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Title SAFETY PRINCIPLES FOR FARM TRACTOR OPERATION

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A large portion of farm accidents involves tractors. The study assumes that safety education is one method of decreasing the accident rate. The problem facing educators involves fragmentation of safety information and insufficient understanding of motivation as influenced by factors such as emotions and attitudes. The majority of literature most readily available specifically pertains to tractor safety and contains fragmented rules, laws, and facts. Some of the less widely disseminated literature deals with the psychological, physiological, and educational aspects of safety. The most recent study trends explain the psychological factors of accidents to determine why the accident happened, while earlier studies were concerned primarily with tractor and environmental conditions.

The purpose of the study is the identification of

safety principles which will be useful to Oregon high school teachers when teaching tractor operation to freshmen.

The procedure used in the study involves the development of tentative principles from safety literature. These principles are reviewed by agriculture teachers and experts in psychology, agricultural engineering, and teacher training. The revised results are the findings of this study.

Twenty-two safety principles related to tractor operation and tractor safety education are developed. The psychological principles deal with decision-making, hazard perception, reaction time, stress, operator's strength, and hazard threat reduction. The physical principles deal with mechanical reliability, stability, tractor maintenance, moving parts, unattended tractor, heat, fire prevention, and roadway hazard. Educational principles identify the inadequacies of knowledge, motivation, operator needs, training in decision-making, principles and laws of learning, inspection and maintenance, and integration of safety instruction.

SAFETY PRINCIPLES
FOR
FARM TRACTOR OPERATION

by

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CHAPTER I

INTRODUCTION

Each year a great number of tractor accidents bring much unhappiness to rural America. Twenty-eight percent of all farm machinery accidents involve the tractor in some way (8, p. 277).

National Safety Council (25, p. 3) statistics from 1952 to 1958 indicate the national death rate per 100,000 farm tractors increased from 18 to over 27. There were approximately 45,000 nonfatal accidents per year during this time. The total cost of all tractor accidents exceeded 100 million dollars per year.

A National Safety Council (23, p. 4) summary of two studies, one prior to 1950 and the other since then, indicated 34 percent of the tractor fatalities were less than 20 years of age. They showed that 55 youngsters between the ages of 10 and 14 years were killed in tractor accidents. Sixty-two victims were between the ages of 15 to 19. These two age groups include the years when many farm boys have the opportunity to study agriculture.

If a program can be developed to reduce accidents, as measures were developed to reduce serious and widespread diseases such as rabies, small pox, and polio,

then rural-families would lead happier and more productive lives.

Little has been done in developing safety programs in farm mechanics, specifically in tractor operation, that goes deeper than the mass communication level. Pamphlets with safety rules, recommendations, and tips are available. Tractor manuals, newspapers, magazines, and movies carry similar messages. In some instances speech and essay contests involve a few students.

The operation of agricultural machinery differs from the relatively formalized equipment operation in industry. Where the worker in industry performs primarily one type of operation in a standardized environment, a farm worker must perform a large variety of operations under greatly varying conditions. Industry usually works on a time schedule of eight hours, while farmers in some seasons may work twelve or more, thus possibly developing a hazard due to fatigue.

Training must be provided so that there will be flexibility. Technical agriculture changes so rapidly that many of the facts, rules, and procedures learned today may be obsolete tomorrow. The individual must learn to adapt himself to this changing world, for if he is to remain progressive, staying alive and well, there will rarely be someone to tell him what to do.

The agriculture teacher will need to have a safety program of instruction that is practical, effective, economical of class time, and of sufficient depth and scope to actually change attitudes and impart understanding.

I. STATEMENT OF THE PROBLEM

How can agricultural education help rural people avoid tractor accidents? One way is through education (2, p. 98). The instructor is faced, however, with many rules, facts, and laws. He also knows that the memorization of this information will not, in itself, always produce safe behavior. The problem facing educators is the fragmentation of safety information and insufficient understanding of motivation as influenced by factors such as emotions and attitudes.

Tractor Safety Information Is Fragmented

Tractor safety information is fragmented into many rules, laws, and facts. This information in turn is disseminated throughout many references. How can this material be brought together to develop a program of tractor safety instruction which is effective, and also economical of time? Underlying this fragmented information are there a small number of basic

principles? If there are, they may provide an aid in providing sufficient depth and scope to the instruction and yet be economical of instruction time. The memorization of rules may be less effective for helping the student deal with his future world and will not be remembered as well as concepts.

Can safety principles be identified? They are not currently set down as such in the literature. Some are implied, but only one, (5, p. 582), is found stated as such.

Development of Understanding

Safety rules, laws, and facts, besides being fragmented, tend to emphasize procedures rather than understanding underlying causes. Why do operators become involved in accidents by doing something which they "know" is unsafe? Is a program of safety education complete if it offers only knowledge of how a tractor operates but excludes the motivation of the operator?

II. PURPOSE OF STUDY

The purpose of this study is to identify safety principles which will be useful to Oregon high school teachers when teaching safe tractor operation to freshmen.

The purpose for developing principles is:

1. So that instruction will be generally more meaningful, inclusive, and economical of time.

2. To provide an objective which can be used to evaluate the development of the student's safety concepts.

3. To develop a relatively more inclusive understanding than can be obtained from fragmented safety rules and tips.

4. To bring to light important factors of safety which previously have not been emphasized.

III. ASSUMPTIONS

This study is based on the following assumptions:

1. That when safety principles are applied by tractor operators, accidents will be reduced.

2. That when these principles are used by the teacher, instruction will be more effective, efficient, inclusive, and meaningful.

3. That specialists and educators are qualified to identify those principles most valuable for use by Oregon teachers.

IV. DEFINITION OF TERMS

Concept

In this study a concept is the development within the individual as a result of his experiences a law of conduct which has general applications that forms a basis of action for him. It is a personal formation and is differentiated from a principle in that a principle is developed by another person or group.

Decision-making Process

In this study the term decision-making process means the process whereby an individual assimilates information then takes some form of action based upon that information.

