Lesson 3

Types of tractors- p. 25

The history of the development of crawler tractors parallels that of wheel tractors.

Crawler tractors are still used on some large farm but they are less popular in agriculture now then once were.

Although large-wheel tractors have largely displaced crawler tractors in agriculture, the latter are widely used in construction industry.

The rows-crop tractor can be used for traction work and is also adaptable to many machines used for growing row crops.

The Tricycle design of early row-crop tractors has given way to the use of wide front axles, which are pivoted at the center.

The standard tractor is similar to the row-crop tractor, but it is used primarily for traction work and does not have a three-point hitch.

High-clearance tractors are row-crop tractors that have been modified to give extra clearance for working in tall crops.

Orchard tractors have a low profile and are sometimes equipped with special, streamlined fenders for working under trees.

Utility tractors are usually smaller and have less clearance than row-crop tractors.

Utility tractors are often used for jobs farmstead.

An implement carrier is a universal tractor that is specially designed to carry combines, field choppers, and other implements.

Use of universal tractor avoids the duplication of a separate propulsion unit for each of several self-propelled implements.

Industrial tractors are similar to farm tractors, but they are more rugged in order to withstand the continuous duty encountered in road or building construction or similar jobs.

Industrial tractors are often equipped with front-end loaders and back hoes.

Some row-crop tractors are equipped with optional front-wheel drives.

the front wheels are driven hydraulically on some models and mechanically on others.

the front wheels are usually smaller than the rear wheels.

The 4-wheei-drive tractor is largest tractor used in agriculture.

It usually has equal-size wheels at the front and rear.

Some 4-wheel-drive tractors have four steerable wheels, while others pivot the frame in the center to accomplish steering.

The latter arrangement is called articulated steering.

Many 4-wheel-drive tractors are suitable only for heavy traction work, but some manufacturers have produced 4-wheel-drive row-crop tractors with articulated steering.

Operating speeds- p 31

On still wheels, the maximum drawbar power that can be developed gene-rally falls off rapidly at speeds above 3-4 m.p.h. (4.8-6.4 km/h), owing to increased rolling resistance.

Because of the limitations imposed by wheel slip at high drawbar pull, modern pneumatic-tyred tractors can only exert their maximum drawbar powers at moderately high speeds.

But the ability of pneumatic-ty red tractors to produce their highest drawbar power output at a fairly high forward speed is not the only consideration: results of many trials show that on tillage work, draught often increases substantially with forward speed.

For example, increase for speed of ploughing from 2.5 to 4 m.p.h. (4 to 6.4 km/h) increase the draught by 10 to 20 percent.

The increased draught is sometimes justified by better work (due to more pulverization of the soil).

There are, however, certain jobs such as spraying, hoeing, combining, etc., which cannot be performed at above a certain critical speed without causing very poor work.

For ploughing, special high-speed bodies are required for work above 5-10 m.p.h. (8-16km/h). normal plough bodies simply will not stay in the ground at high speeds.

A practical objection to the use of very low speeds is that they necessitate high drawbar pulls to provide a full load.

It may be inconvenient to provide large enough implements, and in any case, under ordinary field conditions the tractor may be unable to exert very high drawbar pulls owing to adhesion difficulties.

For heavy draught work at normal speeds modern tractors need about 100kg of weight on the drive wheels per kw of power.

The kind of power/weight ratio is more easily available in 4-wheel-drive tractors than in rear-wheel-drive.

On the other hand, unnecessary weight in a tractor that in used mainly on PTO work is undesirable: it adds to rolling tone.

So ballast should be easily removed when necessary.

Most modern rear-wheel-drive tractor have to be compromise in specification because of their all-purpose needs.

Their standard tires are often not big enough and their ballasted weight not heavy enough to secure highest efficiency in heavy draught work.

4-wheel-drive versions can provide the extra weight as well as the extra wheels, and experiments have shown that, in adverse conditions, the fuel savings resulting from reduced slip and a faster work rate can be up to about 30 percent for a given job.

Nevertheless, the standard 2-wheel-drive version can be more efficient as well as cheaper for many kinds of work not requiring a high drawbar pull in adverse soil conditions.

Where high drawbar pulls required from 2-wheel-drive tractors the fitting of larger or dual tires can usefully be considered.

For example, a 60 KW tractor might be fitted with 20.8-34 single or 16.9-34 dual wheels.

Ballast can then be added to bring weight on drive wheels to 100Kg/KW, including the weight of a mounted implement.

A heavy rear axle weight is undesirable when the tractor is used on damp seedbeds or on growing crops.

It is often difficult to utilize fully the power of large wheeled tractors which may have been purchased with the autumn cultivations in mind.

When it comes to relatively low-drought work such as harrowing and spring drilling, the conventional implements are not wide enough to utilize the available drawbar power.

There is a practical limit increases in either forward speed or width of the implement.

Under these circumstances farmers might well consider the use of multiple hitches to pull two corn drills or one drills plus a set of harrows and rolls at the same time.

This not only saves on the number of operations but helps to reduce the possible ill-effects of too many wheeling on the seedbed.

At the same time, it more effectively utilizes the tractor power available.

The usual design of multiple hitch provides a braced framework carried on castor wheels.

Individual implements are hitched by means of adjustable brackets to the rear bar of the frame, sometimes by drawbars of differing lengths to allow a slight overlap of the working parts.

In other cases, implements may be specially designed to hitch side by side, rub buffers being provided avoid fouling during turns.

Where very wide hitches are used, a pair of inner wheels may be non-castor, and the outer sections with castor wheels may be arranged to fold for transport, the lifting being by hydraulic cylinders.

The value of high road speed on an all-purpose medium-powered tractor is now generally agreed.

A road speed of up to 2o m.p.h. (32KM/h) is invaluable for rapidly moving to scattered fields, and also for some forms of road transport.

Type of Tractor- p 34

In most instances the tractor will need to be a 'multi-purpose' machine which can be applied to almost any kind of farm work, including ploughing, cultivations, sowing, row-crop work, harvesting, transport and stationary PTO-work.

This will apply particularly to small farms where one or two tractors are required to do everything.

On larger farms, there may be sufficient particular kinds of work to warrant using special types of tractors, e.g.

large 4-wheel-drive tractors to cope with the autumn cultivation in good time, or light tractors of the self-propelled tool-bar type for drilling and inter-cultivation of root crops.

Market gardeners may require tractors specially adapted for work in vegetable crops, and such special types of tractor avail-able are described.

Most modern medium-powered tractors incorporate such features as make them suitable for work in all common farm row crops. Standard wheel-track widths of 60 and 72 in.

