object may stretch the cords until they are broken, or perhaps crush them against the rim causing a break. The rear tires carry the pulling load between the soil and the tire rim. This force has a tearing action on the side walls of the tires. If kept inflated to correct pressure the tire side wall can better withstand the tearing action. When tires are under-inflated there is more danger of the tire slipping on the rim and causing damage to the inner tube. Some people are of the opinion that tires have more traction when under-inflated. This is an expensive practice with practically no benefits, since under normal conditions the traction is not materially increased.

Over-inflation of tires forces the cords to be stretched tight. Under these conditions, if a sharp object is hit it may cause the cords to break. When tires are over-inflated the area coming in contact with the ground is reduced. This may cause a high per cent of slippage and as a result excessive tire wear. Over-inflation and exposure to the elements may cause weather checks or cracking in the tires. Usually this is not serious but occasionally it is advisable to paint them with some protective coat recommended by the tire dealer. This paint will seal the cracks and prevent water and dirt from causing deterioration of the cords.

Tire inflation pressures should be varied with the number of wheel weights added to reduce slippage, and also to take care of the weight of mounted implements. The pressure should be increased as the weight on the tire is increased. However, it is not advisable to increase weight and air pressure above that recommended by the manufacturer.

Inflation pressures of 28 pounds per sq. in. for 4-ply tires and 36 pounds per sq. in. for 6-ply tires are recommended. Rear tires on tractors should have a minimum inflation pressure of 12 pounds per sq. in. with the exception of the small cross-section dual tires which should have 20 pounds per sq. in. When plowing, increase the pressure in furrow wheel tire 4 pounds. These pressures have been adopted by the Tire and Rim Association.

Concrete and cast iron wheel weights and liquid in tires are common means of adding weight to reduce slippage. It is good economy not to use more weight than is needed to keep slippage down to a safe value. Extra weight causes the tractor to roll harder, and this in turn increases fuel consumption.

Slippage is the chief source of tractor tire wear. It may be caused by over-inflation, insufficient wheel weight, and by trying to pull too great a load. Variation in ground surface may cause appreciable difference in slippage. Tests have shown that slippage should be held under 16 to 18 per cent for field operation and under 5 per cent on paving.

It is simple to check the per cent of slippage and it may be worth while in order to reduce tire wear. Tie a string or rag on the spoke of a drive wheel and drive
tractor unloaded for thirty revolutions of the wheel. Mark this distance off with stakes. Next hitch to the load and drive the same distance counting the wheel revolutions under load. Care must be taken to keep tractor from running in the same tracks. Subtract the thirty revolutions from the number under load, and divide the difference by the number of revolutions made under load. Multiply the answer by 100 and the result is the per cent of slippage or travel reduction.

Example: A tractor under load made 35 revolutions where it made 30 revolutions under no load, or a difference of 5 revolutions. Then 5 divided by 35 equals 1/7 or 0.143 and 0.14 times 100 equals 14 per cent slippage on the loaded basis.

When minor damages do occur, prompt attention and repair may prevent more serious damage and expense. Exterior cuts should be washed clean with gasoline and allowed to dry. The injury may then be filled with a suitable repair material obtained from a tire dealer. Nail holes are best repaired by using rubber plugs inserted from the inside.

Broken cords on the inside of the tire may be repaired by cementing a tire patch over the break after it is cleaned with gasoline, and then dried. Boots are commonly used to repair a small break in a tire. Vulcanizing is the best treatment, provided the added tire life is worth the expense.

Prolong tractor tire life by:

1. Keeping all oil and grease off of tires as they will cause deterioration of the rubber.
2. Inspecting tires frequently for cuts and bruises and promptly repairing them.
3. Checking tire inflation at least once each week.
4. Removing embedded stones or other objects from the tread.
5. Operating tractor with minimum slippage.
6. Owning and using a good tire pump.

Suggested Club Project:

Check the slippage of the drive wheels on a tractor. From this test, is the slippage excessive? If so, what preventive measures can be taken?

PULLEYS

The power from a tractor engine cannot be increased or decreased by the changing of pulley sizes. However, it is possible to obtain a more favorable mechanical advantage, and by so doing make the tractor perform better.

For instance, of two general-purpose-type tractors of the 2-3 plow size now used on many farms, Tractor A has a pulley speed of 654 r.p.m. (revolutions per minute) and a 14-inch belt pulley. Tractor B has a pulley speed of 975 r.p.m. and a 12 13/16-inch belt pulley. Here is an example of what may quite often happen. Tractor A is used to operate an ensilage cutter which is designed to run at
650 r.p.m. A 14-inch pulley is being used and the cutter is operating satisfactorily.

If the operator used Tractor B but does not change either pulley, the cutter speed would be 900 r.p.m. or an over-speed of approximately 250 r.p.m.

The power needed to operate the fan is an appreciable part of the total power requirements of an ensilage cutter. An over-speed of 35 to 40 per cent would probably not affect the cutting mechanism a great deal, but the fan would consume from 2 to 2 1/2 times as much power as at rated speed. This means that Tractor B would be able to operate the cutter at only a fraction of its normal capacity, since the excessive power requirements of the higher fan speed would leave less power available to cut the ensilage. If the fan blast at 650 r.p.m. is sufficient to blow the ensilage into the silo, then power is wasted if the fan is run at a higher rate.

An alternative would be to reduce the tractor engine speed to about 70 or 75 per cent of its rated value. The cutter would then run at the proper speed but the engine power at this reduced speed would be so much less that the cutter could not be operated at normal capacity. The logical thing to do would be to install a pulley of the correct size on the cutter, which in this case is 19 or 20 inches.

Proper pulley sizes are very important on many machines in addition to ensilage cutters. In some machines, power is wasted and also quality of the work is changed. Some of the machines particularly sensitive to speed changes are threshers, hullers, hammer grinders, and irrigation pumps.

Pulley size selection may be done by using a speed counter and the trial and error method. However, it is more simple to measure the speed of the tractor pulley when operating at rated speed and then make a few calculations.

The ratio of pulley sizes is inversely proportional to the pulley speeds. To put this into mathematical terms:

\[
\frac{A}{B} = \frac{C}{D}
\]

where

\[
A = \text{diameter of driven machine pulley}
\]

\[
B = \text{diameter of tractor pulley}
\]

\[
C = \text{tractor pulley speed in r.p.m.}
\]

\[
D = \text{driven machine pulley speed in r.p.m.}
\]

From the above relationship the following equations are derived:

1. \[
A = \frac{B \times C}{D}
\]

2. \[
D = \frac{C \times B}{A}
\]

3. \[
B = \frac{A \times D}{C}
\]

4. \[
C = \frac{A \times D}{B}
\]

Example 1: A tractor pulley runs at 500 r.p.m. and a hammer grinder is to run at 2000 r.p.m. The tractor is equipped with a pulley 12 inches in diameter. What size pulley is needed on the grinder?
Solution! After studying the problem, the following things are known:

- \( B = 12 \) inches = diameter of tractor pulley
- \( C = 500 \) r.p.m. = tractor pulley speed
- \( D = 2000 \) r.p.m. = driven machine pulley speed, or in this case the grinder speed

Determine the size of the pulley needed on the grinder or "A"

\[
A = \frac{B \times C}{D} \quad \text{so} \quad A = \frac{12 \times 500}{2000} = 3 \text{ inches in diameter}
\]

The calculated size needed on the grinder is 3 inches in diameter.

Example 2: It is desired to run a burr grinder 500 r.p.m. with a tractor having a belt pulley speed of 600 r.p.m. The operator wishes to use a 12-inch pulley on the tractor. What size pulley would you recommend on the grinder?

Example 3: Mr. Smith has a hammer mill which is to operate at 2500 r.p.m. He says a 4-inch pulley is the smallest size he can purchase for the mill. The tractor pulley operates at 600 r.p.m. If it is not possible to buy a pulley of the exact size, the nearest size should be obtained. In this case, what pulley would be the recommended size?

BELTS

Mineral oils cause swelling and gradual rotting of rubber belts. When oil is on one edge of a belt it will cause that edge to stretch and this results in a crooked belt. As an extra precaution, shields may be made to keep oil dripping from bearings from being thrown onto the belt. Where protection is impossible, close woven duck belts are recommended, since they resist the penetration of oil.

Rubber belts are flexible and no belt dressing should be used, since it will damage the belt by penetrating into the structure. On new belts or belts with a glazed surface caused by slippage, vegetable oils may be used to improve the surface. Oils such as castor oil, tung oil, boiled linseed oil, or good liquid belt dressing may be used.

The safest method of cleaning belts is to wash them with soap or tri-sodium-phosphate and water. It is important to rinse the belt thoroughly after cleaning. In some cases, belts are dry cleaned; however, such a practice involves hazards and the necessary chemicals are not always readily available.

Suggestions for Belt Maintenance:

1. Keep pulleys lined up.

2. Keep pulleys clean. Do not allow dust, dirt or any caked material to build up on the pulleys.

3. Keep reasonable tension on belts.
4. Avoid the use of belts wider than the face of either the driving or driven pulley.

5. To reduce belt wear, remove all rust or rough spots from vee-belt pulleys before starting the machine.

6. Store rubber belts in a cool, dry, dark place.

Suggested Club Project:

Check the pulley size on tractor and on a driven machine. From the tractor instruction book or Nebraska Tractor Test Bulletin No. 338, find the tractor pulley speed and make calculations finding the speed the driven machine pulley would run. Check results by using a speed counter to measure the pulley speed.

TRACTOR STABILITY

In general, tractors may be divided into two groups, the crawler or track layer machines, and the wheel type tractors. The wheel type tractors are again divided into two classes, the conventional four-wheel or standard machine, and the one more popular in the middle west, the tricycle, row-crop or general purpose type. It is interesting to know how and why tractors perform as they do.

In order to have tractors operate satisfactorily, certain characteristics must be built into them. Some of these characteristics are as follows:

1. Row-crop tractors must have sufficient clearance to permit cultivation of crops, such as corn.

2. It is desirable to have a short turning radius since this makes it easier to handle the tractor under field conditions.