Hazard

A hazard, as used in this study, is a situation or condition with a relatively high accident probability.

Latitudinal Stability

When used in reference to the tractor, latitudinal stability is the result of forces which tend to keep a tractor from overturning sideways.

Longitudinal Stability

When used in reference to the tractor, longitudinal stability is the result of forces which tend to keep a tractor from overturning either forward or backward.

Principle

The term principle is defined in this study to mean:

> A fundamental truth; a law of conduct which has general applications, and which is a basis for action. It is a generalization based upon facts and upon elements of "likeness" common to a number of situations. Since a principle is a generalization, there are sometimes minor exceptions to it, but it still has general application (3, p. viii).

Response

When used in referring to the action of a tractor, response is the resultant of forces exerted by the environment combined with changes due to the manipulation of controls by the operator.

Safety

Safety is a process whereby a choice is made between experiences which involve relative degrees of hazard and relative probabilities for achieving a desired ultimate goal. Safety education involves the

development of abilities to determine the relative hazards, determine the ultimate goal, and then make a decision based on this information.

V. DESCRIPTION OF PROCEDURES

The procedures involved in developing the principles in this study follow these major steps:

1. A survey of the literature by the writer to consolidate as many rules, laws, practices, and principles as could be found into a list of proposed principles.

2. Presentation of the principles to farm machinery specialists, psychologists, and vocational agriculture teachers. Their purpose is to determine those principles most valuable in the process of teaching safe tractor operation.

3. The principles with any changes resulting from the comments are then incorporated into the findings of this study.

VI. LIMITATIONS OF THE STUDY

The following limitations are placed on this study, or are inherent in it:

1. The selection of principles is delimited to those which apply to safe operation of wheeled farm

tractors.

2. The study is further limited to the instruction of freshman agriculture students in high school in Oregon.

3. The principles developed are for the use of agriculture teachers, not students.

4. The findings of the specialists are in essence the opinions of that body. While they represent a concensus, these opinions may still be in error.

CHAPTER II

SURVEY OF RELATED LITERATURE

Literature pertaining to safe tractor operation is organized in this chapter into four main areas: self understanding, physiological aspects of tractor operator safety, understanding hazardous tractor situations, and education for safe tractor operation, in that order.

I. FACTORS OF SELF UNDERSTANDING IN SAFE TRACTOR OPERATION

Much of the statistical reporting and literature on prevention of accidents deals with the operator's manipulation of the tractor in the environment. However, when accidents were probed in depth, factors were found which precluded the use of known safe practices. The psychological approach is a relatively new and unapplied emphasis in safety programs.

Karl Menninger (18, p. 1-7) stated in 1959 that there was little research on the motivation of accidents, but in his psychosomatic research he has found that when investigators attempted to

use accident cases as "controls", they found many instances of provocation, frustration, and disappointment very similar to events in heart and stomach cases. Schultzinger (20, p. 2) emphasized the importance of an accident syndrome due to physical, physiological, and psychological aberrations.

The National Safety Council (22, p. 5-2) recognizes the importance of psychological factors to safety. It devotes an entire chapter of a handbook for industrial safety to individual differences, motivations, emotions, attitudes, and learning processes.

Hersey (11, p. 59-65) found that low emotional vigor, mental conflicts, and elation contributed to accidents. Stack and Elkow (32, p. 46) emphasize that emotions are the basic psychological force in accident occurrence.

Florio and Stafford (8, p. 34-37) write that in cases of relatively extreme emotional insecurities accidents may be a compensation for inferiority feelings or a desire for self destruction. Also, adolescents in failing to gain status in socially approved ways may seek to assert themselves against the authority of parents and teachers

through destructive behavior.

Researchers attempted to analyze personality characteristics to determine if they could predict an accident prone individual. Birnbach (2, p. 98), when comparing accident repeaters with accident free junior high school boys, found accident free pupils were better informed about safety practices and were better adjusted to home and school conditions. Harris (10, p. 455-459) found that no significant personality differences could be measured between accident repeaters and accident free workers. Johnson (13, p. 489-532), attempting to detect accident prone drivers by personality characteristics, was able to select classes of accident prone drivers, but not individuals with any degree of significance. Krall (15, p. 99-107) and Langford (16, p. 405-415) describe the accident repeater as tending to show more aggression, less reality orientation, and more domineering, but not to a predictable degree.

In their review of research, Stack and Elkow (32, P. 47) found intelligence, except at lower limits of I.Q., and years of education were of no significance in accident rates. However, those who were well informed

about safety and safe practices tended to have fewer accidents. As a group, those with physical disabilities showed fewer accidents than normal groups.

The National Safety Council states that 12 year olds may be sufficiently strong, but lack ability to concentrate, good judgment, and responsibility needed for safe tractor operation.

II. PHYSIOLOGICAL ASPECTS OF TRACTOR OPERATOR SAFETY

Studies indicate that physiological stress, strength, and reaction time are important physiological factors of safe tractor operation.

Dupuis (6, p. 510) found excessive stress, premature fatigue, and impaired health increased accident probability. Back pains, indicating possible spinal damage, and impaired work performance were found by Hornick (12, p. 675) to be the result of tractor vibration transmitted to the operator.

Schmitz (28, p. 526) found visual attention, hand coordination, motor coordination, and strength were decreased by both high and low temperature extremes. Bright sunlight reduced the rate of sensitivity in dark adaptation and, combined with glare, may result in relative blindness. Reduced auditory sensitivity, increased energy and muscular tension resulted from

continuous high intensity noise.

Receiving much attention in driver education but also important in tractor operation is reaction time. Stack and Elkow state (32, p. 51) that a short time lag between perception and motor response is an asset only when an appropriate response is initiated. They also indicate that there are several factors which affect reaction time.

III. UNDERSTANDING THE HAZARDS OF TRACTOR OPERATION

This section deals with accident studies, general safety rules, tractor safety rules, and the physical stability of tractors, in that order.