(1.50 and 1.80 m) meet most needs, but some adjustment is normally provided and is often needed for work such as ploughing.

Lesson 4

Ignition circuits in spark-ignited engines- p 36

A 15000 to 30000 V potential is needed produce an arc across a spark-plug gap and ignite the air and fuel mixture of spark-ignited engines.

Most ignition systems are inductive.

That is, they use mutual induction and a collapsing magnetic field to supply the required voltage form a 12 V storage battery.

Conventional Kettering ignition system are inductive.

They store energy by establishing a magnetic field in the primary windings of a coil while the points are closed.

Opening the points collapses the field, thereby inducing a sufficiently high voltage in the secondary winding of the coil to fire spark plug.

A capacitor is connected across the points to prevent an arc from forming across the points when they open.

A transistor-assisted system Kettering increases point life by using a transistor to interrupt primary current.

The points switch only the tiny base current when triggering the transistor.

The inductive-type electronic ignition system goes one step further by eliminating the points completely.

A pulse amplifier switches the primary current when triggered by a rotating timer gear and pick-up coil.

The capacitive discharge system differs from inductive systems in that energy is stored by charging a capacitor between spark plug firings.

When triggered by a timing circuit, the capacitor quickly discharges into a pulse amplifier and fires the spark plug while the magnetic field is rising.

The capacitive discharge system produces three to ten times greater spark plug voltage then do inductive systems.

All ignition systems for multi-cylinder engines include a distributor to deliver the high secondary voltage to the spark plugs in the proper order.

The set of points or the break less timing mechanism is housed within the distributor.

In integrated electronic ignition systems, all components, including the coil, are housed in the distributor.

The spark must be timed properly for all engine speeds and loads

A centrifugal advance mechanism rotates the cam follower assembly relative to the cam to increase spark advance with engine speed.

When the mixture lean and more spark advance is needed, a diaphragm uses the increased vacuum in the intake manifold to advance the spark.

Mechanics time the spark by rotating the distributor housing while using a timing light to illuminate timing marks on the flywheel when the no. I spark plug fires.

The housing is clamped in place when the timing is correct.

In the future, microprocessors may permit automatic optimum spark timing in response to many measured engine variables.

Spark plugs are specially constructed to provide a spark at high voltages and temperatures.

Misfiring can occur if the electrode gap is either too wide or too narrow.

Spark plug heat range is determined by the distance heat must travel before escaping to the metal shell.

Pre-ignition and rapid electrode erosion occur if the spark plugs are too hot.

Sluggish combustion and electrode firing are the result if the spark plugs are too cold.

The Coil Ignition Circuit- p 41

There are two separate electrical circuits in the system: the primary circuit and the secondary circuit.

In Figure 4-1, the black arrows show the current flow in the primary circuit, and the red arrows show the flow in the secondary circuit.

When the ignition switch is closed, current flows from the battery into the ignition coil where it passes through the primary winding.

After passing through this winding, the current then passes to the distributor which houses a contact breaker assembly which is a form of automatic switch.

This contact breaker assembly is also in the primary circuit and, as the cam rotates, the contact points will open and close.

Now the current coming from the coil passes, as shown by the arrows, through the points and back to earth, thus completing the circuit. But this only happens when the points are closed.

The flow of current also causes a magnetic field to be set up around the primary winding.

The moving contact is insulated from the distributor or body by an insulating washer, therefore the current must go to earth through the fixed contact.

Notice also that a small part known as a condenser is in the primary circuit.

Now if this circuit is broken, in other words, the current cannot flow to earth in its usual way, the magnetic field surrounding the primary windings collapses and, in doing so, cuts across the windings in the secondary circuit.

This produces a small current at high voltage which flows through the secondary circuit.

The voltage may be up to 10,000 V.

The red arrows in Figure 4-1 show where this current flows.

It leaves the ignition coil through the high tension lead and goes to the Centre of the distributor cap where the carbon brush is in contact with the metal segment on the rotor.

If this segment is opposite a segment in the distributor cap, the current will pass from one to the other and then through the plug lead.

It passes through the plug lead to the spark plug where it goes down the centre electrode, jumps across the gap creating a spark and then to earth to complete the circuit. The current is able to jump across the gap because of the high voltage pushing it.

When the engine is running, the drive shaft of the distributor is rotated by the engine camshaft and as this drive shaft has the cam and rotor fixed to it these will also rotate.

This means that as the shaft rotates, the cam will operate the contact breaker points, causing them to open and close, and the rotor will pass each segment on the distributor cap in turn.

Now the ignition system of an engine is timed so that when a piston is at the top of its compression stroke, the rotor segment is opposite to the segment of the plug lead leading to that cylinder, and the contact breaker points are also open.

So the following takes place:

1. The ignition switch is closed and the engine is turned over by the starter.
2. Current flowing through the primary circuit creates a magnetic field in the windings.
3. The contact breaker points are opened by the cam; this breaks the primary circuit causing the high voltage .to be induced into the secondary circuit.
4. The rotor is opposite a segment leading to a plug in the cylinder where compression is taking place.
5. A spark is created across the plug points and the mixture is ignited.
6. The engine starts to run.

This sequence of events occurs when each piston in turn is at the top of the compression stroke.

Dynamo- p 46

Dynamo is driven by the engine and supplies direct current (d.c.) to the battery.

At this stage It Is only necessary to mention some aspects of maintenance.

The dynamo is mounted on the side of the engine and in such a position that it can be driven by the belt which also drives the radiator fan.

It is also conveniently arranged so that the dynamo can be moved to set the tension of the belt when necessary.

This belt tension should always be kept correct because if it runs too slack, slipping will occur and this will result in a reduced speed of the dynamo pulley and also the radiator fan.

The ultimate result of this could be that the cooling system overheats or the dynamo may not run at sufficient speed to give full charge. If the belt is run too tight, it is likely to stretch and also to cause excessive wear to the dynamo bearing.

Some dynamos are fitted with a lubricator which requires a few drops of light oil periodically, but many are now pre-lubricated and require no further attention.

The only other maintenance likely to be done to the dynamo is the fitting of new carbon brushes and undercutting of the commutator but this work is better carried out by a skilled mechanic.

Lesson 5

Weight Transfer and Traction- p 48

The primary purpose of a tractor is to provide drawbar pull and drawbar power.

The fraction of the dynamic weight on the drive wheels that is converted to drawbar pull is called the dynamic traction ratio (DTR).

Tractive efficiency is the fraction of axle power that is converted to drawbar power.

Thus, both high DTR and high tractive efficiency are needed for achieving maximum drawbar pull and power.

Drawbar pull also can be increased by increasing the dynamic weight on the drive wheels-for example, by ballasting or by weight transfer.