3. The tractor should have ability to follow a ridge with a minimum of effort on the part of the operator.

4. Tractor wheels must be spaced so as to run between the crop rows.

5. High top speeds are desirable to reduce time of travel from farmstead to fields.

In order to satisfy these demands it has been necessary to sacrifice some desirable characteristics. The following analysis will give a few of the resulting disadvantages:

1. To obtain the necessary clearance for cultivating certain crops, it was necessary to build the main body of the tractor high off the ground. This makes the row-crop tractor easier to upset than the conventional standard or four-wheel type.

2. In order to have a short turning radius it was necessary to design the front wheels so they could turn at a sharp angle. Turning brakes were also added to the drive wheels to facilitate short turns. The turning brakes are designed to operate independent of each other. Various methods have been used to operate
these brakes from one control lever when driving in the higher gears. However, few tractor brakes are so designed that they will stay in adjustment and give uniform braking on each wheel over a long period of time, as is the case with automobile brakes. For that reason it is difficult, if not impossible, to secure equalization of braking effort by the methods used by most manufacturers. Application of the hydraulic principle would help tremendously toward that end.

3. Many tractor front wheels are designed to follow a ridge and as a result when driven on the road, they do not as readily follow a straight line as does an automobile in good repair.

4. To solve the problem of wheel spacing and crop clearance, the tricycle-type tractor was developed. With two front wheels close together, or with a single wheel, and adjustable rear wheels it is possible to operate the tractor between crop rows of various spacing. It is universally conceded that because of the concentration of weight high in the body of the tractor, together with the narrow front tread, that the tricycle-type tractor is not as stable as the low to the ground standard machine, or in other words, it is easier to upset. In order to upset, a tractor must tip to an angle where the weight is concentrated outside of the line connecting the wheels. In the tricycle type, the angle is not as great as it is in a conventional four-wheel tractor, and as a result it is easier to overturn. See Fig. 1.

5. When rubber tires came into use it was then possible to increase tractor speeds, and in many models a road gear was added. Tractor tires are large and usually are not inflated to high pressures. There are no springs or shock absorbers on tractors as on automobiles, and as a result tractors bounce when a bump is hit. The use of liquid weight tends to reduce the bouncing, but occasionally causes a dangerous amount of unbalance in the tire at unusually high speeds. This objection may be overcome by filling the tire almost completely with liquid.

From the preceding discussion it can be seen that there are features in tractors that may be improved. Here is what has happened in too many communities. Mr. Farmer is busy with his field work in the spring. It is 12 o'clock noon, so he unhitches from his implement, jumps on the rubber-tired tractor and starts home at a good speed. While rolling along he hits a bad bump, the tractor bounces, he loses control and the front wheels turn short, heading for a ditch. Mr. Farmer applies the brakes, but they are not balanced and they give the tractor a further jerk. Now this is a row-crop tractor, high off the ground and the rear wheels set at a narrow spacing. As a result, the tractor upsets and Mr. Farmer is lucky if he is not killed.

Fig. 2 is a copy of part of a manufacturer's curves on a typical general purpose type tractor. These curves show how short this tractor can be turned at a given speed and still not upset. For example, if it were to be turned on level ground at an average turning radius of 15 feet, the tractor must not be going faster than 11 miles per hour. Notice that the shorter the turning radius the slower the tractor must travel in order to remain upright. Notice also the effect of slope upon the turning radius and travel speed relationship.

Modern tractors have many desirable operating characteristics. However, it is up to each operator to realize the limitations of modern tractors and govern himself accordingly.
These three drawings show the angle through which these tractors must tip before they will overturn. Tractors A and B are identical. The rear wheels in A are adjusted to maximum width and in Tractor B they are at the narrow width. Tractor C is a standard type, four wheel tractor of the same size. Compare the angles "X" at which these tractors will tip before overturning.

Note: The point in the tractor around which all the weight is concentrated is called the center of gravity - C. G. Its location varies in makes and models of tractors, and the amount of weight added to the tractor in the form of mounted implements and wheel weights. The C. G. which is usually located on the center line of the tractor is about the same height and distance ahead of the rear axle as is the center of the belt pulley.
### TYPICAL GENERAL PURPOSE TYPE TRACTOR

**84" Wheel Tread**

**Point at Which Tractor Becomes Unstable**

**501n Turning Due to Centrifugal Force**

<table>
<thead>
<tr>
<th>Turning Radius - Feet</th>
<th>Speed - Miles Per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>12</td>
</tr>
</tbody>
</table>

**CURVE NO. 1 ON LEVEL GROUND**

**CURVE NO. 2 ON 5° SLOPE**

**CURVE NO. 3 ON 10° SLOPE**

---

**The Tractor Stability Curves**

Furnished through the courtesy of John Deere Tractor Company, Waterloo, Iowa.

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**Suggested Club Projects:**

Examine several tractors and find answers to the following questions:

1. Are the brake drums mounted on the rear wheels? On one of the transmission shafts?

2. Can both pedals be operated by one foot? Is there any provision for equalizing the braking effort on the two wheels? If so, is it adequate?

3. Measure the turning radius of several tractors with and without the use of brakes.
4. Compare the relative height of several tricycle and standard type tractors measuring from the ground to a point in the approximate center of the differential or transmission housing.

5. Determine for each of these machines the relationship of the height just measured to the center-to-center distance between the rear wheels. Repeat this for various possible adjustments of the rear wheels.

6. Estimate the speed at which each tractor can be SAFELY turned, on both its smallest radius and on a 25-foot radius for level ground, for a 5% slope, for a 10% slope.
Cleanliness is one of the most important items in prolonging farm tractor life. For every gallon of fuel burned in a tractor approximately 9,000 gallons of air are used. This means an air cleaner must be used in order to have motor cleanliness. Three general types of air cleaners have been used.

1. Pre-cleaners.

Pre-cleaners are used on many tractors to remove the large impurities from the air before it reaches the filter. Air drawn into the pre-cleaner is given a whirling motion which throws the heavy particles to the side where they collect in a container. See Fig. 3.

2. Oiled-fiber Type Air Cleaners

This type of air cleaner is found on some of the older tractors. Air cleaners of this type have a fiber cartridge which is covered with oil. Air is drawn through the cartridge and into the carburetor. Dirt and dust are held to the cartridge by the oil.

To service this type of cleaner, remove cartridge and wash it in kerosene or distillate until the dirt is removed. The cartridge is allowed to drain and is then dipped into fresh oil. After most of the oil has drained from the cartridge...
it is replaced in the filter. The principal disadvantage of this type of filter is that it becomes poorer and poorer the longer it is used, until it is again cleaned. If this filter is neglected, the dust closes up the cartridge and it may cause too rich a fuel mixture which will cause excessive fuel consumption and crankcase dilution.

3. Oil-washed Type Air Cleaners

An air cleaner can do its work best only when it is serviced properly. It is difficult to state just how often an oil-washed cleaner must be serviced, for this depends entirely on the severity of dust conditions. However, the operator must keep in mind that the service an engine will give depends on how well the air cleaner is cared for, and therefore he is charged with the responsibility of giving the air cleaning equipment regular and constant attention. Always bear in mind that the drier the air conditions, the more attention the air cleaner will require.

Servicing the air cleaner should not be left to memory or guess-work, but should be checked at regular intervals. The operator can easily tell how rapidly dust collects after a few inspections under various dust conditions. As dust collects in the cup of an oil-washed cleaner the oil begins to thicken. The oil should be replaced before it becomes too thick to flow freely. Under unusually severe dust conditions this may be necessary two or three times a day, but under average farming conditions daily servicing is generally sufficient.

The air cleaner which is recommended for use on tractors is very sturdy and is capable of handling large quantities of dust. It is always carefully fitted to gas and Diesel engines and placed so that the air can be taken in from a point where the least amount of dust is likely to be found.
OIL-WASH TYPE AIR CLEANER

FIG. 5
The best performance of an oil-washed cleaner is obtained by the following:

1. Keep the oil level up to the point indicated on the oil cup. To raise the oil level above this point does not increase the efficiency, and to use a high level is a waste of oil. In some cleaners it may be very detrimental to carry the oil level too high.

2. Inspect connections from the air cleaner to the carburetor and the manifold frequently to be sure they are tight. A surprising amount of dust can go through a very small opening and do a great deal of damage. The throttle and choker shaft bearings should be kept tight and when they become worn, should be replaced or sealed. Worn throttle and choker shaft bearings may cause hard starting by allowing air to leak past loose-fitting parts. This leakage will change the air-fuel mixture and also reduce the intake vacuum.

3. Fill the oil cup with an oil that will flow freely at the prevailing temperature. In summer an oil of S. A. E. 30 or 40 grade may be used, or it may be satisfactory to use the same grade of oil as used in the engine crankcase. In winter, at temperatures above freezing, it is best to use an S. A. E. 20 oil, and an S. A. E. 10 oil at temperatures of 0° to 30° above. At temperatures below 0° it is best to use S. A. E. 10 or 10W. If the temperature is 30° below zero, it may be necessary to dilute S. A. E. 10 oil with Diesel fuel. Gasoline should not be used to dilute the oil, as gasoline evaporates. Always use an oil that flows freely and easily at existing temperatures. A good rule to follow is to use the same grade of oil as is being used in the crankcase. CAUTION: Do not use Diesel engine oils that contain additives which may cause foaming.

4. Service the cleaner as often as needed and in case of a farm tractor, the best time to do this is at noon and again at night just after the engine is stopped. This should be done before the dust has had time to settle out of the oil in the cup. If the cleaner is left to stand for some time, the fine dust settles out of the oil, leaving a layer of clean oil at the top, which may lead the operator to believe that all of the oil is clean. However, there may be a heavy layer of dirt in the bottom of the oil cup, and the next day's run may collect enough dust to overload the cleaner.

The screens in an oil-washed air cleaner will require very little attention if the above instructions are followed. However, the screen element should be inspected whenever the cup is removed, because lint, chaff and other light materials do not settle in oil rapidly, and occasionally a small deposit may accumulate. This accumulation can easily be washed off by dipping the lower part of the cleaner in gasoline or kerosene.

The discussion on oil-washed type air cleaners furnished through the courtesy of The Chek-Chart Corporation, Chicago.

Suggested Club Projects:

Inspect air cleaners on several tractors and determine how they work. Check the following points with reference to the cleaner.