Tractor Accident Studies

A study (25, p. 3) of Ohio tractor accidents found 58 percent were overturns. The remaining 42 percent included accidents classified as highway, crushed between, and run over by tractor. Fifty six percent happened while equipment was being pulled. Five percent are attributed to mechanical failure. The causes and direction of overturns and the ways the operator was killed are included in this study.

Knapp and Hildman (14, p. 34-37) from a pilot study of farm tractor-motor vehicle accidents developed three hypotheses:

1. There is a "typical" tractor-motor vehicle accident, 2. Tractors are not designed to protect the operator, 3. Farm tractor accidents show a sequence pattern.

General Safety Rules

Safety rules applicable to tractor operation are found to be of general nature applying to farm life as a whole, or specifically to tractor operation. They are reviewed in that order. In most cases the rules are repeated in the various sources, but no list was found to be complete.

Stack and Elkow (32, p. 73) present the most complete list of general safety rules in the form of desirable practices. Their primary concern is with emotional and physiological aspects of safety. Florio and Stafford (8, p. 274-275) list five general safety rules covering both physiological and equipment aspects.

Tractor Safety Rules

Specific safety rules for safe tractor operation are available from many sources such as text books, equipment manuals, and pamphlets. Most lists are incomplete. The most complete list found is contained in a pamphlet published by the Farm Equipment Institute

(7, p. 1-4) in cooperation with the National Safety Council. It is well organized and divided into tips for safety before starting, while operating, and after operating the tractor. Florio and Stafford (8, p. 279) and Moses and Frost (20, p. 465-466) list additional safety rules not covered in the previous source. The National Safety Council publishes additional safety information such as their rules for refueling (26, p. 3).

Tractor Stability

Over one half of the tractor accidents involved its stability (25, p. 3). Culpin (5, p. 582) cites the "principle of moments" which describes the stability of the tractor in terms of the forces acting upon it at any given moment. He elaborates, pointing out conditions which will cause the tractor to overturn. Moses and Frost (20, p. 445) describe in similar terms the increasing instability as the tractor's front end rises. Richey (27, p. 100) describes the problem of weight transfer. Barger (1, p. 270-319) indicates the complex variety of forces influencing the tractor chassis.

IV. SAFETY EDUCATION

The literature on safety education is organized into goals, psychological considerations in learning,

recommended inclusions in the course of study, and methods of teaching tractor safety, in that order.

Goals of Safety Education

Florio and Stafford (8, p. 29-32) write that the goal of safety education is to motivate students to develop and practice protective skills. The aim is to teach the operator to shield himself from potential danger, including hazards not previously encountered.

Stack (31, p. 11) emphasizes cautious behavior, but not to the extreme that would inhibit one's enjoying life. Stack and Elkow (32, p. 35-38) state that safety of self and others is the responsibility of everybody, for unsafe practices may injure others than the violator. They also indicate that the way to deal most effectively with the problems of safety is through the development of attitudes and judgment which are applied universally as a way of life, rather than to a segment of life.

Florio and Stafford (8, p. 34) indicate that students should be made to understand that safety regulations are for the student's protection; therefore, he in return must give up the right to do as he pleases. "The best safety device known is a safe operator." (8, p. 276)

Psychological Considerations in Safety Education

The National Safety Council (22, 5-16 to 5-18) lists the laws of learning which are involved in safety education. These also apply to general education. Messerly and others (19, p. 79) emphasizes readiness for the beginning operator in terms of maturity of judgment as well as physical maturity.

Of great importance is the development of attitudes. Diebrecht (33, p. 3) states that attitudes are developed from emotionalized experiences. They cannot be "taught". Stack and Elkow (32, p. 56) consider attitudes to be fundamental factors in safety and the hardest to develop or modify in that they involve the emotions. For people the tendency is to withdraw or resist situations that conflict with existing attitudes. Sherif and Cantril (30, p. 19-20) state that internal factors such as temperment and motivation, or social factors such as suggestion and prestige contribute to attitude formation.

Motivation, write Florio and Stafford (8, p. 30) is a difficult but essential task faced by the teacher. They view the problem as being one of channeling reckless behavior into careful, orderly behavior. The teacher must understand the satisfactions derived from

unsafe behavior. The National Safety Council (22, p. 5-6) indicates that if safety is to be achieved, it must be motivated by one or more of the fundamental needs of people. In using self preservation, Florio and Stafford state that emphasis should be on preserving oneself from injury. "The desire for group recognition is one of the strongest motives in contemporary American Life." (8, p. 31) Responsibility can be a strong incentive to proper behavior. Stack and Elkow (32, p. 55) list self preservation, personal gain or reward, group membership or loyalty, responsibility, pride, rivalry, and leadership as motivations of value in teaching safety.

Recommended Inclusions in the Course of Study

Stack and Elkow (32, p. 40) state that material which is most closely associated with the problems and processes of life is most suited for safety education. They also recommend covering several hazards in the use of farm machinery. Moses and Frost (20, p. 446) write that the prime requisite to tractor safety is a knowledge of construction and an understanding of operation.

Stack and Elkow (32, p. 275) state that a course of study for a safety program should contain certain well-defined characteristics. These characteristics

would be most applicable when the course was prepared by other than the teacher.

Dr. Schulzinger (29, p. 5) recommends that guidance should be provided on all aspects which will affect an individual's safety. These include vocational placement, inexperience, alcohol, fatigue, aggressiveness, temperature, and others.

Methods of Teaching Tractor Safety

Florio and Stafford (8, p. 32-35) emphasize the importance of group decision on approved behavior. Freshmen are at an age when peer approval is important. Discussions should center around evaluation of existing rules, development of their own rules, and around incidents which need new rules. Group rather than teacher or parent pressure should be used to bring offenders into line. Discussion may provide catharsis for objections and give opportunity for alternative suggestions.

Carney (4, p. 83), in a study of shop safety, found all references agreed that the basic method of teaching safety is by instructing in the proper procedure so that the student learns the safe procedure at the time he learns a new skill.