Too much dynamic weight causes excessive soil compaction and axle stress.

Tractor tire terminology was developed before 4-wheel-drive tractors became popular.

Thus, lugged tires suitable for traction are known as rear tires, and non-lugged tires suitable for steering are called front tires.

An arrow is provided on rear tires to show the proper direction of rotation for best use of the lugs in providing traction.

Tire sizes are indicated by a code giving rim diameter and tire width in inches; metric sizes are not yet available for tractor tires.

Both front and rear tires are available with either biased ply or radial ply construction.

Radial tires are more expensive, but they provide increased traction and a smoother ride.

Dual tires can improve traction by providing increased contact area with the soil and improved flotation on soft soils.

Because soil is deformable, wheel slippage is necessary to compress and strengthen the soil enough to support drawbar pull.

The reduction in forward speed accompanying pull and increased slippage is referred to as travel reduction.

Travel reduction and drawbar pull increase together: therefore, a tractor cannot produce drawbar pull without travel reduction.

For a given tractor on a given soil, there is only one optimum travel reduction that gives maximum tractive efficiency and drawbar power.

With less travel reduction, drawbar power and efficiency decline because of reduced pull; with more travel reduction, efficiency declines because of reduced travel speed.

The many factors involved in traction have been incorporated into the Zoz chart for predicting tractive potential of tractors with rear-wheel drive.

Nebraska Tractor Test data can be used to predict the potential drawbar pull and power for specific situations in the field.

The potential pull and power can be achieved only with the perfect matching of an implement to the tractor, but data from the Zoz chart provide a good starting point for implement selection.

The Zoz chart also can be used to select the amount of ballast needed for a desired amount of travel reduction, and the selection procedure gives insight into the importance of tractor speed.

Too much ballast is needed to limit travel reduction when the tractor is used to pull very large implements at slow speeds.

For satisfactory use of drawbar power, a small enough implement should be selected to permit travel speeds of at least 7.5 km/h.

The pulling performance of a tractor usually is limited by axle torque in high gears and by traction-that is, excessive wheel slippage-in low gears.

Stability can become the limiting factor in some situations; the tractor can develop enough weight transfer to lift the front wheels off the ground.

Then, the hitch point becomes critical.

Selection of an improper hitch point can cause the tractor to flip over backwards.

Tractors also can overturn sideways due to operation on steep side slopes and/or turns at high speeds.

Thus, accidents can occur easily if tractors are used incorrectly.

Accidents surveys show that farming is the second or third most dangerous occupation in the United States and that tractors are involved in many of the farm accidents.

Accident prevention measures can be grouped into the three categories of engineering, education and enforcement.

Enforcement has limited applicability in preventing farm accidents because independent, self-employed farm tractor operators have no supervisors to enforce safety rules.

Tractive Efficiency Performance- p 54

The pull, torque and slip characteristics of a driving wheel define both the magnitude and efficiency of tractive performance.

The pull/weight ratio or net tractive coefficient is an accepted term for defining performance level. Similarly, the term tractive efficiency (TE) has been adopted to define efficiency.

Tractive efficiency of a wheel is defined as:

TE= (output power)/ (input power)

which can be expressed as:

$TE=(H.Va)/ (Tw)=(H.Va)/(T((V.t)/R)=(H/W)/(F/W)*(1-S)$

Where

TE= tractive efficiency

H= pull

Va= actual travel speed

T = wheel torque

w = angular velocity of wheel

V = theoretical wheel speed = rw

r = rolling radius of wheel on hard surface

W = weight of the wheel and any vertical. reaction force from the vehicle on which the wheel is mounted

F = gross tractive force acting at a moment arm equal to the roIIing radius r

S = wheel sleep

The variation of tractive efficiency and the pull/weight (H/W) ratio of a driving wheel with slip is shown in Figure 5-1.

It is readily observable that TE reaches a maximum at a relatively low slip and then decreases with increasing slip.

Also note that the maximum TE occurs at lower slip values for the large C; values that are associated with higher soil strengths or lower wheel loadings.

Maximum power output of a wheel occurs at the wheel slip of maximum TE.

However, the HIW ratio is not close to its maximum value at this slip. The requirement for a large drawbar pull necessitates that the design slip be selected to the right of the slip corresponding to the peak of the TE curve. A typical design TE curve is shown in Figure 5-1.

From this curve the design TE, HIW, and slip for a variety of soil strengths and wheel loading combinations, in terms of Cn, can be determined: for example, for Cn=30, TE-O. 72, HIW= 0.51, slip=0.16. This approach permits balancing the design of the vehicle over the range of soil strengths it will probably encounter in its operational life.

Cone index is used as the measure of soil strength in the traction equations.

Cone index is the average force per unit base area required to force a cone-shaped probe into soil at a steady rate.

The design and use of the cone penetrometer is discussed in American Society of Agricultural Engineers (ASAE) R3 l 3. I. (Agricultural Engineers Yearbook, 1977).

Cone index characteristically varies with depth of penetration (see Figure 5-2).

Thus the question arises as to what cone index value should be used.

For the traction equation, the Oto 6 in. (15 cm) average cone index has produced the best correlations for machines with tire sinkage of less than 3 in. (7.5 cm).

However, if the tire sinkage is greater than this value the cone. de) {should be averaged over the 6 in. (15 cm) layer, which includes the maximum sinkage of the tire. In general, cone index should be measured before the soil is subjected to wheel traffic.

Highly compactible soils, such as freshly tilled soils, present a special problem in predicting tractive performance.

The soil tends to compact and increase in strength under heavy tire loads.

Cone index measured after traffic may be several times the value measured before traffic.

Best results to date have been accomplished by using after-traffic cone index values in the developed equations for highly compactible soils.

No satisfactory method has been devised for predicting after-traffic cone index from before-traffic measurements.

Traction Improvement- p 58

For certain soil conditions, traction aids are helpful. Strakes and halftracks are more commonly used in Europe.

Tractors with both rubber tires and wheel extensions (strakes) are commonly used on weak surfaces such as rice paddy soils.

Rubber traction tires, as compared to steel traction wheels, have greatly improved the tractive efficiency, the maneuverability, and the comfort of farm tractors.

Except on very firm soils, however, rubber tires have not increased the traction. In fact, under some conditions, such as when the surface of the soil is very wet and slick, or when the soil is covered with a thick cover crop, the traction of rubber tractor tires is poor.

When traction conditions are good, the largest improvement in traction can be made by simply adding more weight to the tractor drive wheel.

However, when the surface soil is very wet, the internal friction, Q, approaches zero, and therefore an increase in the soil pressure will not increase traction significantly unless the traction device can 'cut through' the low friction surface layer.