1. Dirt in oil cup.
2. Amount and quality of oil in cup.
3. Connections from cleaner to carburetor.
4. Check amount of foreign material on bottom of filtering unit.
Clean fuel is another essential for good motor operation since there are a number of small openings that dirt can easily close.

Clean containers and storage will help keep dirty fuel from entering the fuel system. In many tractors there is a glass cup between the fuel tank and the carburetor for the purpose of trapping dirt and water from the fuel line. Also, screens should be periodically cleaned and the glass bulb drained.

Fig. 6 shows two fuel tanks containing air, fuel and an accumulation of water. In the tank to the left is found a larger amount of water than the one on the right. The explanation is that most of the water accumulation is due to condensation of water vapor inside the tank. This condensation can be reduced by filling the fuel tanks immediately after each day's work, and in this way reduce to a minimum the amount of moisture-laden air in the tank. It is also advisable to periodically drain the water accumulation from the bottom of the tank.

Fuels used in tractors vary a great deal and unfortunately there are few tests available to farmers that will indicate the operating characteristics of a fuel in a tractor. With this fact in mind, the operator should try to buy fuel according to the manufacturer's specifications.

Fuel specifications commonly include the octane number and distillation curves. Some of the manufacturers specify the octane number while the state laws specify fuels with certain distillation curves shall be sold as gasoline, distillate, tractor fuel, etc.

Octane number is a measure of the anti-knock quality of a fuel. The higher the octane number the higher the anti-knock quality of the fuel. The most practical way for a tractor operator to find a suitable fuel is to buy samples from different dealers and use them in the tractor. This will make it possible to select fuels with desirable anti-knock characteristics.
"E" - 4 OCTANE - KEROSENE WITH 539° END POINT

"D" - 35 OCTANE - COLD TRACTOR FUEL

"C" - 24 OCTANE - HOT TRACTOR FUEL

"B" - 26 OCTANE - HOT TRACTOR FUEL

"A" - 70 OCTANE - GASOLINE

DISTILLATION CURVES

TEMPERATURE - DEGREES F.

PER CENT DISTILLED

0 10 20 30 40 50 60 70 80 90 100

FIG. 7
The distillation curve is a measure of boiling points of a fuel. Water has one boiling temperature at a given pressure. Fuel, however, is a mixture and parts of the mixture boil at different temperatures while under constant pressure. The distillation curve is an indication of the per cent of fuel that will vaporize at a given temperature. See Fig. 7.

The vertical scale indicates temperature and the horizontal per cent distilled. Curve "A" is a gasoline and the initial boiling point is around 90° F. and at 140° F. nearly 15 per cent of the fuel has boiled off and distilled. The last part or "heavy end" of the fuel must be raised to over 380° F. before it will boil off to be distilled. Compare this gasoline curve to "C", "B", "D", and "E". It is desirable not to have much range in temperature between the initial and end point of the distillation curve. With a small range it is easier to adjust the heat on the carburetor so as to vaporize the "heavy ends" of the fuel, but not have the "light ends" too hot. Compare curves "E" and "D" for this characteristic. The temperature of the initial boiling point gives an indication of the ease in starting a tractor on a fuel.

The Food, Drug and Oil Division of the Nebraska Department of Agriculture run distillation tests on fuels to check compliance with the State Laws. It is possible for the public to have samples distilled by the Department. For further information, write to the Food, Drug, and Oil Division, Department of Agriculture, Capitol Building, Lincoln, Nebraska.

If purchase of one of the tractor fuels or kerosenes shown in Fig. 7 was being considered, what comments might be made about these fuels?

The following discussion on fuels is taken from "Fuels for Pumping" by Carlton L. Zink.

Due to the difference in the cost per gallon of gasoline and low-grade fuels it is often not practical to use the more desirable but also more expensive gasoline. The difference in the price of the two fuels to the consumer will vary from 1 or 2 cents to as high as 10 cents per gallon. Where operating conditions are favorable to the low grade fuel it is not considered economical to pay more than 3 cents premium for gasoline. If the work is such that there are many starts and stops with a great deal of idling, then the user can afford to pay even more for the more volatile fuel.

Some of the advantages of gasoline over low-grade fuel such as kerosene, distillate and tractor fuel, when used in a tractor, appear below.

1. Easier starting:
   a. Fuel in carburetor bowl is always the right fuel.
   b. Eliminates draining the bowl before starting.

2. Dilution of oil by fuel ceases to be a problem when gasoline is used:
   a. A careful operator using a good grade of distillate or tractor fuel can keep the oil dilution down to 15% or 20%, while the not-too-good operator using poor fuel can easily have dilution as high as 35% to 40%.
b. The dilution when using gasoline will seldom be over 5%.

c. While it is true that the feeling now is that diluted oil if CLEAN does not do the harm once attributed to it, it is also true that much of the diluted oil is NOT CLEAN and the thin film of the diluted oil offers less protection against wear.

3. Longer oil life when using gasoline:

a. An engine needs clean oil and yet it makes it dirty. This contamination can come from unburned liquid fuel, from partially-burned fuel in the form of carbon particles and from dust introduced through the carburetor or the engine breather. The contamination due to partially-burned and liquid fuel is much greater with low-grade fuel than with gasoline.

b. Engine makers recognize that low-grade fuel operation requires more frequent oil changes and the general practice is to recommend that the drain intervals be twice as long when using gasoline than when using distillate or other low-grade fuels.

4. Use of gasoline extends life of tractor engines:

a. Operation of light or idling loads promoted dilution and the washing of the lubricating oil from the pistons and cylinders. Holding the radiator temperature high (195° to 200° F.) and keeping considerable heat on the intake manifold would reduce the chance of damage BUT many operators either do not know or do not care enough about the matter to take these precautions. A distillate-burning tractor engine operating a pump jack or other light load can easily be ruined in 10 to 20 hours of running with low radiator temperature (140° to 150° F.) and the manifold heat set at the COLD position.

b. Gasoline burning engines will operate cleaner than distillate engines. This is shown in less ring and valve sticking.

5. An engine designed to burn regular grade gasoline to the best advantage will develop 15% to 20% more power than one designed to get out all it can from distillate:

With that in mind, many farmers in Illinois, Iowa, Kansas, Indiana and other agricultural states where the net price of gasoline is reasonable have converted their low-compression distillate-burning engines to high-compression units by installing different cylinder heads, by planing some material off from the head or by using high altitude pistons. It is also necessary to use less manifold heat with gasoline and that can be done by adjusting the heat valve or installing blind gaskets to keep the exhaust heat away from the intake manifold. This extra power often permits the doing of an operation in the next higher gear and so speeds up the work.

6. Electric starting is standard on several tractors and a reasonable option on many others. It is much better adapted to the gasoline-burning tractor than to one using low-grade fuel.
To properly burn low-grade fuel in a carbureted engine, a high cooling medium temperature must be maintained, from 190° to 207° F., depending upon the design of the engine, the load and the quality of the fuel. The manifold heat control should be set to produce a sufficiently high incoming fuel charge temperature to eliminate dilution. That adjustment can be obtained from the manufacturer's instruction book or from observation made on the particular fuel being used under the prevailing atmospheric temperature and power requirement conditions. Some method of cooling medium temperature control should be provided, such as a high temperature thermostat, a radiator shutter or both. The manual controls for the radiator shutter and manifold heat valve should be within reach of the operator on the tractor seat.

The terms "distillate" and "tractor fuel" are rather indefinite and have been used to cover a wide range of low-grade fuels. Tractor fuels, in many localities, are divided into two groups. Those known as "hot" quite often have a distillation range within that of gasoline. One popular, typical "hot" tractor fuel has an initial boiling point of 250° F. and an end point of 410° F. The upper limit on United States motor fuel gasoline is 437° F. so that it is evident that there should be little dilution when using this fuel. Numerous and varied legal restrictions as to the initial boiling point, the 10% point and the end point of the fuels all tend to produce a large variety of low-grade fuels. One large refinery operating in the mid-west markets eight different tractor fuels to meet the legal requirements of as many states.

Until there is more similarity between States as to what are the proper and essential specifications of a good tractor fuel, there will continue to be a wide range of fuels from the "hot" just as described, to the "cold" which often has an initial boiling point of 350° to 375° F. and an end point of 510° to 550° F. The "cold" tractor fuels are known to many users as distillates or No. 1 furnace oils. The modern tractor engine equipped to burn low-grade fuel can handle "cold" tractor fuel satisfactorily if the operator will properly adjust the manifold heat and the cooling temperature controls.

Suggested Club Projects:

1. In what type of containers is fuel stored and handled? Do these containers keep dirt from entering the fuel system?

2. Look at several different tractors and determine the ways the manufacturer has attempted to take dirt out of the fuel after it has entered the tractor.
The purpose of lubrication is to provide a protective film which will reduce friction, wear and heat in the machine parts. There are three general types of friction, namely, sliding, rolling, and fluid. For example, a log which floats on the surface of still water (fluid friction) is much easier to pull than where it is sliding on the ground (sliding friction) because the fluid friction offers much less resistance than does the sliding friction. Lubricated bearings and working surfaces have fluid rather than sliding friction.

Clean oil and grease are other parts of the campaign for longer tractor life. This means oil and grease must be stored in clean, tight containers, funnels, cans, grease guns, and fittings should all be kept clean to help prolong tractor life through clean lubrication.

Modern tractors have parts operating under many different conditions, and for this reason it is important to select and use suitable lubricants. For example, temperature and load are two important factors to consider in the selection of a lubricant. Bearings operating under a heavy load need a lubricant that will not squeeze out of the bearings. Lubricants that will not thin out under high temperatures are needed in many bearings.

Club members are urged to try the following experiments on different lubricants and observe the results when various types or lubricants are used.

1. Shock load. A hammer, flat piece of iron, and a number of different types of greases are needed for this experiment. It is desirable to have a chassis lubricant of the "tacky or stringy type" and a cup grease in the assortment of greases. Place a sample of grease, about the size of a cherry, on the iron and then hit the grease with a hammer. You will notice how some greases splatter more than others. This will give an indication of the superior ability of the "tacky" type grease to absorb a shock load, as is present in a mower pitman bearing.

2. Water solubility. Two cans, approximately one quart in size; a stove, transmission oil, and water pump grease are needed for this experiment. Fill cans about three-fourths full of water and heat on the stove. In one can place a sample of transmission oil and in the other some water pump grease. Boil these mixtures on the stove and observe the difference in water solubility of the greases.