Stack and Eiebrecht (33, p. 56) list ten techniques for developing safe attitudes. These are commonly used,

with some techniques being more effective than others.

The Machine Safety Subcommittee of the National Institute for Farm Safety (9, p. 12-13) has developed six important steps for teaching tractor operation safety. These steps would apply in teaching any skill to an individual student.

V. SUMMARY OF SURVEYED LITERATURE

The literature reviewed deals with the psychological, physiological, and educational aspects of safety as well as specific procedures for safe tractor operation. These procedures pertaining specifically to tractor safety contain primarily fragmented rules, laws, and facts. The majority of safety information available to the average operator is of this type. In only one instance, the principle of moments, was a principle of safety stated as such. Many lists of rules for safe tractor operation are available, but none is truly complete. Most studies of tractor accidents deal with factors other than the operator's motivation. However, most recent trends of study are delving into the psychological factors of accidents in an attempt to determine, in depth, the causes of unsafe behavior.

CHAPTER III

FINDINGS

This study attempted to identify safety principles which would be used to guide the instructor. It was also hoped that they would aid in elimination of duplication and repetition, thus making instruction more efficient. It was found that principles could not be determined which would cover all areas of tractor safety well enough so that safety rules could be avoided entirely. A few safe procedures must be covered individually without being covered by principle. This indicates that principles have application only where generalizations can be made.

Some formulations of safety procedures into lists such as the Farm Equipment Institute's pamphlet (7, p. 1-4) are quite complete. In most cases if the operator understood the reasons behind all the procedures, his knowledge would be quite adequate for most operating conditions. However, these rules for avoiding hazardous situations do not deal with the operator as a person subject to factors which may influence his decision in such a way that he selects procedures he knows are unsafe.

Tractor operation contains many hazards which cannot be avoided if tractor work is to be done. Farm tractors cannot be designed to be completely safe without interfering with reasonable accessibility and efficient machine operation (35, p. 793). Increased power, complexity, and speed have increased the hazard. Improper use of farm tractors may result in the operator's injury. Back injury due to vibration and jostling over rough ground, ear damage due to loud noise, and heat stroke from exposure to heat and sun are some of the inherent hazards in farm tractor operation.

If the operator avoided all hazard, he could not operate the tractor. Just as a tow rope may be fastened to the axle housing or to the drawbar, there are several ways of accomplishing a task, some of which are less hazardous than others. By developing a recognition of those operations which are relatively hazardous or safe, the operator has greater probability of leading a more active, vigorous, and challenging life without being handicapped by injury (32, p. 31-42).

The remainder of this chapter contains the principles which were developed in this study. They are presented as psychological principles, physical principles, and educational principles.

I. PSYCHOLOGICAL PRINCIPLES OF SAFE TRACTOR OPERATION

SAFE TRACTOR OPERATION IS BASED UPON THE DECISION-MAKING PROCESS CONTROLLED PRIMARILY BY THE EMOTIONS, LIMITED BY ADEQUATE KNOWLEDGE OF HAZARDS AND THE PHYSIOLOGY OF THE OPERATOR PRIMARILY IN REACTION TIME AND STRENGTH.

Of the psychological factors which influence decision-making processes, emotions are the basic force in accident occurrence (32, p. 46). Worry over the job, about close interpersonal relationships, and other periodic emotional disturbances create low physical and emotional vigor. Conflicts between mental judgment and deep down unwillingness to abide by restrictions may alter judgment. Hurrying a job because of overenthusiasm or elation may lead to an accident (11, p. 59-65). Self destruction is an escape from a seemingly intolerable emotional situation. Consciously or unconsciously incurring a disability may serve as an attention-getting device to cover some felt inadequacy, such as the operator who sprains his ankle while jumping from the tractor platform to the ground and will as a result be relieved of a few days work (8, p. 35). "Showing off" may be a means of the operator's attempting to prove to others and himself that he is of some worth (8, p. 37).

Freshmen as a group are, because of adolescence, relatively insecure and may feel a need to show adults that they are capable of taking care of themselves, when actually they have not yet developed the skills, judgment, and strength necessary for their safety. Thrills may give a sense of power and therefore act as a substitute for real security (8, p. 37).

DISTRACTIONS TEND TO DECREASE PERCEPTION OF HAZARDS AND INFLUENCE THE FUNCTIONING OF THE DECISION-MAKING PROCESS.

Distractions may be of various types. Considered already are the emotional factors in the previous principle. Secondly are the more evident environmental factors, such as people, which divert the operator's attention from such hazards as children or animals in the tractor's path. Pain and fatigue are physiological distractors. Attention, such as looking for hidden obstructions, strengthens perception.

Each operator has a different psychological makeup in that reactions may be different to similar stimuli (22, p. 5-2). Where one operator would stop and analyze a new situation, another may "plow on".

An important psychological consideration in the perception of limitations is the hazard created when the operator of a tractor exceeds his physiological

capabilities. This involves such factors as reaction time, strength, and stress. In recognizing limitations an individual has an opportunity to compensate for them. Known physical disabilities seem to have no adverse effect on safety, and as a group the physically handicapped appear to be safer than non-handicapped workers (32, p. 47).

THE SPEED OF A REACTION WILL INCREASE THE OPERATOR'S ABILITY TO AVOID AN ACCIDENT, PROVIDING THE RESPONSE IS APPROPRIATE.

The speed and precision of decision-making and reaction to a stimulus will increase the ability of the operator to avoid an accident when immediate response is essential. The operator must determine if the nature of the hazard warrants using a conditioned response if the response must be altered.

Reaction time may be increased by fatigue, decreased sensitivity to the stimulus, resistance of the nervous system, how the brain handles the stimulus, the limitations of the motor organ, and lower temperature (28, p. 526). An increase due to age may be compensated for by increased ability to perceive a hazard. Attention tends to shorten reaction time (32, p. 51).

Inappropriateness of the semiautomatic functioning

process during tractor operation is a hazard. This is exemplified by an operator accustomed to using a foot clutch who is unable to stop automatically a tractor with a hand clutch. Retraining and practice are necessary to adapt the semiautomatic reaction.