Lesson 6

Hydraulic Systems and Hitches- p 60

Hydraulic systems have taken over the heavy work of controlling tractors and implement and have removed physical strength as a necessary qualification of tractor or operators. Also, hydraulic motors allow power to be transmitted to remote locations.

A complete hydraulic system includes hydraulic oil, a pump, a reservoir, a filter, valves, one or more actuators, and possibly, other components. Open-center systems were the first hydraulic systems used on tractors and are still used on some modern tractors.

These systems minimize standby losses by permitting the free flow of oil from a fixed displacement pump to the reservoir through tandem-center valves.

When more than one actuator is used, system pressure rises only enough to move the highest load. Sequential moving of loads can result.

Pressure-compensated systems include a pressure-compensated piston pump that automatically adjusts its stroke to maintain constant system pressure.

Closed-center valves block all flow during standby so that standby losses are low.

Pressure-compensated systems avoid the problem of sequencing, but they are not well-suited for use with hydraulic motors.

Pressure-flow-compensated (PFC) systems include a differential pressure compensator (DPC) valve to control the stroke of a piston pump.

The DPC valve maintains a constant pressure drop across a flow control valve, thereby maintaining the flow rate selected by the operator.

The DPC valve, also maintains system pressure just high enough to move the heaviest load. Standby losses are low because both pressure and flow are low.

Sequencing is not a problem, and PFC systems also are well-suited for use with hydraulic motors.

some hydraulic systems use a small, fixed displacement pump and unloading vaIve to charge an accumulator.

Hydraulic cylinders are connected to the accumulator through closed-center directional control valves.

The system is ideal when relatively long standby periods are available for recharging the accumulator and the stored hydraulic energy is needed in short, intense bursts.

The three-point hitch was developed in the 1930s, standardized by ASAE in 1959, and now has become the standard hitch on tractors.

On modem tractors, the operator can set the hitch at a desired position, for a desired implement draft, or for some combination of position and draft.

Four categories of three-point hitches have been developed to fit tractors of varying size.

Although hydraulic systems appear complex, their operation is governed by a small set of logical principles.

These principles and the Joint Industry Conference (JIC) symbols for hydraulic circuits provide the basis

for understanding and troubleshooting hydraulic systems.

Control Valves- p 65

Both spool- and poppet-type control valves are used in agricultural power steering systems. Poppet valves are used more often in closed-center than in open-center systems because of their superior sealing capabilities.

The spool-type valve, owing to its relative simplicity, is by far the most common type used in power-steering systems today.

The size of a directional control valve used for a given flow rate will be influenced by the type of hydraulic system.

Open-center, constant flow systems normally require larger diameter valves than do closed-center systems to provide low flow losses in the neutral or centered position while maintaining an acceptably small valve travel and deadband.

In closed-center systems, only that flow required by the load passes through the valve; therefore, higher intermittent flow losses, occurring only during steering maneuvers, can be tolerated.

Directional flow and pressure control valves contain both passage- and orifice-type restrictions. Except at extremely small openings, flows through valve metering apertures and across seats conform closely to orifice characteristics.

Experience shows that the geometry of sharp-edged orifices has no significant influence on pressure-flow relationships under turbulent flow conditions.

In addition to the sizing of valve dimensions to obtain acceptable pressure losses at maximum flow, the valve design must also provide a flow gain characteristic, the ratio of flow increment to valve travel at a given pressure drop, to maintain good control over the complete operating spectrum of loads, temperatures, and steering rates.

Fortunately, power-steering systems can tolerate considerable input to output error or phase shift in comparison to high precision servo systems for machine tools for example.

Smoothness of operation and reasonable costs are more important than precision and can be provided with valves manufactured to practical tolerances.

Two types of four-way spool valves are commonly used in position servo systems. These are:

1. Open center, in which sufficient metering land underlap is provided to allow the maximum desired flow to pass through the valve in the null position without excessive pressure drop. These valves are low in cost, because tolerances on land locations and, to some extent, radial clearances are less critical as used in power-steering systems.

2. Closed center, where positive overlap is provided to reduce high pressure leakage in the null position (see Figure 6-1). Land locations and radial clearances are much more critical than on the open-center valve owing to the tight sealing requirement and the sensitivity of steering control characteristics to the port opening timing sequence.

The mechanical or hydraulic ratios between steering wheel rim and control valve travel are usually sufficiently high that valve operating forces do not significantly affect steering effort, assuming that hydraulically balanced or pilot operated valves are used.

When flow rates approach 25 gpm (95 L/min), however, such as on large articulated tractors, valve flow forces must be examined more closely.

Since steady-state flow forces always tend to close the valve, they can contribute valuable stabilizing effects to the system.

For this reason, some flow metering methods increase the centering flow force with beneficial results; but with high flow rates, flow force compensation may be required to maintain acceptable steering efforts.

The rather complex theory of flow forces and compensation methods for control valves is well documented (Merritt, 1967).

Whatever type of valve is used in a power-steering system, it is important to match the total valve travel required for the maximum flow, maximum load condition to the desired steering wheel error at this condition.

This phase error is more noticeable on open-center systems because of the accompanying increased deadband, but it can also produce undesirable effects on closed-center systems during rapid steering reversals with heavy loads.

Excessive steering wheel-to-valve travel ratios become very noticeable during the manual operating mode without power since the entire valve travel then becomes lost motion.

A total steering wheel rim travel of 12 in. (300 mm), equal to approximately 90° rotation on a 16-in. (400 mm) diameter wheel, is felt to be about the acceptable limit.

With total valve travel typically in the 0.020 to 0.50 in. (0.5 to 13 mm) range, ratios of 20 or less will remain within this limit.

A valve deadband, while operating under power, from approximately 1 to 3 in. (25 to 76 mm) at the steering wheel rim is suggested.

Beyond these limits, the steering becomes either too sensitive to small unintentional inputs or can initiate tractor wander and overcorrection tendencies due to excessive lost motion.

Classification of Hydraulic Controls- p 69

The hydraulic control systems being used on farm tractors can be classified into two systems. Modifications and combinations of these systems exist.

Nudging System

This system is used to raise, lower, or position an implement, either mounted or trailed, by moving a hand lever either forward or backward from its neutral position.

If the control level is moved (nudged), the hydraulic cylinder will move a complete stroke.

If the lever is returned manually to its neutral position before the end of the complete stroke, the cylinder will stop and remain in that position, provided leaks do not exist in the system.

In the nudging system there is no relationship between the position of the hand control lever and the cylinder piston.

In control language the nudging system is an open-loop system.