These experiments show a few of the characteristics of different lubricants. There is no perfect lubricant, but the following analysis may help in making the correct selection of grease and oil for farm tractors.

1. Transmission and Differential

Transmissions and differentials do not operate at high temperatures but they do have bearings and gears that need protection. The manufacturer's lubrication chart will indicate the weight - S. A. E. number - oil to use in summer and winter. Many operators follow the practice of thinning the summer lubricant with about 10 per cent kerosene or a very light lubricating oil for winter operation. It is advisable to either change or thin the summer oil before operating in cold weather.
to be sure the oil is thin enough to flow over the gears. The oil should be changed in the spring before summer work begins. It is desirable to drain the gear case at least once a year to remove dust, dirt, metal worn from gears, and other contaminants. Flushing out the gear case with kerosene or distillate before replacing the new oil is a practice to be recommended.

With the increased use of rubber tires on tractors, the practice of pulling them behind cars and trucks has become common. Tractor differential and transmission gears are not designed for high speeds as are those in automobiles, and as a result, will wear rapidly if pulled faster than 4 or 5 miles an hour above the tractor's road gear or high speed.

Transmission and differential case breathers should be kept in good condition to prevent the movement of dust into the gear case. Many of these breathers are serviced in a manner similar to the oiled-fiber type air cleaner. If there are rubber or leather dust seals or boots around the gear shift lever, be sure these are in good condition to prevent dust and dirt from dropping down into the gear case. Dust usually is around the cover plates on the transmission housing. Many times the gaskets are poor or the bolts work loose and allow dirt to enter. By using good gaskets and keeping bolts tight, oil contamination can be reduced.

**DUST AND DIRT PROVIDE AN EXCELLENT GRINDING COMPOUND TO WEAR OUT GEARS AND BEARINGS**

2. **Bearings**

There are different types and qualities of bearings used in farm machinery. However, most of the bearings in tractors are finely machined and the manufacturer has made an effort in his design to keep out the dirt. The operator must assume the responsibility for maintaining clean grease in the bearings. Pressure gun fittings and dust seals are commonly used on tractor bearings.

Care has been taken to write instruction books which explain the method of lubricating the bearings. For example, if a sealed bearing is over-lubricated, the grease is forced out, breaking the seal. This is the case on many tractor front wheels. Remember where grease comes out, dirt may go in. Many tractors have sealed bearings in the front wheels to keep out the dirt. These bearings may be cleaned, new seals installed, packed with a good wheel bearing grease and then operated through a full season without further attention. This has long been a standard practice in automobile and truck front wheel lubrication and is becoming increasingly popular in tractor maintenance.

3. **Motor**

There are four main things a motor oil is expected to do. They are:

a. Oil must lubricate each working surface.

b. Oil should seal the hot gases from leaking past the piston and rings.

c. Oil must cool the very hot working surfaces.

d. Oil should keep the working surfaces washed clean of carbon, dust, metal worn from bearings, and other contaminants. This cleaning process is called scavenging.

In summarizing, it may be said a cylinder oil is expected to lubricate, seal, cool and scavenge.
The requirements of cylinder oil are conflicting. This can be shown by:

1. For an oil to seal it should be thick, but to cool and scavenge it should be thin.

2. To lubricate, the oil should be clean and in order to scavenge, an oil will get dirty.

As a result of the four conflicting requirements, a cylinder oil must be a compromise. Authorities differ on how a cylinder oil is best made and unfortunately there are no simple tests the consumer can make that will guide him in the selection of an oil. Probably the best procedure is to buy oil from a dependable company who has a reputation for quality products.

Many people feel an oil of a certain color or from a certain oil field is of superior quality. With modern refining processes, oil can be made of desired quality and color. Color and feel are not reliable characteristics by which to judge new oil.

Tractor manufacturers make definite recommendations as to the proper weight of lubricating oil to use under various temperature conditions. These recommendations sometimes overlap each other and when in doubt one should use the lighter of the two oils. The consumption may be a little higher, but one will be sure that the oil will be thin enough to flow to all of the wearing parts.

The normal tendency is to use a heavier grade of oil when wear in the engine increases the rate of oil consumption. To a limited degree, this is satisfactory, but too heavy oils will increase the friction in the engine itself and will cause increased fuel consumption, together with a small decrease in horsepower. A few years ago one of the tractor manufacturers found the following to be true. An engine was tested successively on S. A. E. #50, 40 and 30 weight oil. The power developed by the engine increased 10% from #50 to #40 oil, and another 10% from #40 to #30. This would not be true for all engines, of course, but we do get one suggestion from it. It is this - use as light an oil as possible and still give adequate protection to the wearing parts.

Again we find that we must compromise - too light an oil will not give proper protection to bearings nor will it seal the rings well and consumption may be higher than if the heavier bodied oil were used. The light oil will cool better, scavenge better and produce less friction horsepower with an increase in horsepower at the belt or drawbar and less fuel consumed. Don't go to either extreme - use common sense.

When oil remains clean in an engine it usually means one of two things. Either the engine is actually clean inside or the oil is not picking up the contaminants, but is permitting them to accumulate in various parts of the engine. In the development of the high-speed Diesel engine, serious trouble was encountered in finding an oil that would keep the carbon and gum from forming under the piston rings, as well as some other close fitting parts of the engine. In an attempt to solve this problem, detergent oils were developed.

Detergent oils have more cleansing power than ordinary lubricating oils. This will result in the oils rapidly becoming dirty, but in doing so they have cleaned...
the inside of the engine. By carrying these contaminants in the oil and passing it through a good filter, it is possible to remove the solid material such as the carbon, sludge, dirt or metal particles.

When an engine, in good repair, dirties an oil rapidly, it is an indication that the oil is doing a good job of scavenging.

The relative performance of detergent and non-detergent oils in a dirty engine may be compared with one trying to clean his greasy hands in water alone, or in gasoline, tractor fuel or kerosene. The water alone will not reach into the pores of the skin and take out the grease, neither will the non-detergent oil carry all of the contaminants.

There are products on the market for the specific purpose of loosening carbon and gum accumulations under piston rings, on valve stems or valve lifters, piston pins, or distributor drive shafts. These products should be used according to the manufacturer's instructions. Since their action is sometimes rather severe, care should be taken to drain the crankcase soon enough to prevent the loosened material from covering the oil pump screen and stopping oil flow. This might cause bearings to burn out or pistons and rings to seize. The same precaution should be taken in the use of detergent oils in a dirty engine. Since the rate of cleansing varies with the various brands of detergent oils it is well to follow closely the refiner's change period recommendations. After three or four fills of detergent oil, the engine is usually clean enough to permit the resumption of the normally recommended drain period.

Oil filters are installed on many tractors for the purpose of cleaning grit and dirt from the oil. Some of the common materials used as filtering mediums are mineral wool, cotton waste, yarn, cloth, paper, and metal screens. Many consider it good design to permit the dirty oil to have access to a large filtering area. This makes it possible for the oil contaminants to be spread thin on as large an area as possible. This reduces the possibility of stopping the flow through the filter by plugging up the cartridge with oil contaminants. See Fig. 8.

When an oil filter is correctly installed it is connected into the oil line in such a way as not to reduce the oil pressure on the engine bearings. It is also very important to have the filter securely mounted and the oil lines in good condition since any leak will allow the oil to be pumped from the engine, and this may cause a great deal of damage to bearings and other working surfaces.

The manufacturer's recommendations as to oil drain intervals are normally based on average to severe operating conditions and occasionally an operator may safely extend the drain interval beyond the point recommended if the operating conditions are quite favorable.

THINGS TO DO FOR GOOD TRACTOR LUBRICATION

1. Keep clean oil at correct level in crankcase.
2. Watch oil gauge to make sure pump is circulating oil.
3. Service air cleaner, oil filter and all breather caps regularly.
4. Keep correct weight and quantity of oil in transmission and differential.
5. Consult lubrication chart as to how, when and where to grease.
6. Remember over-lubrication today doesn't take care of lubrication tomorrow.
Suggested Club Projects:

1. How does oil pass through the oil filter on your tractor, and what type of cartridge does it have? How often is it necessary to change the filter cartridge in order to keep the oil clean in your tractor? Automobile?

2. How many different types of lubricants are needed for your tractor and where should each be used?

COOLING SYSTEMS

Approximately 10.5 per cent of the energy contained in the fuel burned in the tractor is converted into power at the drawbar and 41 per cent of the energy is dissipated as heat in the cooling system. In other words, nearly four times as much power passes from the radiator as from the drawbar. If this energy is not carried off in the cooling water the engine would become so hot it would cease to run. For this reason it is necessary to maintain an efficient cooling system.

Air and liquid cooling are the types used on internal combustion motors and the latter is usually used in farm tractors. The cooling systems in most farm tractors are designed to have the cooling liquid 100°F above the surrounding air temperature. Two types of liquid cooling systems are used in tractors, namely, natural circulation and pump circulation.

Hot water has a tendency to rise and upon this principle the natural circulation cooling systems operate. The water which is heated by the motor tends to rise. This hot water is replaced by cool water and the circulation is started. In other words, water warmed by the motor rises and passes to the top of the radiator. In the radiator it cools and settles to the bottom where it is ready to pass into the motor and repeat the cycle.

In the pump circulation cooling systems the liquid flows through the system in the same direction as in the natural circulation. However, a pump is used to force the liquid through the system. See Fig. 9.

It is desirable to maintain a temperature from 180°F to 200°F in the cooling medium, depending on the fuel being used and the boiling temperature of the cooling liquid. If low temperatures are maintained, unburned fuel may pass down into the crankcase and cause excessive dilution of the cylinder oil. In order to maintain the desired temperature, curtains or shutters are used on the radiator to raise the liquid temperature. Thermostats are commonly used in pump circulation systems to automatically control the liquid temperatures. These devices will raise the temperature of the cooling liquid if it is too low, by restricting the flow until the temperature is sufficiently high.