ENVIRONMENTAL FACTORS CREATING A CONDITION OF STRESS IN THE OPERATOR ARE A HAZARD TO SAFE TRACTOR OPERATION.

Vibration (12, p. 675), temperature extremes, bright sun, continuous noise (28, p. 526) above 115 decibels for ½ hour, dust, and insects create a hazard of excessive stress. This stress may result in premature fatigue (6, p. 510), impaired health (32, p. 73), and inadequate strength for emergencies, as well as impaired performance before stress fatigue sets in.

A HAZARD IS CREATED WHEN THERE IS INSUFFICIENT STRENGTH TO PERFORM THE TASK OR TO MEET EMERGENCIES.

Size and strength, as in the case of the average child under twelve, pose a hazard to the young operator if he should try to operate a farm tractor of even small size. Impaired health, recent illness, or sickness may sufficiently reduce strength to be hazardous (32, p. 73). Limitations, if recognized, may be compensated for.

THE PERSONAL SIGNIFICANCE OF A HAZARD TENDS TO BE REDUCED WITH TIME IF AN ACCIDENT DOES NOT OCCUR

When an operator works close to a hazard for a long period of time and the hazard does not manifest itself, then the fear of the hazard is reduced. A process of fear reduction may be involved when a tractor has shown no tendency to tip and the operator becomes more careless until one day the tractor does tip.

II. PHYSICAL PRINCIPLES OF SAFE TRACTOR OPERATION

Along with the psychological principles are the physical or mechanical principles. Psychological principles deal primarily with the operator as a person; the physical principles deal primarily with the machine in a variable environment. At this point safe tractor operation is concerned with physical manipulation of machine and materials to utilize various physical laws through an understanding of them.

FARM TRACTORS OPERATE MECHANICALLY IN ACCORDANCE WITH KNOWN PHYSICAL LAWS.

Safe tractor operation is dependent upon the operator's understanding the cause and effect relationships as he manipulates the machine under a wide variety of environmental conditions. To anticipate the response

the tractor will make under various conditions the operator must understand the physical laws involved. This involves knowing the effects of hillside operation, striking of hidden objects and holes, various loadings, and different speeds, all within the framework of the job being done.

A TRACTOR'S STABILITY IS AFFECTED BY THE PRINCIPLE OF MOMENTS WHICH STATES: "IF A SYSTEM OF FORCES IN ONE PLANE ACTS UPON A BODY AND KEEPS IT IN EQUILIBRIUM, THE ALGEBRAIC SUM OF THEIR MOMENTS ABOUT ANY POINT IN THE PLANE IS ZERO".(5, p. 582)

> The principle of moments assists in an understanding of such practical problems as the avoidance of overturning when operating tractors. So long as it is stationary, and a vertical line through the center of gravity passes inside the lower wheel, the tractor's weight exerts a mechanical couple that resists overturning. The higher the center of gravity and the narrower the wheel track, the greater is the risk of overturning. The risk can be greatly increased by centrifugal forces caused by sharp turns. Carrying a load in raised position on a front loader has the effect of raising the center of gravity to what may be a dangerous extent. The danger of overturning is also greatly increased by momentum caused by the lower wheel dropping suddenly into a depression, or the upper one running over a boulder (5, p. 582). (Figure #1)

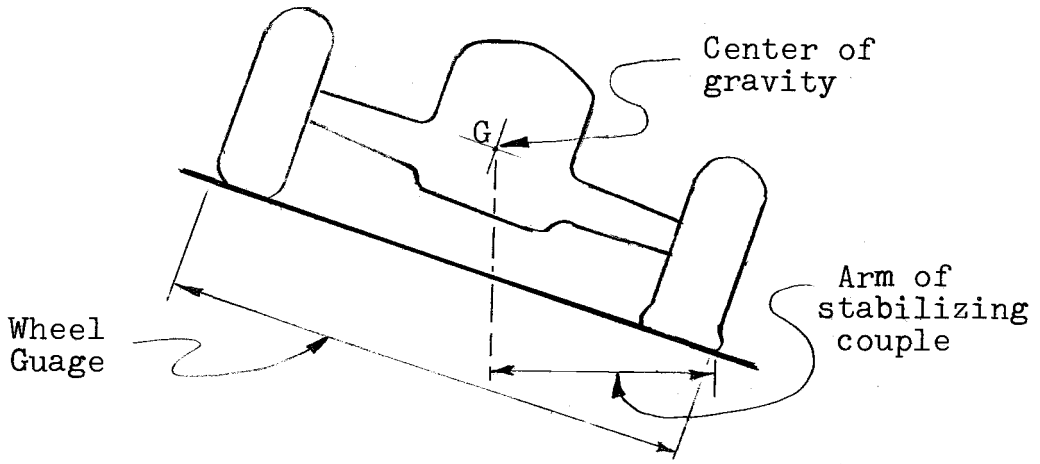

FIGURE 1

STABILITY OF A WHEELED TRACTOR AS AFFECTED BY THE RELATIONSHIP BETWEEN CENTER OF GRAVITY AND POINTS OF SUPPORT.