A modified nudging system limits the stroke of the piston by an adjustable stop on the cylinder, or a hydraulic shut-off to lock the piston.

When using the modified nudging system, the operator can lower or raise an implement to a predetermined position without visually determining its position.

The modified system often provides for a detent on the valve to hold the hand lever unaided until the piston reaches the end of its stroke or an adjustable stop, at which time the valve is returned to neutral.

Automatic Position-Control System

This system provides automatic control of an attached implement and allows the operator to preselect and to position the implement as determined by the position of the hand control lever. The relative position of the hand lever and the hydraulic cylinder are always identical.

Within the limit of the relief valve controlling the maximum pressure, the hydraulic cylinder will automatically move the implement to its predetermined position and maintain it there, regardless of any leakage in the system.

The position-control system is normally associated with a three-point hitch system. It is not used with a remote cylinder. The most element form of a position control system is shown in Figure 6-2.

Lesson 7

Tractor Safety- p 72

Statistics on the number of fatal accidents per 100 000 workers usually indicate that farming is more dangerous than most factory jobs.

Typically, it ranks as the second or t third most dangerous occupation.

Accident prevention measures can be grouped into three categories: engineering, education, and enforcement.

Safety can be in increased by designing or engineering equipment that is safer to operate.

When workers are educated as to the proper use of equipment, they are less likely to have accidents.

Finally, Safety can be Increased through the enforcement of safe work rules.

The latter approach has limited applicability to tractor safety because farm tractors often are operated by independent, self-employed farmers who have no supervisors to enforce safety rules.

Therefore, improvements in tractor safety must come primarily through engineering and education.

Early tractors had far fewer safety features than do tractors of today.

For example, in the 1920s, when research led to a clearer understanding of the requirements for safe hitching, the frequency of rearward overturns experienced with some early tractors was diminished. Also, when it was learned that hand cranking a tractor could cause serious or fatal accidents if the tractor was left in gear and happened to start quickly, electric starters were introduced.

They improved safety by allowing the operator to start the engine from the driver's seat.

As a further improvement, interlocks were designed to prevent the engine from being cranked when the tractor was in gear.

Many designs for increased tractor safety were introduced during and following the 1950s.

Roll-Over Protective Structures (ROPS) are among these and have been very effective in reducing fatalities from tractor overturns.

Some ROPS can protect operators only if they seats; thus, seat belts should be worn.

Some ROPS include an overhead canopy that serves as a sun shade.

Some cabs are designed to provide the strength of a ROPS.

The ASAE has published standards for the design and testing of ROPS.

During an impact, the ROPS must deform enough to absorb energy but not enough to allow the operators to be crushed.

Sometimes, tractor operators are forced to make quick decisions when using tractor controls.

Therefore, the ASAE has developed a standard(S335.2) that "is based on the principle that a given direction of movement of any control produces a consistent and expected result."

The location of many controls also is specified in the standard.

For example, a foot clutch (if provided) should be actuated by the operator's left foot, with the direction of motion forward and/or downward for disengagement.

" Such a clutch could be operated more quickly in an emergency than could one that required an unfamiliar motion for disengagement.

Locations and actions of other standard controls are similarly specified in the standard.

A companion document describes standard symbols for operator controls.

A fatigued operator is more likely to make mistakes than one who is well-rested. Therefore, features that improve the convenience and comfort of the tractor operator also are safety features.

Hydraulic controls and power steering have increased convenience by greatly reducing the effort required from the operator for controlling the tractor and attached implements.

Operator comfort has been improved through improved seats and by use or cam; to protect the operator from noise, dust, precipitation, and temperature extremes.

It is virtually impossible to design a tractor so safe that operators cannot cause injury to themselves or others.

Therefore, there is a continuing need to educate tractor operators as to procedures for safe operation.

Education takes many forms, including use of operator's manuals, safety decals, magazine and newspaper articles, radio and television shows, meetings, and so forth.

Some procedures for safe operation relate to specific tractors, while others apply to any tractor.

One general rule is that only qualified persons should operate tractors.

Sometimes farm children are permitted to operate tractors as soon as they have enough physical strength to do so.

However, they may lack the maturity to make sound decisions when unexpected events occur and, therefore, may cause an otherwise avoidable accident.

Inexperienced operators should always be given some instruction before being permitted to operate a tractor.

It is likely that there will always be some element of risk in operating a farm tractor.

For example, tractors have high centers of gravity because of the need to provide crop clearance under the axles.

Therefore, the tractors are subject to tipping on side slopes.

Continuing efforts will be needed to engineer more safety features for farm tractors and to educate operators as to their safe use.

Operator Seating- p 78

A tractor can be considered as a spring-mass-damper system vibrating with 6 degrees of freedom. Displacement and acceleration inputs to the base of an operator's seat will consist of vertical, lateral, longitudinal, roll, pitch, and yaw components.

The research of Raney (1961), Pradko (1968), and Janeway (1975) shows that the predominant vibrational motion of a wheel tractor is vertical (Z_s) and that the seated operator is most sensitive to vertical acceleration.

If we consider only vertical motion imparted to the base of the operator's seat, a 2 degree-of-freedom system applies.

The vertical motion imparted to the tractor seat is approximately

Z input= Zt +RB

where Z input = vertical motion imparted to base of seat, m

Zt= vertical motion of tractor center of gravity, m

B= rotation or pitch about tractor center of gravity, radians

R = longitudinal distance from operator's seat to the tractor center of gravity, m

For small B, the term RB represents the vertical motion resulting from the pitch motion of the tractor.

Then

where Z input = vertical acceleration imparted to base of operator' s seat, m/s2 z 1 = vertical acceleration of tractor center of gravity, m/s2

RB= vertical acceleration resulting from pitch, m/s2

The operator's seat and suspension is represented schematically.

in Figure 7-1.

For suspension-type seats the cushion is mounted to a guided linkage incorporating some type of spring and damper (shock absorber) along with travel limit stops.

Friction is also inherent.

This seat suspension system is a vibratory mechanical system subjected to the tractor chassis input Z input-

Seat motion is a function of seat spring rate, mass, damping and frequency content of the input vibration.

For a given input vibration Z input to the seat base, the seat develops a corresponding output vibration.

If we grossly simplify the system in Figure 7-1 to consist of a rigid mass, M=m1+m2 coupled to the tractor chassis via a linear spring K2 and a viscous damper C2, we can simplify the following discussion about reducing the vibration intensity transmitted to the operator.

The relationship between the output (seat) vibration for a given input (tractor chassis) vibration as a function of frequency is known as the transfer function or the frequency response function of the system.