Cooling System Maintenance

Scale similar to that found in teakettles is often formed on the inside of the radiator and engine. A formation of 1/8-inch thickness will reduce the rate of heat transfer 20 per cent. It is desirable to use rain or soft water in the cooling system when possible. Hard or alkaline water deposits the scale. Where necessary to use hard water, the cooling system should be regularly flushed with washing soda before deposits cause trouble. See Fig. 10.
NATURAL CIRCULATION - SOMETIMES CALLED THERMO-SIPHON

PUMP CIRCULATION

FIG. 9
If the use of washing soda does not remove the scale from the water jacket, remove the upper and lower radiator connections and thermostat; plug the lower hose connection and, after installing an old head gasket, bolt down the cylinder head; then fill the block with a solution of three parts muriatic acid to one part water and allow to remain for ten to twelve hours before flushing out thoroughly. DO NOT USE ACID SOLUTION AS DESCRIBED ABOVE IN THE RADIATOR.

When foreign material collects around the radiator tubes between the cooling fins the flow of air through the radiator is reduced and the motor may overheat. Many times this material may be removed by using of water pressure or throwing water on the back side of the radiator. Sometimes it is necessary to use a small wire to loosen the accumulation. Care should be taken not to damage the radiator.

Grease or oil sometimes enters the cooling system and it may collect dust and rust which adheres to the inside of the cooling system. This material will not conduct heat readily and so the water is slow to absorb the heat in the motor and does not pass it rapidly to the air through the radiator. By the use of water-pump grease, where recommended, this trouble may be minimized, since this grease is not readily soluble and will float to the top of the radiator where it can be skimmed off. There are several commercial solvents available on the market for removing the oil coating on the inside of cooling system.

When preparing a tractor for winter operation, the thermostat should be checked to see if it will maintain the cooling liquid at the desired temperature. In summer operation the thermostat should be wide open at the desired temperature so as not to cause over-heating. For these reasons it is advisable to check thermostats twice each year.

A thermostat is simply a heat controlled valve. Rust and gummy substances prevent the thermostat from operating by preventing free movement of the parts. These foreign materials also have an insulation effect and as a result change the range of temperature at which the thermostat operates. If after a thermostat has been cleaned, it appears to be in good mechanical condition it is worth testing.
Cold Test: Thermostats should be completely closed at room temperatures. If a light clicking sound is detected when tapping the top of the valve with the finger, it is not completely seated. When thermostats do not close they should be replaced.

Test of Thermostat Operating Temperatures: Submerge the thermostat in a container of water so it is easily visible. Heat the water and measure the temperature at which the thermostat starts to open. Apply more heat to the water until the thermostat is completely open and then again measure the water temperature. The temperature at which the thermostat is completely open should be about 30° to 35° above the temperature at which it started to open.

It is wise to check hose connections to make sure hose is in good shape. Often the hose will disintegrate on the inside and obstruct the flow, but remain in good condition on the outside. Fan and fan belt should occasionally be inspected to make sure of continued operation. Fan belts should be tight enough to prevent slippage but not so tight as to cause excessive wear on the bearings and belt. Ordinarily it should be possible to push the belt about 3/4-inch to 1-inch out of line with the thumb. See Fig. 11.

Never pour cold water into an empty or partially empty cooling system when the engine is hot, as this may cause the cracking of the cylinder head or block.

Water is the most common cooling liquid used. However, in cold weather operation, an anti-freeze solution may be used. Alcohol or other low-boiling point anti-freeze solutions should not be used when burning a low-grade fuel because of the necessity of high cooling temperatures. An anti-freeze solution with a glycerine base should be used for such operations since they have a higher boiling point.

When reassembling parts of the cooling system, such as hose, water pump or radiator connections, it is a recommended practice to coat the sealing surfaces with gasket cement, red or white lead. This will be particularly desirable if expensive anti-freeze is used.
Suggested Club Projects:

1. Hot water test of a thermostat. Many times thermostats apparently cease to operate or it may be desirable to test them before installing in a tractor. This is the method commonly used.
   a. Equipment needed - thermostat, stove, pail, and thermometer that will read up to at least 215°F.
   b. Procedure - place thermostat in water so it can be observed. Heat the water and measure the temperature when the thermostat first opens and when it is wide open.
   c. Conclusion - at what temperature does it operate, and is this correct for the motor in which it is being used?

2. Inspect cooling systems on tractors, and other internal combustion engines. What types of cooling systems are found?

3. Check fan belt tension. How may the belt be adjusted?
IGNITION SYSTEMS

Two general types of internal combustion engines are used in farm tractors, namely, Diesel and spark ignited. This problem will deal with the two types of spark ignition systems. These two types are magneto and battery.

Magneto's most commonly found on farm tractors have a low tension and a high tension coil, breaker points, condenser, and distributor all built into one assembly. Many of these parts are small and rather complicated. As a result, they are usually serviced by experienced persons who have tools for this special job.

When magneto's are turned over slowly they give off a very weak spark. In order to overcome this, the manufacturers have added to the magneto a unit called an impulse. When the motor is turned over slowly a spring is cocked, the magneto stops turning until the impulse is tripped at the desired time. This gives the magneto a quick turn and a hot spark is produced. Some of the impulses on older magneto's had to be cocked manually while on the newer ones they function automatically. Many magneto's have a manually-operated spark control and if this is not retarded the engine may kick when one attempts to crank it.

There is little that the average operator can do to service the magneto except to lubricate as recommended in the manufacturer's instruction book, and to replace or adjust the breaker points to the specified clearance.

Battery ignition systems adapt themselves readily to the use of starters and lights for night operation, since they use a storage battery. This type of ignition system is built in several assemblies with the parts more accessible than those in the magneto. As a result, the operator often does the maintenance work.

The following is a discussion of the function of some of the parts found in battery ignition systems:

1. Generators are used to furnish the electrical energy.

2. Batteries are storage reservoirs for electrical energy.

3. The coil is an electrical mechanism so built that when a low voltage current is flowing through it and then is stopped quickly a high-voltage current is produced.

4. The breaker points are used to open the low voltage circuit in order to stop the flow of current through the coil.

5. The condenser helps the points to quickly stop the flow of electricity. The action of a condenser in this electrical circuit may be compared to an airdome in a water system. When water flowing through a pipe is stopped quickly, the momentum of the water tends to keep it moving. This may result in a great strain on the pipe unless an airdome is used. In the electrical circuit as the points open quickly, the electricity rushes into the condenser. This helps reduce sparking and burning of the breaker points. See Fig. 12.
6. The switch is used to open and close the low voltage circuit.

7. The distributor, rotor, cap and wires are used to distribute the high voltage current to the desired spark plug. The distributor assembly also contains the breaker points and the condenser which are used in opening and closing the low voltage circuit.

8. The spark plug conducts the high voltage current to the combustion chamber. The spark gap of the plug is in the combustion chamber and when the electricity jumps the gap, the resulting spark ignites the air-fuel mixture. The following is a simplified diagram showing the essential parts of a battery ignition system.
When reading the following paragraph it will be helpful to frequently refer to Fig. 13. The generator furnishes current to charge the battery. The current flows from A, B, C, D and through the generator to A. When the switch is closed, electricity can flow from the generator or battery B or A through switch to coil E, from the coil through the breaker points F and to the ground G. The current then flows through to D or C and up to the point from which it started B or A. When the breaker points F open, with the aid of the condenser, this current is stopped quickly. This produces a high voltage current in the coil E which flows to the distributor H, where it goes on to the desired spark plug. From the spark plug the current flows through the ground to C or D and up to B or A and then through the switch to coil E.

This discussion gives the operation of a simple battery ignition system found on many tractors. In tracing the circuits on a tractor or car one may find other wires leading to accessories, such as lights, ammeters, and self-starters. The condenser, breaker points and distributor are commonly built into one assembly. With the aid of the preceding diagram and discussion it should be possible to trace the wiring in a battery ignition system.

Maintenance Hints on Battery Ignition Systems

1. **Generator** Brushes wear down and occasionally need to be replaced in order to keep generator charging. The commutator often becomes dirty and pitted, making it necessary to be cleaned with a rag or very fine sandpaper. Sometimes it is necessary to turn the commutator down in a lathe. In most generators it is possible to shift one of the brushes and thereby change the rate at which it charges the battery. One should oil the generator bearing according to the manufacturer's instructions. Do not allow oil to come in contact with wiring as it will cause deterioration of the insulation.

Mounted on the generator or close by is usually found a device called a cut-out. The purpose of this unit is to prevent the flow of current from the battery back through the generator when the generator is not running. It is advisable to replace this unit when it fails, rather than to try to repair it.

2. **Batteries** The liquid should be kept about 1/4-inch above the top of the plates. Use distilled water which has been stored in glass or crockery containers. Felt washers may be made, slipped over battery posts, so that they are placed between the cable and the top of the battery. When this felt is kept soaked with oil it reduces corrosion around the battery posts.

3. **Coils** Usually no service work can be done on coils. When they give trouble it is necessary to replace them.

4. **Breaker Points** The breaker point clearance is very important in order to assure the engine starting easily and operating smoothly. Commonly this gap is about .020-inch, however, it varies with makes and models of engines, so best
results can be obtained by following the manufacturer's recommendations. Points are made with one having a rounding surface and the other flat. This gives a small area in contact between the points when they are closed. It is possible to use a file or preferably a small stone to smooth up the points after they have been pitted or burned. Be sure to get them smooth and square on the end. This will make it possible to use the engine for a while longer, but the points will probably give more trouble in the near future. For this reason it is advisable to replace worn points as soon as convenient.
5. **Condensers** Ordinarily it is not possible to repair a condenser when it fails to perform properly. A burned-out condenser will act similar to an airdome with a hole in it. If the airdome in Fig. 12 has a hole in it the valve cannot stop the flow of water. When a condenser is burned out it will let the electricity leak through and hence the points cannot quickly stop the flow of the low voltage current in the coil. When an airdome has the inlet nearly plugged, the water cannot rush in so it surges on and causes a great strain on the pipe. When a condenser has a loose connection the electricity cannot rush into it and so the points burn and the flow is not quickly stopped. A condenser with a loose connection, or one which is nearly burned out will cause the motor to start hard or fail to run.

6. **Switch** It is usually necessary to replace a switch when it become faulty.

7. **Distributor** If a distributor cap is cracked or has a pencil mark on it, it may short and cause the engine to miss fire. Cracked caps must be replaced.