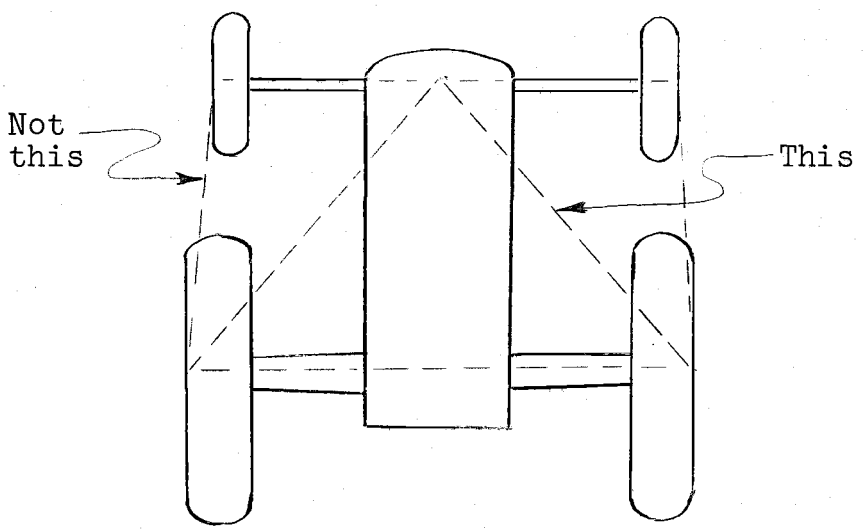

FIGURE 2

APPARENT AND ACTUAL POINTS OF SUPPORT OF A WHEELED TRACTOR

Due to the fact that most four-wheel tractors use a pivoted front axle, the stability pattern is affected about the same as for a tricycle type. The center of gravity must be inside a triangle formed by the two rear wheels and the center of the front axle (17). (Figure #2)

For determining longitudinal stability:

> The tractor may be considered as a lever pivoted about the point of contact between the rear wheels and the soil (O). The drawbar pull through L has a tendency to make the tractor rear the magnitude of the couple being I (R-X). The tractor's weight, W, acting through the center of gravity, exerts a stabilizing couple W x b. Factors tending to increase the risk of overturning as a short wheelbase and a high hitch point (5, p. 582). (Figure #3).

When the load is varied, such as by a manure loader, the tractor's center of gravity is also transferred.

> With rear-mounted loaders the additional load imposed on the rear wheels is greater than the weight of the bucket and its contents, since part of the tractor's weight is transferred from front to rear wheels. The forces must be considered as pivoting about the rear axle and the additional loading due to the weight W_3 is
>
> $$W_1 + \frac{W_2 \times W_3}{Y},$$ (5, p. 582). (Figure #4).

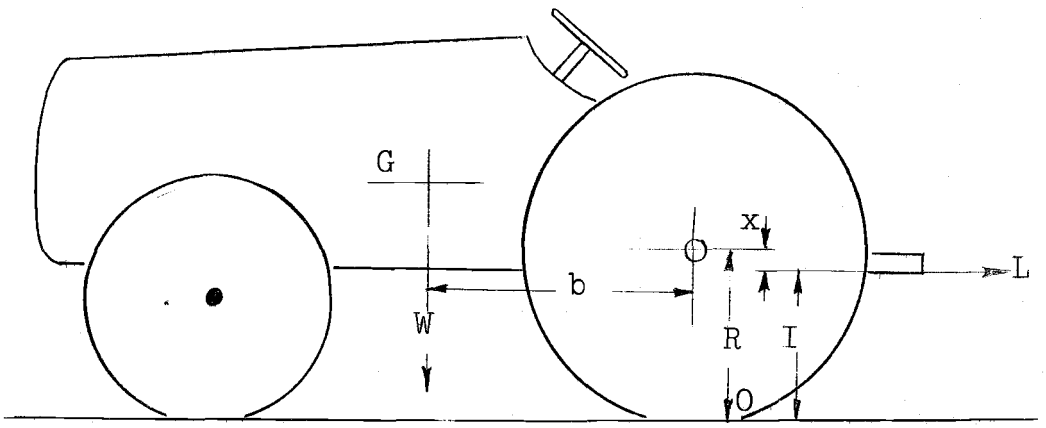

FIGURE 3

RELATIONSHIP OF FORCES AFFECTING LONGITUDINAL STABILITY OF A WHEELED TRACTOR WHEN A LOAD IS APPLIED TO THE DRAW-BAR

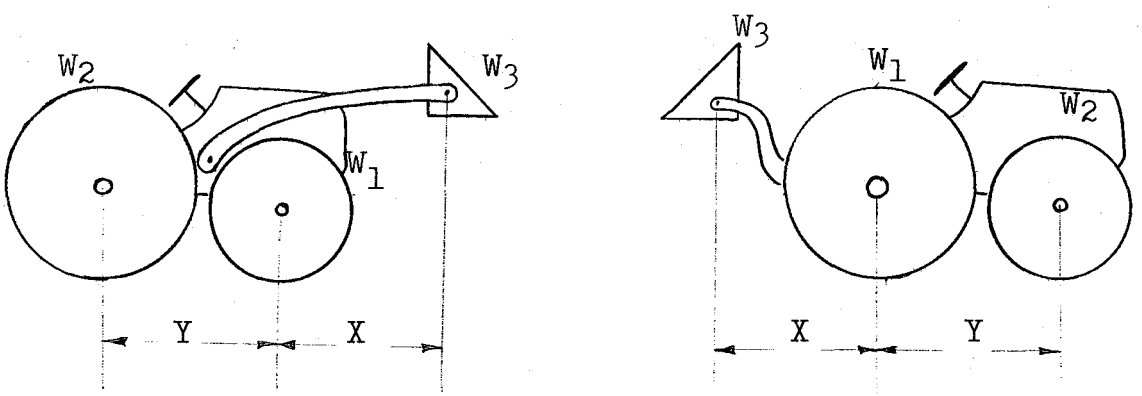

FIGURE 4

SHIFT OF CENTER OF GRAVITY AS AFFECTED BY FRONT AND REAR LOADING OF A WHEELED TRACTOR

As the front end of the tractor rises due to climbing a grade, suddenly engaging the clutch, or overloading, the tractor becomes increasingly less stable.

> If the front end rises, b (the stabilizing couple) decreases as the center of gravity rotates about O, and unless L (load) decreases or traction fails, the tractor will overturn. (20, p. 445). (Figure #5)

Tractive forces may move ahead of the center of gravity, resulting in forces which tend to raise the front end (Diagram #6). Thus the tractor may tend to turn over backward rather than move forward. A tractor which has "dug itself in" and has steel wheel lugs or rubber tires with a timber chained to it exemplifies this condition. This shift of forces has less probability of occurring with rubber tires (1, p. 288). Backing out of a ditch, mud, etc. will tend to force the front end down, increasing stability.