The ratio of output vibration intensity to input vibration intensity is called the transmissibility, as expressed by equation3:

For proper seat design, values of C2 and K2 must be judiciously selected

so that the transmissibility is less than1.

This will result in a reduction of the vibration intensity imparted to the seat by the tractor chassis.

A transmissibility in the range of 0.5 to 0.65 is considered satisfactory.

The transmissibility function (equation3), for a single degree of freedom linear spring-mass-damper system is derived by Den Hartog (1956).

The resulting equation for a steady-state input Z input is:

It is important that the student thoroughly understand the contents of Figure 7-2 and equation 4.

In proper seat-suspension design, the transmissibility must be less than unity, which occurs at Wt/Ws ratios of greater than 1,414.

It should be apparent that the frequency Wt of the input vibration must be known in order to design a seat-suspension system for the tractor.

The tractor frequency in general will be in the 3- to 10-Hz range.

Since occasionally a Wt/Ws ratio near unity will be experienced, the importance of damping should be apparent.

Finally, it should be pointed out that transmissibility is independent of input amplitude for linear systems.

The true transmissibility of a seat is much more complex than equation 4 indicates because of nonlinear cushion characteristics and nonlinearities in the suspension such as inherent friction, limit stops, and so forth.

In practice the transmissibility of a seat is determined experimentally by laboratory procedures.

Once the seat transmissibility is determined, the ride quality can be related to vehicle ride criteria.

For example

Az = (transmissibility) (Z input) (8)

where Az = vertical acceleration, (RMS) m/s2

Z input = RMS value of the acceleration defined in equation 2, m/s2

Az corresponds to the acceleration used in the acceleration criteria of ISO 2631.

Considerable research has been done in seat-suspension design and ride comfort.

The reader is encouraged to consult Janeway (1975), Stikeleather (1970, 1973, 1976), Young (1973).

and Matthews (I 973).

Standards for Roll-Over Protective Structures (ROPS)- p 84

Much effort has been expended to develop standards for ROPS that establish test and performance requirements. Current standards are ASAE S383 ("Roll-Over Protective Structures (ROPS) for wheeled Agricultural Tractors") and ASAE S3 l 0.2 ("Overhead Protection for Agricultural Tractors-Test Procedures and Performance Requirements"). The reader is encouraged to consult the most recent Agricultural Engineers Yearbook for revisions or additions to those mentioned.

Testing of ROPS consists of either a static or dynamic loading test in the laboratory, a crush test, a field upset test, and a temperature-material test. After the static or dynamic test, the same ROPS is subjected to a static crush test. The field upset test may be omitted if the laboratory test (static or dynamic) indicates certain compliances. Special steels that must meet certain impact strength have been developed and certified for ROPS.

Lesson 8

Tractors of the Future- p 86

How will tractors of the future differ from those of the present? One way to make predictions about future tractors is to extrapolate from past trends.

Figure 8-1 shows trends in the drawbar power tractors tested at the Nebraska Testing Station.

Continuation of the upward trend will require increased pulling capability and/or increased operating speeds from future tractors.

Pulling capability can be increased through the use of more massive tractors or, if tractive devices can be improved, through higher pull/mass ratios.

The implication of Figure 8-2 is that tractor power/mass ratios have been increasing primarily due to increased speeds and that tractive improve- through occur in traction research, reasonable limits on tractor size and speed probably will cause a leveling off of the upward trend in the drawbar power of future tractors.

The small, inexpensive digital computers called microprocessors are

likely to increase the use of monitors and automatic controls on farm tractors.

If an engine-efficiency monitor was included on a tractor with a hydrostatic transmission, for example, the operator could adjust the transmission speed ratio to maintain peak efficiency from the engine.

The next step would be to control the transmission automatically.

Use of automatic controls on farm tractors is not a new idea.

Engine governors automatically control engine speed, and three-point hitches include automatic control of hitch height.

Recently, a microprocessor has been used to control the meshing of gears in a tractor transmission.

Will microprocessors eventually permit the automation of tractor steering?

The increasing cost and scarcity of petroleum fuels are likely to lead to changes in engine design.

Will engine efficiency be increased through the use of the higher operating temperatures permitted by ceramics and other new engine materials?

Will engines become more efficient through the use of slower speeds?

Will spark-ignition and diesel engines be supplanted by multifuel engines that can run on whatever fuel is most readily available and least expensive?

Some trends in tractor design may end.

For example, as was discussed earlier, the upward trend in drawbar power may level off.

Innovations have led to improvements in design throughout tractor history, however, and such improvements are likely to continue.

Tractorbot- p 92

The robotic tractor will more closely resemble a robot.

You will not find a stereo, a seat, or even a steering wheel on these machines.

The robotic tractor will be built with off-the-shelf components of industrial and mobile vendors.

The robotic tractor design would incorporate pneumatics, hydraulics, electronics; 12 volt, 110 volt, and 240 volt electrical systems.

The words traction and motor formed the word tractor.

When computer control devices are added to the tractor and the operator is eliminated the tractor becomes robotized.

The descriptive tractorbot is formed when the words tractor and robot are combined, Before installation of a tractorbot, improvements will be made to the field initially to insure consistency.

Debris (such as rocks and stones) in the top soil, that might disrupt the operation of the tractorbot would be removed. The fields drainage would be evaluated.

Tile and surface drains would be installed to achieve consistent moisture throughout the field.

Some topographic changes would be feasible such as squaring a small weaving ditch with field borders. Also, leveling a small sand hill or filling a gully, would have added benefits from a conservation standpoint, thus, improving the stewardship of the land.

A tractorbot will he installed on the farm in much the same way as a center pivot irrigation system is adapted to a field.

The system will be able to be transported to another field, but, not required to be backed in the barn every night.

The tractorbot will pull larger machinery at reduced speeds compared to tractors.

A computer will be carried on board cushioned by air bags.

The software will be programmed to one standardized working width of machinery x and Y coordinates will be used to define the field's perimeter, also the location of any obstructions.

Hills will not impose a problem to the tractorbot because accuracy is not important, but consistency is on subsequent trips through the field.

The tractorbot will not be programmed to follow a weaving ditch.

It will make its progression across the field in straight passes.

Initially the tractorbot will not be feasible for contour farming because of high programming cost.

The tractorbot will consist of a prime mover, power train, guidance system, monitoring system, control system and coupling for machinery.

A practical design will evolve from the cost of available resources and technology of the times.

The design of the tractorbot will dictate the structure of farming.

The prime mover will be initially a highly efficient, air-cooled, diesel engine.

It will be sized to handle the less power-demanding jobs such as spraying, rotary hoeing and spreading fertilizer.

For more demanding operations a slave tractor will be coupled to the tractorbot.