8. **Spark Plugs** Spark plug gaps vary from 25 to 40 thousands of an inch. It is important to use the gap specified for a particular engine in order to maintain a balanced ignition system. New spark plugs are not always adjusted with the correct gap so it is wise to check them before they are installed.

While the length of time plugs will stay in reasonably good adjustment varies it is wise to check them every 200 to 250 hours. When adjusting plugs bend only the outer electrode and do not strain the center electrode.

Hot and cold spark plugs are made because of varying engine designs and varying operating conditions. The "hot" and "cold" refers to the temperature maintained by the plug at the spark gap. In the plug at the right in Fig. 16 the heat must travel a longer distance, from the spark gap to the cooling water. Hot plugs are used in gasoline engines operating under light load or in engines burning low-grade fuel where it is necessary to keep the temperature high in order to prevent the plug from fouling. Cold plugs are used in engines operating under heavy load where it is necessary to carry the heat away rapidly in order to prevent burning the plug. It is generally safe and satisfactory to stay with the manufacturer's recommendations.

9. **Ground Connection** It is important to have ground connections that are tight and free from corrosion. A path should be provided in the ground so the electricity does not have to flow through greasy bearings. For example, some car motors are mounted on rubber. In this case it is much better to ground to the motor instead of the frame. By grounding on the motor, the electricity has an easy path through which to flow.

10. **Under-size cables, poor connections, cables with broken strands, and poor insulation,** may all cause trouble. Each case will need to be analyzed individually and the defects repaired.
The following questions and answers were taken from the Exide Technical Manual, and may help give a clearer understanding of batteries. While it is evident that this material was written primarily for automobiles, it has a direct application to the problems of the tractor which uses similar battery ignition.

1. What is a storage battery?

   A storage battery is a reservoir for the storage of electrical energy. This electrical energy is put into the storage battery in the form of direct current electricity. When needed, this electricity can be delivered by the storage battery.

2. How does a storage battery work?

   Suppose two different pieces of metals are suspended in a solution so that they cannot touch each other. If the solution can attack these metals chemically, there will be electric pressure or voltage between them which can be measured with a voltmeter. If wires from the two pieces of metal are connected outside the solution, current will flow and discharge will take place. The essential elements of a battery have been provided - two plates of different metals separated from each other in a solution called electrolyte.

   Further, if the metals and electrolyte used are such that putting back electricity or charging, restores them to their original condition, the battery can rightfully be called a storage battery.

   When fully charged the two different metals used are sponge lead for the negative plates and lead peroxide for the positive plates. These plates are kept from touching each other by separators. The solution or electrolyte is a mixture of pure water and sulphuric acid.

3. What happens when a storage battery discharges?

   When a battery discharges, the acid goes out of the electrolyte (thereby weakening the electrolyte) and gradually combines chemically with both the negative and positive plates until they become alike or the same metal—lead sulphate. Being alike, there is no electric pressure or voltage between them and the battery is completely discharged.

4. What happens when a storage battery is charged?

   When the process is reversed and electricity is put into the battery (charging), the acid comes out of the plates and goes back into the electrolyte, thereby strengthening the electrolyte. The chemical reaction gradually restores the plates to their original state.

5. What is the voltage of a storage battery?

   Voltage is the term used for electrical pressure just as "pounds per square inch" describes water pressure. In a storage battery, voltage depends on the materials selected for plates and electrolyte. All batteries using lead plates and acid electrolyte, have a voltage of approximately 2 volts per cell. In most automotive batteries there are three cells for 6 volts. If there are six cells, the battery has 12 volts. Regardless of size—each cell has only 2 volts.
6. What is the capacity of a storage battery?

Capacity is the term used for the quantity of electricity which can be taken from a storage battery for a definite time just as the capacity of a water storage tank might be described as containing enough water to provide a flow of so many gallons for so many hours or minutes.

The capacity of a battery, sometimes called its electrical size, is measured either in ampere hours or in the amperes or current it will deliver continuously for a definite time in hours or minutes before its voltage lowers below a useful value. Capacity depends on how well the battery is constructed, the size of its plates, and how many plates are assembled in each cell.

7. What does the specific gravity of the electrolyte tell?

Most batteries use a mixture of sulphuric acid and water (electrolyte) which has a specific gravity of about 1.280 when the battery is fully charged. When the battery discharges, the chemical reaction takes acid out of the electrolyte into the plates and replaces the acid with water. Having less acid and more water, the electrolyte is weaker or its specific gravity is lower. Measuring the specific gravity or taking a hydrometer reading, shows the strength of the electrolyte which determines the battery's state of charge—how much discharged or how near full charge.

In automobile batteries the following specific gravity readings indicate the different charge values.

- 1.280 - Full charge
- 1.225 - Half charged
- 1.150 - Discharged

8. Why do batteries run down?

In any system of storage, if more is taken out than is put back, the reservoir for storage ultimately becomes empty. If the car is not in good order, more current may be required for starting than the generator can put back, even though it is adjusted to maximum output. If the car owner installs electrical accessories requiring more current than is provided by the car manufacturer the battery will become run down or discharged. There are seven common causes of run-down batteries and starting failures, which are listed below.

a. The battery itself may be worn out, poor quality or construction, or undersize.

b. Cables may be worn, corroded or undersize.

c. Accidents include switches left on, short circuits in wiring, burned-out starting motors or generators.

d. Crankcase oil of improper grade increases difficulty of cranking.

e. Spark plugs, breaker points that are worn, fouled, or out of adjustment prevent proper ignition.
f. Gasoline of poor grades requires prolonged cranking.

g. Generator charge rate is insufficient for requirements of the car.

9. Can a fully charged battery freeze?

In a fully charged battery the electrolyte has its highest specific gravity. The freezing point of electrolyte at a full charge specific gravity of 1.275 is about 85° below zero. As a battery becomes discharged its specific gravity is lowered because the electrolyte contains a larger amount of water, consequently its freezing point gets closer to the freezing point of water as shown in the table below:

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>Freezing Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.375</td>
<td>-85° F.</td>
</tr>
<tr>
<td>1.250</td>
<td>-62° F.</td>
</tr>
<tr>
<td>1.225</td>
<td>-45° F.</td>
</tr>
<tr>
<td>1.200</td>
<td>-16° F.</td>
</tr>
<tr>
<td>1.175</td>
<td>-4° F.</td>
</tr>
<tr>
<td>1.150</td>
<td>+13° F.</td>
</tr>
<tr>
<td>1.100</td>
<td>+19° F.</td>
</tr>
<tr>
<td>1.000 (Water)</td>
<td>+32° F.</td>
</tr>
</tbody>
</table>

10. How frequently must water be added?

How often water must be added to a battery depends upon how much the owner drives his car, upon his generator charge rate, and how hot the weather is. For example, a car averaging 2000 miles per month will require water more frequently than one averaging 500, and if the weather is warm, more water will be required than if cool. On the average, filling every month should be sufficient. Very frequent additions of water indicate too high generator charge rate which results in unnecessary overcharge and wear on the plates.

11. What kind of water should be used?

Only distilled water (NEVER BOILED) or water from local sources approved by the battery companies, should be used for filling batteries. Analysis, without charge, will be made of samples of water from a local source to determine if the water is satisfactory for battery use. Quart samples should be clearly identified and shipped to the company manufacturing the battery. When drawing water from a faucet for use in batteries, allow it to run awhile to remove pipe accumulations. Any supply should be transported or stored only in glass, earthenware or rubber receptacles not used for anything else.

12. Should anything but distilled or approved water ever be added to a battery?

Never add anything but distilled or approved water unless the battery has lost electrolyte by being tipped over in transit, or by leakage because of damage in service. The electrolyte contained in a battery when new is sufficient to last its entire life. Only water, not acid, is lost by evaporation and charging in service.
13. In cold weather when is the best time to add water?

Just before the car is going to be driven so that the water will become mixed with the electrolyte. If not mixed, the water will stay on top and freeze at about the freezing point of water, 32° F.

14. Should special or patented electrolytes be used?

Adding compounds or patented electrolytes to a battery voids the service guarantee and adjustment policy covering it. A great number of these special solutions, powders and jellies have been investigated, analyzed and tested. Not one has ever been found to improve the performance of a battery. On the contrary, many have a corrosive or rotting action on battery plates, reducing voltage, capacity and life. The use of anything except distilled and approved water or battery electrolyte is prohibited by many manufacturers. The U. S. Bureau of Standards has investigated this subject. The results are published in their Technical News Bulletin No. 94, available from the Bureau of Standards, Department of Commerce, Washington, D. C.

15. How should the battery be cleaned?

Dirt should be brushed off with a stiff bristle (not metal) brush. Wipe with a cloth wet with ammonia or bicarbonate of soda solution (one pound of soda to a gallon of water). This will neutralize any electrolyte sprayed or spilled out. Wash the battery with water. Keep the vent plugs in place during cleaning, after which they should be examined to make sure that the gas-escape holes are clear.

16. How is corrosion removed and prevented?

Corrosion, the rusting effect on metal parts in the presence of spilled electrolyte, should be scraped or brushed off with a stiff brush. Then washing with ammonia or soda solution will neutralize any electrolyte remaining on the metal surfaces. After rinsing in water and drying, a thin coating of grease or vaseline should be applied. Lead does not corrode. Imperfectly lead-plated parts on which the lead coating is worn or scraped off in removing corrosion should be replaced.

17. Why should the battery be held firmly in its compartment?

To prevent wear from road vibration, the battery must be held firmly in place, otherwise the case may be damaged and connections may be loosened. In extreme cases the connections have actually been pulled from the terminal posts.

18. How much should the holding device be tightened?

Only snugly enough to secure the battery without putting too much strain on the battery case. Too much pressure may cause sealing compound to crack or it may warp the container in warm weather.

19. Is much current required for starting?

The discharge rate from the battery while cranking the engine will vary between 100 and 400 amperes depending upon the engine's size and whether it is warmed up or cold. For the few seconds required to start, about forty times as much current may be used as is necessary to operate all the lights. Starting current does not register on the dash board ammeter.
20. Why are proper cables and connections important?