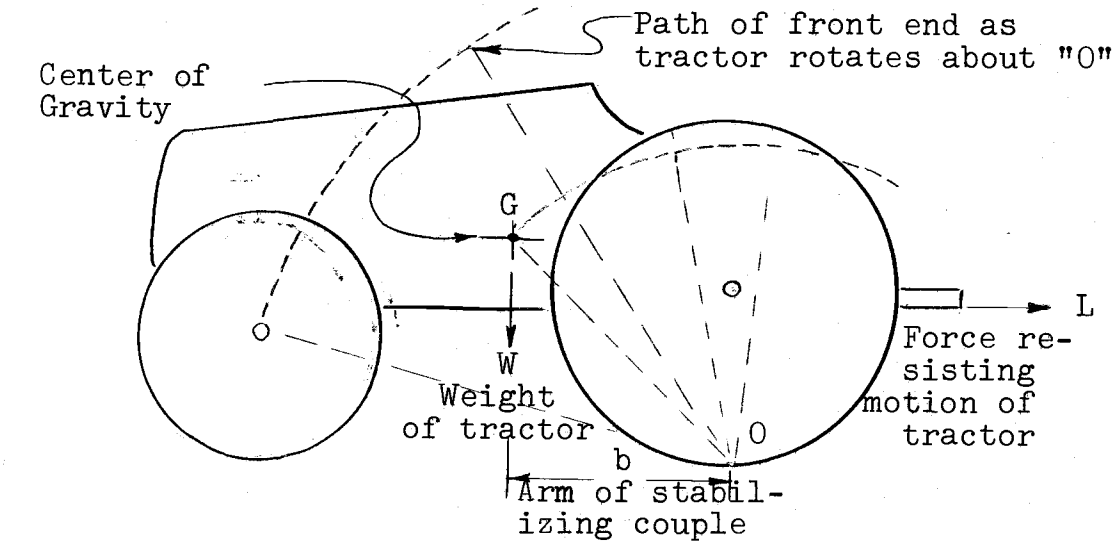

FIGURE 5

RELATIONSHIP OF FORCES SHOWING DECREASING STABILITY OF A WHEELED TRACTOR AS THE FRONT END RISES

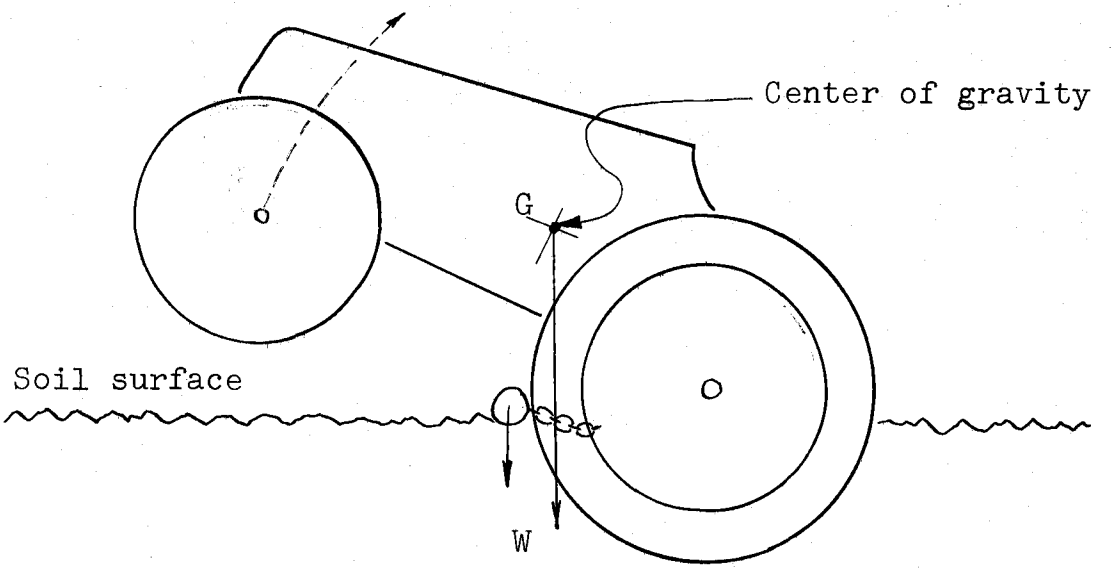

FIGURE 6

A CONDITION AFFECTING LONGITUDINAL STABILITY OF A WHEELED TRACTOR WHEN AN UNYIELDING OBJECT ON THE TRACTION SURFACE CAUSES A FORWARD SHIFT OF TRACTOR SUPPORT AHEAD OF THE CENTER OF GRAVITY

The time required for the front end of a tractor to rise to a point of complete instability varies from 0.5 to 1.5 seconds for a typical farm tractor (1, p. 299). The speed is increased with engine RPM and higher gear. Normally, there is insufficient power on level ground when the tractor is in high gear to turn it over backwards. However, the stored energy in the rapidly revolving flywheel as the clutch is suddenly engaged may result in rapid overturn. In low gear and with the clutch engaged the tractor front end will rise more slowly (17).

The front wheel load gives an indication of stability with respect to turning over backwards. This may be indicated by a decrease in steering response or effort. As soon as the force approaches zero or becomes negative the tractor overturns backward (27, p. 100).

All of these forces are affected by the operator's control, such as speed, width of wheel track, turning radius, loading, choice of terrain, rate and evenness of start and stop.

ADEQUATE TRACTOR MAINTENANCE IS AN ESSENTIAL PART OF SAFE TRACTOR OPERATION.

Adequate maintenance is necessary because mechanical failure may sufficiently alter the response

of the tractor to present a hazard. Predictable functioning is necessary for adequate operator decisions. The failure of a fatigued part may not be easily determined by means available to the operator. However, regular inspection (20, p. 465-466) of hitches, steering, brakes, seats, and levers may make it possible to anticipate malfunctioning and to follow with repair or replacement if necessary. Repairs or adaptations, such as equipment not originally designed for that specific tractor, that fail or alter the functioning or balance of the tractor may increase hazard possibilities.