This high horsepower slave tractor will develop high tractive efficiency from low pressure crawler type tracks and couple to follow the tractorbot through the field.

There will be mechanical coupling with feedback loops for steering and speed control of the slave tractor.

The prime mover on the slave tractor will be sized to handle the high horsepower and traction requirements of plowing, secondary tillage and harvesting.

Since much of the heavy work on the farm could be done around the clock, alternative prime movers for the slave tractor could be considered.

A fluidized-bed biomass combustor coupled to a steam turbine is one such prime mover under development to consider.

During harvest operations there would be direct fueling and excess heat could be utilized to dry the grain aboard the harvester and remove the morning dew on the crops.

The harvesting unit could be easily adapted to set on top of the slave tractor utilizing its horsepower and floatation to carry the separator and grain across soft fields.

The platform for the cutting or picking of the crop would be mounted on the front of the tractorbot.

A conveyor belt would lift and feed the crop to the separator.

The grain tank would have excess capacity to make at least one round in the field before it would be dumped into a holding cart.

Tractorbot Lowers the Farming Cost- p 96

The tractorbot will prove more efficient by doing more work per dollar compared to a tractor.

A tractorbot can change a farmer's accounting methods.

The tractor operator's labor is considered a variable cost of production.

When tractor operator's labor cost is eliminated on a tractorbot, major production cost is saved.

The cost and set-up cost of the tractorbot would be part of the farmers' fixed cost.

This would directly lower a farms variable cost of production.

As a result, the shutdown level of a farms production would lower.

This would enable a farm to continue to minimize losses at lower commodity prices.

The cost of the tractorbot would be amortized over many years.

Because the variable cost of operating a tractorbot would be lower than operating_ a tractor, its role in farming would be increased.

More specialized tasks would be feasible because benefits could be achieved at lower cost.

For example, a tractorbot could make mechanical tillage more competitive with farm chemicals.

Tillage is a substitute method of controlling weeds.

Some value could be justified in reducing the hazards of farm chemicals.

The tractorbot would allow farm management to intensify through more exacting methods and by freeing the farmer from the tractor seat to do critical analysis.

Industry will benefit from tractorbots. Light weight and low-cost tractorbots will likely wear out sooner than tractors.

When smaller standardized units are built, more units will be demanded to farm a nation's land.

People will benefit from tractorbots by a continuation of low-cost food.

There will be an opportunity for individuals to start a family farm and provide a decent living for the family.

Jobs will be created for technical people from programming to repair.

Lesson 9

Definitions for Agricultural Tillage Implements- p 98

1**. Disk Harrow**: A primary or secondary tillage implement consisting of two or four gangs of concave disks. Adjustment of gang angle controls cutting aggressiveness. Disk harrow hitches are either rear mounted or pull type.

2**. Offset Disk Harrow**: A primary or secondary tillage implement consisting of two gangs of concave disks in tandem. The- gangs cut and throw soil in opposite directions.

3. **One-Way Disk Harrow**: A tillage implement equipped with one gang of concave disks. When mounted in short flexible gang units, the harrow conforms to uneven soil surfaces.

4. **Moldboard Plow**: A primary tillage implement which cuts, partially or completely inverts a layer of soil to bury surface materials, and pulverizes the soil. The part of the plow that cuts the soil is called the bottom or base. The moldboard is the curved plate above the bottom which receives the slice of soil and inverts it. Moldboard plows are equipped with one or more bottoms of various cutting widths. Bottoms are commonly right-hand that turn alt slices to the right. Two-way moldboard plows are equipped with right-hand bottoms that are alternately used to turn all slices in the same direction as the plow is operated back and forth across the field.

5. **Chisel Plow**: A primary or secondary tillage implement which shatters the soil without complete burial or mixing of surface materials. Multiple rows of staggered curved shanks are mounted either rigidly, with spring-cushions, or with spring resets. Interchangeable sweep, chisel, spike, or shovel tools are attached to each shank. Working width is increased by adding

folding wings to the main unit. Combination in1plements consist of chisel plows with gangs of flat or concave disks or individual rolling coulters preceding the shanks to cut surface residue and vegetation. Chisel plows differ from cultivators by being constructed stronger with wider spaced hanks for primary tillage. (See field cultivators.)

6. **Disk Plow**: A primary tillage implement with individually mounted concave disk blades which cut, partially or completely invert a layer of soil to bury surface material, and pulverize the soil. Blades are attached. to the frame in a tilted position relative to the frame and to the direction of travel for proper penetration and soil displacement. Penetration is increased by the addition of ballast weight. Disk plows are equipped with one or more blades of diameter corresponding to intended working depth. Disk plows are commonly right-hand, but two-way plows are equipped with right-hand and left- hand blades.

7. **Subsoiler**: A primary tillage implement for intermittent tillage at depths sufficient to shatter compacted subsurface layers. Subsoilers are equipped with widely spaced shanks either in-line or staggered on a V-shaped frame, Subsoiling is commonly conducted with the shank paths corresponding to subsequent crops rows. Strong frame and shanks are required for deep operation.

8. **Bedder-Pidger**: A primary tillage implement or a secondary tillage implement for seedbed forming. Bedder tools are either moldboard lister bottoms which simultaneously throw soil in both right-hand and left-hand directions or short disk gangs with two or more disks of equal or varying diameters. Each disk gang throws soil in one direction and is followed by another disk

gang throwing soil in the opposite direction to form a furrow. Planting attachments are sometimes added behind a bedder for planting either on top of the beds or in the furrows.

9. **Field Cultivator**: A secondary tillage implement for seedbed preparation, weed eradication, or fallow cultivation subsequent to some form of primary tillage. Field cultivators are equipped with spring steel shanks or teeth which have an integral forged point or mounting holes for replaceable hovel O! sweep too.ls. Teeth are generally spaced 15 to 23 cm (6 to 9 in.) in a staggered pattern. Frame sections are folded upwards or backwards for transport.

10. **Row Crop Cultivator**: A secondary tillage implement for tilling between crops rows. The frame and cultivating tools are designed to adequately pass through standing crop rows without crop damage. Gangs of shanks are often independently suspended on parallel linkages with depth controlling wheels to provide flotation with the soil surface. Tool options are shanks with shovels or sweeps, spring teeth, and ground-driven rotary finger wheels.

11. **Harrows**: Tillage implements used for seedbed preparation and in some cases light surface cultivation after the seed is planted and before or after the crop emerges. Harrows level the soil surface, enhance moisture retention, pulverize surface clods, and disturb the germination of small weeds. Harrows have staggered teeth of either rigid spikes, coil-spring round wires, flat-spring bars, or S-shaped spring bars.