The battery, when connected to the starting and ignition systems through undersized, corroded or worn cables, cannot supply enough current for good cranking speed or sufficient voltage for good ignition. It is like trying to run water through pipes clogged with rust. Cables and connections should be checked thoroughly. First, undersized cables or cables having broken strands should be replaced. Second, cables, if too stiff because of a small number of strands, put too much strain on the battery posts. Third, connections must be clean and tight. Sufficient current to start the engine cannot flow through loose connections, although the lights may be light. The connection where the "ground" strap is bolted to the frame must be tight. Corrosion, which sometimes eats away the terminals, prevents solid contact between the cables and battery posts. The cables should be removed and if the lead plating is worn off, new cables should be installed. Fourth, badly-worn insulation will allow the cable to short-circuit when touching metal parts of the car. This discharges the battery or may even cause a fire. Cables found with worn or bad insulation should be replaced.

21. How much current does electrical equipment require?

Current required by equipment is listed below:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Current in Amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition</td>
<td>1/3 to 3</td>
</tr>
<tr>
<td>Radio</td>
<td>3 to 6</td>
</tr>
<tr>
<td>Heater Fan</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Horn</td>
<td>5 to 10</td>
</tr>
<tr>
<td>Electric Windshield Wiper</td>
<td>1/3 to 2</td>
</tr>
<tr>
<td>Gasoline Gauge</td>
<td>0.2 to 0.3</td>
</tr>
<tr>
<td>Water Temperature Gauge</td>
<td>0.2 to 0.3</td>
</tr>
<tr>
<td>Turn Indicator</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Defroster</td>
<td>3 to 8</td>
</tr>
<tr>
<td>Cigar Lighter</td>
<td>10 to 30</td>
</tr>
<tr>
<td>Starter</td>
<td>100 to 400</td>
</tr>
</tbody>
</table>

Electric clocks require only a very small amount of current varying between 1/200 to 1/3 of an ampere hour per day, depending on the make of clock. If the clock is connected, but not running, it may use up as much as 3 ampere hours per day.

22. How can the wiring be checked for short circuits?

With all electrical equipment switched OFF and the ground strap connected, tapping the other cable terminal against its battery post will produce sparking if there is a short circuit in the wiring. Before doing this, the stop light switch should be checked to make sure it is not stuck and fuses should be checked to see that they have not been burned out.

23. Does burning the headlights in the daytime help the battery?

Generally speaking it does not. The exceptions might be a long daytime trip in hot weather, and to lessen the current being supplied to the battery to prevent overheating on cars having generators without voltage or current regulators. Some cars have automatic devices to increase the generator output when the lights are ON. With such cars the purpose of burning the headlights would be defeated. On long trips, overheating will be reduced if water is added to the battery every few days.
24. What wears out batteries?

The chemical action of charge and discharge when a battery works produces wear on the plates and separators. The active material is constantly changing chemically. This change contracts and expands it. The gas produced on charge is very active and in rising to the surface knocks minute particles of active material off the plates. These particles, together with any active material dislodged from the plates by road vibration, collect as sediment in the bottom of the battery container. As the plates lose material, the battery loses capacity. Wear finally reaches the point at which the battery capacity is insufficient for the car's requirements and starting failures result.

25. What are the most common forms of abuse which result in short life batteries?

Unintentional abuse and lack of care shorten the life of many batteries. A battery may be "starved" by receiving too low a charge rate and still perform satisfactorily for a time. Overcharging is often accompanied by overheating and rapid evaporation of water which produce too low electrolyte levels. Excessive vibration may break plates from their connecting straps and the loose plates may then puncture separators and cause short circuits between plates. Too much pressure on the holding device may warp the battery container, break partitions between cells, or crack sealing compound and allow leakage of electrolyte.

26. How does overdischarge shorten life?

On discharge, lead sulphate forms in both positive and negative plates. Lead sulphate formed from normal discharge is easily removed by charging. If, however, the plates are allowed to stand with lead sulphate in them, or are operated continuously in this partly discharged condition, the lead sulphate becomes denser, hard and crystalline. It also expands, which warps or "buckles" the plates. This hardened lead sulphate cannot be removed by charging. In this condition plates are inefficient and, being warped out of shape, tend to gradually cut through the separators which short circuits the cells. The battery runs down quickly and its useful life is shortened.

27. Why does excessive overcharge wear out batteries rapidly?

Excessive overcharge produces heat and heavy gassing. Heat softens and weakens the separators and quickly evaporates the water from the electrolyte. If the electrolyte level is lowered so that the tops of the plates are exposed, the chemical structure of the exposed portion changes. Even after water is added to bring the electrolyte level back to the proper point, the portions of the plates which have been exposed to air never again work to full efficiency. If fact, there are two different substances on the same plate, which in reality become a battery discharging the good portion of the plate. Thus, the battery will not hold its charge and must be considered worn out. As explained previously, the gassing on charge knocks particles of active material off the plates. The heavy gassing which goes with excessive overcharge hastens this wear and sediment accumulates faster than normally.

Suggested Club Project:

Trace the wiring on a battery ignition system either on a tractor or automobile. Name the various parts and discuss their purpose and maintenance.
The object of this problem is to help tractor operators obtain improved performance by the use of correct hitches. The discussion is limited to the types of tractors commonly found on farms, namely, wheel tractors having a differential and two rear drive wheels. Principles discussed will also apply to other types of tractors.

Tractors and machinery are affected by forces in a manner similar to that of smaller objects. To illustrate this, take a piece of wood approximately 4 inches by 2 inches cross-section. The next step is to drive nails in the block as shown in Fig. 15. The nail "D" must be driven in the center of this block.

Now hook a string over nail "A" and pull the block across a smooth floor as shown in Fig. 16. Observe that the block swings around so that nails "A" and "D" are in the straight line with the string. Next, put string on nails "B" and "C" and pull block in the same manner. The block always swings around so that the string and two nails are in a straight line. This experiment shows that the resistance forces are balanced around "D". To further prove this point, the string may be put on "D" and pulled. In this case the block does not swing around and line up in a certain way as it did in the other cases.

Point "D" is where the resistance forces are balanced and is called the center of resistance. Any pulled object has a center of resistance. In machines like a harrow, or grain drill, it is located on a line midway between the ends. When hooking to a machine of this type the point of hitch should be on the center line if the tool is to pull straight.
When pulled near the top, a chair is more easily upset than when pulled from a lower position. This principle also follows in a tractor with reference to the height of the drawbar. Use of the drawbar in a high position has a tendency to make a tractor "light in front". This puts more of the tractor's weight on the rear wheels, which is desirable because it will reduce slippage of the drive wheels. However, tractors which are too light in front cannot be steered easily.

When a horse is hitched to a load, the single-tree is usually hinged in the center. This allows free movement of the single-tree and makes it possible for the horse to pull about the same amount on each shoulder. In reality, the pulling forces are balanced on a line running through the center of the horse. Usually the pulling forces are balanced around a point between the horse's shoulders. This point is called the center of pull.

Tractors having two rear drive wheels connected by a differential are balanced similar to a horse. The friction in the differential is all that allows one drive wheel to pull slightly more than the other. This means the pulling forces are balanced on a line midway between the drive wheels.
When a tractor is not moving, the soil forces supporting the tractor are vertical. As soon as a tractor is moving, it must force lugs into the ground, and also pull them out. In addition, the soil must support the tractor and also resist the pulling forces the tractor is exerting. The result is a group of forces acting at various angles as shown in Fig. 17.

The soil forces on the wheel may briefly be analyzed as follows:

A. Lug being forced into soil: Soil in this section resists penetration of lug, also helps support tractor and makes it possible for the tractor to pull the load.

B. Lug straight down: The soil here resists the force pulling the load and also supports a portion of the tractor weight.

C. Lug being pulled from soil: Soil resists the pulling of the lugs from the ground. This is commonly shown by the lug kicking out small quantities of soil.

These soil forces are balanced around a point in the soil which, for steel wheels and lugs, is 4 to 8 inches and for rubber, 2 to 4 inches ahead of the center of the rear axle. This balance point is technically called the "center of soil reaction."

If the center of soil reaction (balance point of soil forces) is ahead of the rear axle and the pull by each wheel is approximately equal, then the pulling forces balance midway between the rear wheels and a little ahead of the center.
of the rear axle. This point is known as the center of pull. In some respects this corresponds to the center hole in a double-tree. An inspection will show this is approximately where the swinging drawbars are attached to the tractors.

There are four types of hitches on tractors. By knowing where the center of pull is located and by observing the tractor performance it is possible to analyze the hitch.

The four types of hitches are:

1. Center straight pull

This type of hitch is most favorable to the tractor but it is not possible to use it on all machines. There is no side slippage of drivers and no interference with steering. See Fig. 19.
2. **Center angle pull**

This type of hitch has some side slippage of drivers but no interference with steering. When using drawbar free to swing and the outer end is off center you will have a center angle pull. It is also possible to have it with the other types of drawbars. See Fig. 20.
2. Center angle pull

This type of hitch has some side slippage of drivers but no interference with steering. When using drawbar free to swing and the outer end is off center you will have a center angle pull. It is also possible to have it with the other types of drawbars. See Fig. 20.
3. **Offset straight pull**

This type of hitch will have a tendency to cause interference with steering. A straight pull behind a tractor not hooked in the center such as a lister will give this type of hitch. See Fig. 21.

![3. Offset straight pull](image)

4. **Offset angle pull**

There is a tendency to swing the front end of the tractor to one side and as a result it interferes with the steering. There is also a tendency for side slippage of the drivers. See Fig. 22.

![4. Offset angle pull](image)
The general types of hitches have been discussed, and now the problem of determining the kind of a hitch to select, and its adjustment for a particular use will be considered.

When a chain or clevis is in the hitch, it will line up in the line of pull. This line will run from the center of resistance and if extended up under the tractor it is possible to determine where it goes with reference to the center of pull.

Suggested Club Project:

Analyze and discuss the type of hitch shown in examples 2 through 6.

The solution of Example 1 is given herewith: It will be noticed that the clevis is on the same angle the load is. This fact is always true. Now extend a line through the clevis as shown. Notice that the line goes through the center of pull. This means it is an offset angle pull, which gives no trouble in steering, but causes side slippage of the drivers. In actual field conditions it is possible to sight along the clevis or chain and tell where it goes with reference to the center of pull. With this knowledge, hitch adjustments may often be improved. It is suggested that members try the types of hitches on several tractors under field conditions in order to obtain a clearer understanding of the hitches.
EXAMPLE 1
TYPE OF HITCH

CENTER ANGLE PULL

SOLUTION:
CENTER ANGLE PULL

LOAD

LOAD
EXAMPLE 2
TYPE OF HITCH
HARROW
EXAMPLE 5
TYPE OF HITCH
EXAMPLE 6
TYPE OF HITCH

CORN BINDER
PROBLEM VI

THE POWER TAKE-OFF

There are three commonly used outlets for power on a farm tractor, the belt pulley, the drawbar and the power take-off. The principal use of the power take-off is to transmit power to such pulled or mounted machines as the grain binder, the combine harvester-thresher, the mower, the corn picker, or the field ensilage cutter that would otherwise be ground-driven by a "bull-wheel" or powered by a separate mounted engine.

Of these machines, the larger combines are the only ones which use mounted power units extensively. The combine is perhaps more sensitive to changes in speed than the other machines. It is easier to operate the mechanism of the combine at a uniform speed when using a mounted engine than with the power take-off or the ground drive.

However, the cost of any of the power take-off machines is less than one with a mounted unit, and but little more than that of the ground-driven. It has many practical advantages over the ground-driven machine, the most outstanding being that the uniformity of speed and power supply is not as readily affected by unfavorable conditions as snow, mud, sand, steep slopes and heavy crop growth.

Power take-off speeds are fairly well standardized and for all tractors they are calculated on the basis of rated engine speed. If, for instance, the engine speed drops 300 revolutions because of pulling a loaded combine up a steep grade, the speed of the combine cyinder, straw-racks, chaffer and sieves will all drop a proportionate amount. It is particularly important that the tractor have ample power and when operating under adverse conditions, the tractor be shifted into a lower gear so the engine can maintain its rated speed. The tractor operator controls the speed of power take-off machines and in this way plays a very important part in controlling the quality of work done. There is a proper operating speed for each of the driven machines and on some it is very important. EVERY OPERATOR OF POWER TAKE-OFF DRIVEN MACHINES SHOULD OWN AND USE A SPEED COUNTER.

In recent years there has been a move toward standardization of power take-off location with respect to the location of the tractor drawbar. It is still very essential that one should know what make and model of tractor will be used to operate the machine so that the proper hitch and power take-off couplings may be furnished. If one buys a used combine or another tractor different than the one formerly used, it is necessary to check the hitch and obtain from the company building the driven machine, the necessary parts. The length of the take-off shaft, the size of the coupling and the safety shields all need to be checked.

The following suggestions may help to work out a satisfactory hitch:

1. Before using any power take-off shaft, either solid or telescoping, where there is a yoke at each end of the shaft, be sure that both yokes are in the same plane. In other words, if the shaft were lying on the floor, both yokes would be flat on the floor and not one flat and the other standing up. See Fig. 23. Improper assembly of the power take-off will result in a great deal of destructive vibration.
Notice here that each universal joint is turned at about the same angle. Hitching with the drawbar pin halfway between the two joints divides the turning angle equally between them. A universal joint should not be used at an angle greater than 22 1/2°. At best, two joints can take care of only 45° or one-half of a right angle. Excessive angularity will result in vibration and rapid wear if not actual breakage.
The swinging drawbar should be locked, usually in the mid-position, whenever the power take-off is used.
Notice first that the drawbar pin is directly below and midway between the two universal joints in the power take-off shaft. Distance "C" is important. If it is too small, the take-off shaft may strike the hitch in going across field ditches. If distance "C" is too great then a great deal of telescoping action in the take-off shaft is required, particularly in going over ridges. This tends to unbalance the shaft and may cause trouble. Distance "B" is more important in some machines than others. Be very sure to consult the combine instruction book for the proper distances "A", "B" and "C".

HITCH MEASUREMENTS

FIG. 25
Whenever possible, mount the power shaft and make the hitch so that the shaft runs in a straight line. Universal joints are made to take care of some misalignment but they run smoother and last longer if their working angles are not too great.
2. If the tractor is equipped with a swinging drawbar it should be locked, usually in the mid-position, if the power take-off shaft is centrally located at the rear of the tractor. Fig. 24 and 25 show the recommended manner of attaching the hitch to the tractor. The manufacturer's instruction book dealing with the driven machine should give definite instructions as to the proper height of the hitch above the ground and also the clearance between the take-off shaft and the hitch.

3. In the power line from tractor to driven machine there is usually a slip or safety clutch. The function of this unit is as its name implies, to safeguard the machine, so that if it should become jammed or clogged, some of the parts will not be broken by the surge of extra power that might come from the tractor engine. These units are adjustable and should be checked, at least at the start of the season, to see that they are free to operate and are properly adjusted. They should be under only sufficient tension to drive the machine under normal load. In case the safety clutch does slip, check the machine thoroughly for the cause of the extra load before adjusting the clutch tighter. Rust, oil and grease, and dust may all affect the operation of safety clutches. Washing the clutch in kerosene or tractor fuel will often restore it to proper working order. See Fig. 27.

4. In the early days of power driven farm machinery, little attempt was made to protect the user against the hazards of open, revolving shafts and universal joints. Since that time, shields and guards have been developed for all of these machines and they have been so standardized that they can be attached to any current model tractor. Despite all of these efforts on the part of the implement manufacturer, many serious accidents and fatalities are caused by failure to install the safety shields provided. REMEMBER! The operator is charged with the responsibility of installing the safety shields on the power take-off.

Since it is so very necessary to have sufficient reserve power on power take-off driven combines the desirable size of tractor to be used should be determined.

The number of pounds of drawbar pull required to handle a combine in a level field will be approximately 7% of the total weight of the machine. If the combine weight is 3000 pounds and the grain tank will hold 20 bushels of grain, then the total weight would be 5000 pounds. Seven per cent of 5000 is 350 pounds drawbar pull which will handle the loaded combine on level ground.

If the tractor engine is used to operate the combine by means of a power take-off, then there should be available in addition to the requirements for pulling the machine, about one belt horsepower for each three bushels of grain harvested per hour.

There are 43,560 square feet in an acre. Taking a full cut with a 5-foot machine, the travel will be 43,560 divided by 5 or 8712 feet to harvest one acre of grain. Dividing 8712 by 5280, the distance traveled is 1.65 miles per acre cut with a 5-foot combine. To make easy calculations, assume that the tractor travel speed is 3.30 miles per hour. Then the rate of harvest will be two acres per hour, and if the grain yields 30 bushels per acre, 60 bushels will be the rate per hour. At the rate of one belt horsepower per each three bushels of grain harvested per hour, the power required will be 60 divided by 3 or 20 belt horsepower to operate the combine.
Slip or safety clutches are used on the main power shaft from tractor to driven machine, and oftentimes on other parts of the machine as well. Their job is to prevent breakage of some part when the machine is clogged or jammed. Be sure that rust does not cause the clutch to stick when it should slip, or oil and grease cause it to slip when it should hold. Adjust the clutch no tighter than necessary to handle a normal load.
ATTACH FRONT END OF TELESCOPING SHIELD TO MASTER SHIELD ON TRACTOR

ATTACH REAR END OF TELESCOPING SHIELD TO SHIELD ON MACHINE

ATTACH REAR SHIELD TO POWER LINE SUPPORT

ATTACH BRACES TO SHIELD ON MACHINE

SAFETY SHIELDS

FIG. 28

All power shafts should be shielded. Many tragedies have resulted from failure to use the available protective devices.

BE SURE THE SHIELD FITS. PUT IT ON! KEEP IT ON!
Earlier it was found that 350 pounds drawbar pull was needed to handle the combine on level ground. Horsepower is the rate of doing work or, Force multiplied by Distance divided by Time. The force of 350 pounds multiplied by 290.4 feet (one mile per hour equals 88 feet per minute and 88 x 3.30 = 290.4 feet) equals 101,640 foot pounds and the time was one minute so 101,640 divided by 1 still equals 101,640 foot pounds per minute. One horsepower is equal to 33,000 foot pounds per minute and 101,640 divided by 33,000 = 3.08 drawbar horsepower. Under favorable conditions, a rubber-tired tractor can deliver 85% to 90% of the belt horsepower to the drawbar. On a conservative basis the 3.08 drawbar horsepower is only 75% of the belt horsepower needed to pull the combine. Dividing 3.08 by 0.75 equals 4.11 and 4.11 plus 20 equals 24.11 belt horsepower which is the minimum requirement. The tractor needed should have at least that much maximum belt horsepower, and would have more reserve if it had a belt rating of 24 horsepower.

Where the ground is not level, more drawbar pull will be required. For each one per cent of slope, one per cent of the total weight of combine and tractor should be added to the 7% of the combine weight to determine the required drawbar pull. For example, if the slope of the ground is 3 feet per hundred or 3%, the tractor weighs 4500 pounds and the loaded combine 5000 pounds, then 3% of 6400 pounds equals 285 pounds. Adding 285 pounds to 350 pounds results in a drawbar pull requirement of 635 pounds.

At 3.30 miles per hour or 290.4 feet per minute, the 635 pounds represents 5.59 drawbar horsepower. (635 x 290.4 divided by 33,000 = 5.59). Dividing 5.59 by 0.75 = 7.45 belt horsepower which added to the 20 belt horsepower required to operate the combine produces a minimum power requirement for a 3% slope of 27.45 as compared to the 24.11 belt horsepower for level ground. Where there are a few short but steep slopes, it is, of course, more practical to shift to a lower gear than to use a tractor large enough to negotiate any of them at the higher travel speed.

Suggested Club Projects:

1. Examine the power take-off shafts on several tractors, noting their points of similarity and differences if any. Check the maximum diameter of the shaft and count the number of splines on the shaft. Does the take-off operate in all of the forward gears?

2. Check the number of universal joints on each power line, how they are lubricated, whether they are worn or in good condition, and whether or not the yokes of each joint are in their proper plane.

3. Note the provision made on all of the late model tractors of various makes for automatically covering the short power take-off on the tractor as soon as the driven machine is "unhitched".

4. Using the method explained earlier in this discussion, select from Nebraska Tractor Test Bulletin No. 338, a suitable tractor for pulling a 6-foot combine in 45-bushel wheat. The combine is driven by the power take-off and the capacity of the grain tank is 35 bushels. About three-fourths of the field lies on a 5% slope and the remainder is at about 10% grade.