12. **Rotary Hoe**: A secondary tillage implement for dislodging small weeds and grasses and for breaking soil crust. Rotary hoes are used for fast shallow. cultivation before or soon after crop plants emerge. Rigid curved teeth mounted on wheels roll over the soil, penetrating almost

straight down and lifting soil as they rotate. Hoe wheels may be mounted in multiple gangs or as short gangs on spring loaded arms suspended from the main frame.

13. **Seedbed Conditioner**: A combination secondary tillage implement for final seedbed preparation. Typical purpose is to smooth and firm the soil surface for flat-planting.

14. **Roller Harrow**: A secondary tillage implement for seedbed preparation which crushes soil clods and smooths and firms the soil surface. It consists of an in-line gang of ridged rollers, followed by one or more rows of staggered spring cultivator teeth, followed by a second in-line gang of ridged rollers.

15. **Packer**: A secondary tillage implement for crushing soil clods and compacting the soil. Packers consist of one or two in-line gangs of rollers. Roller sections may be lugged wheels or any one of various shaped ridged wheels.

16. **Rotary Tiller**: A primary or secondary tillage implement use for broadcast or strip tillage. Rotary tillers are also used as chemical incorporators prior to planting and as row crop cultivators. They consist of a power-driven shaft, transverse to the direction of travel, equipped with curved knives that slice through the soil, {tlwp surface residue, and mix a11 materials in the disturbed layer.

Chisel -Type and Multipowered Tillage Implements- p 105

chisel plows and subsoilers are basic primary tillage implements.

Field also be chisel-type implements, depending upon the type of tooth or shovel employed in a particular application.

Chisel points and sweeps are common.

Field cultivators are used primarily for weed control, seedbed preparation, and other secondary tillage operations. Although the discussion on chisel-type implements in this section relates primarily to chisel plow and subsoilers operating in firm soil, some of the principles and effects are applicable to field cultivators.

Multi powered implements are of particular interest because present-day tractors develop more power than they can transmit efficiently to a high-draft implement through the tires without adding extra mass.

One method of reducing the total mass requirement and the resulting adverse effects of soil compaction is to transm it at least a portion of the power directly to the soil engaging elements through nontractive means such as the PTO.

Engine power is transmitted more efficiently through the PTO than through the wheels.

Therefore, if forces could be applied to the soil at least as efficiently through mechanically moving elements as through passive elements, the total energy requirements could be reduced. Present-day multipowered implements often require more power than passive tools, but some types provide a greater degree of soil breakup than do comparable passive tools.

Chisel Plows and Subsoilers

These implements are used to break through and shatter compacted or otherwise impermeable soil layers and to improve rainfall penetration.

The most effective results are obtained when the soil is dry.

Subsoilers have one or more heavy standards that can be operated at maximum depths of 45 to 75 cm [18 to 30 in.] or more.

Chisel plows have a series of standards usually spaced about 30 cm [12 in.] apart and equipped with replaceable narrow shovels or teeth.

The standard may be rigidly mounted or spring-cushioned, or may have spring trios.

Chisel plows can be operated at depths well below the normal plowing zone if any impervious layer that may be present is relatively thin.

Under adverse soil conditions, or when it is desirable that the soil not be inverted, chisel plows are sometimes employed for primary tillage in place of moldboard plows or disk implements.

Since chisel plows do not pulverize the soil as much as moldboard plows, a greater number of subequent operations may be needed to obtain a good seedbed after chiseling.

Effect of Shape Upon Soil Forces.

Lift angle and the slope of the standard have a marked effect upon draft and the vertical soil force V. Lift

angle is defined as the angle between the face of the tool and the horizontal (Figure 9-1).

Shattering is accomplished with the least effort when the tool exerts an upward shearing force on the soiI, rather than a longitudinal, compressive force.

Tests have indicated that the draft decreases as the lift angle is decreased, at least down to an angle of 20°.

Tanner found that a flatplate tine 51 mm [2 in.] wide had a substantial downward component of soil force V when the lift angle was 20°, but an upward V when the lift angle was greater than 60 to 75°.

He observed that when the lift angle was greater than 50° a stationary cone of compacted soil remained at the tip, increasing in size as the lift angle was increased.

Nichols and Reaves observed a similar formation on the point of a subsoiler having a vertical standard.

Although a 20° lift angle and 20° slope of the standard would be good from the standpoints of a low draft and a large downward V, such a design would not be feasible for deep operation because of the length and forward extension of the tool.

Also, the degree of soil breakup might not be adequate.

A practical compromise is to have a curved standard, as indicated in Figure 9-1 (b), with the slope increasing from 15 to 20° at the tool point to 90° or less at the ground surface.

The best shape of the tool is related to the operating depth.

All of the three shapes in Figure 9-1 would have about the same draft and V at the shallow depth indicated.

When operating at the medium depth, shape (a) would have a greater draft than (b) or (c) because of the effect of the vertical portion below the ground surface.

At the greatest depth shown, the forward curve of the upper part of shape (b) would exert a downward force on the soil, thus causing its draft to be greater than of shape (c).

The effect of shape upon draft is illustrated quantitatively by results obtained by Nichols and Reaves with the three subsoilers shown in Figure 9-2.

When operated 36 cm [14 in.] deep in a highly compacted clay soil, the straight-standard tool had a draft of 12.4 kN [2790 1 bf].

The moderately curved subsoiler had 16% less draft than the straight tool but only 1 % more than the tool with the most curved.

In another comparison, tilting the straight standard backward 15° from vertical reduced the draft 12% and using a curved standard reduced it 28%.

Effect of Depth and Speed Upon Draft of Chisel-Type Implements- p 109

Results obtained by various investigators are not consistent in regard to the effect of depth upon specific draft.

It is likely that the effect of depth is influenced by the tool shape and orientseion, soil type, and soil condition.

The results indicate a general tendency for a moderate increase in specific draft as depth is increased in firm soils.

Most of the available data on the effects of speed is for flat-plate tines at low speeds and is not very meaningful in relation to field operation.

Payne, however, conducted tests up to 9.6 km/h [6 mph] with vertical, flat-plate tines.

In 3 soil types the draft increase between 4.8 and 9.6 km/h [3 and 6 mph] was} I to 16%.

Reed conducted tests with 2 field cultivators (probably having sweep-type shovels) in 2 loam soils and found an increase of 4 to 13% between 4.8 and 9.6 km/h [3 and 6 mph].

Tool surface area, lift angle, depth, and soil condition undoubtedly influence the magnitude of the speed effect for chisel-type implements.

In some cases, a linear relation between draft and speed can be assumed over a limited range of speeds.

END