MOVING PARTS ARE A HAZARD WHICH INCREASES WITH THE PROXIMITY OF THE OPERATOR TO THEM AND MAY BE REDUCED BY SHIELDING OR STOPPING THE PARTS.

Such a hazard is created by the operator cleaning, lubricating, adjusting, or repairing the tractor while it is operating (20, p. 465-466), (7, p. 1-4). Recommendations indicate that the hazard is reduced by stopping the engine or disengaging the power-take-off. While operating the equipment, if he is not able to stay far enough away from moving parts, the operator would do well to see that they are adequately shielded. Clothing which may be caught easily, such as hanging sleeves and open coat, should be avoided.

AN UNATTENDED TRACTOR IS A POTENTIAL HAZARD IF IT CAN BE MOVED OR OPERATED BY AN INCOMPETENT PERSON. (7, p. 1-4)

The hazard may be reduced by relaxing the tension on hydraulic and mounted equipment, parking in such a way that the tractor will not roll if brakes or gears are disengaged, using the ignition lock and removing the key, and disengaging the power-take-off.

HEAT, A HAZARD PRODUCED BY THE EXHAUST AND COOLING SYSTEM, MAY BE REDUCED BY COOLING OR AVOIDING CONTACT.

Waiting for the exhaust system to cool or being extremely careful when working near it will help one avoid burn injury or starting a fire. Burns from the cooling system may be avoided by allowing the pressure to escape slowly through the loosened radiator cap, or cooling the system with a stream of water if there is insufficient time to wait for the system to cool naturally.

TO AVOID FIRE, SOURCES OF IGNITION AND COMBUSTABLES MUST BE KEPT SEPARATED.

A tractor engine is a source of ignition for combustables through heat, flame, or spark. Operating near

straw, hay, dust, or gasoline may start a fire if they come in contact with a source of ignition. Leaking fuel lines, tanks, and carburetors, as well as refueling, constitute the major fire hazards. The hazard of volatile fuel may be reduced during refueling by allowing the tractor to cool, not refueling while it is running, providing room for fuel expansion as it warms in the tank, and allowing spilled fuel to dry before starting the engine (26, p. 3), (7, p. 1-4), (20, p. 465-466). Smoking or other sources of flame may lead to fire or explosion.

TRACTOR OPERATION ON ROADWAYS RESULTS IN A HAZARD DUE TO THE PROPORTIONALLY GREATER SPEED OF OTHER TRAFFIC IN RELATION TO THE TRACTOR, AND TO THE ADDITIONAL WIDTH AND BULKINESS OF IMPLEMENTS AND ATTACHMENTS.

The hazard of widely differing speeds is increased by the driver of the high speed vehicle not perceiving the difference in relative speed; reduction of visibility due to darkness, fog, hills, curves, and obstructed intersections; and insufficient advance warning because of high overtaking speed. This hazard may be reduced by adequate marking through flags, reflectors, and flashing lights to indicate to other drivers that they are approaching a slow-speed vehicle; avoiding moving the

tractor during low visibility times such as dark or fog; using less traveled roads when possible; using highways during times of minimum traffic; following state traffic regulations and principles; performing adequate maintenance so that repairs are not needed on the highway and operation due to faulty brakes or steering is not erratic; avoiding unsafe speeds; and moving tractors long distances on trucks to avoid long exposure to road hazards.

III. EDUCATIONAL PRINCIPLES APPLYING TO SAFE TRACTOR OPERATION

The value of physical principles is increased through motivation and appropriate learning experiences. This process becomes more effective when one is able to influence behavior through educational principles.

KNOWLEDGE IS NOT SUFFICIENT TO PREVENT TRACTOR ACCIDENTS.

Education for safe tractor operation must include not only knowledge of safe practices and understanding of the psychological processes involved, but also a change in behavior. Considering this, knowledge of principles and safe procedures is inadequate for preventing tractor accidents. Facts describe what should be done, but do not consider the operator as a person

subject to a variety of conditions which may contribute to or hinder his use of the procedures or principles. Therefore, it would seem that safety education is more inclusive than just learning about how a tractor is operated. Safety education must also help the operator understand his motivations and attitudes. Tractor safety education must develop attitudes and judgment which are universally applicable as a way of life rather than to a segment of life.

SAFETY EDUCATION WILL BE EFFECTIVE ONLY AS IT PROVIDES EXPERIENCES WHICH RESULT IN THE OPERATOR'S ABILITY TO USE A TRACTOR WITHOUT ENDANGERING HIMSELF OR OTHERS.

The only significant learning in safety education is that which influences behavior. The aim is to provide experiences which develop in the operator concepts and attitudes of safety. The teacher will not be effective in imparting information; he can only provide experiences. The teacher's experience cannot be communicated to the student.

The true evaluation of safety education is the change in behavior of the operator. Observing him as he operates a tractor will determine the extent to which he places himself or others in hazardous situations.

The final evaluation will be in the operator's ability to keep from being injured or killed.

EFFECTIVE TRACTOR SAFETY EDUCATION WILL CONTRIBUTE TO THE DESIRE AND ABILITY OF THE OPERATOR TO PROTECT HIMSELF AND OTHERS WITHIN HIS RESPONSIBILITY (8, p. 32)

Most times the student will provide from within himself the need to protect his well-being. An exception would be in the event of extreme emotion. If the operator is comfortable with himself, lacking hostility, he will tend to be careful of others near the tractor he is operating. Hostility, conscious or unconscious, may lead to a form of carelessness. The safe operator is democratic in that he will not violate the safety of others.

THE PHYSICAL AND SOCIAL NEEDS OF THE OPERATOR MUST BE COMPENSATED FOR IN HIS EDUCATION.

The feelings of the operator toward safety will determine his attitude toward it (33, p. 3). Therefore, the more subtle feelings of the operator are of great significance. The teacher cannot control established attitudes, but he can recognize them sufficiently to deal with them. Of great importance also are the feelings incurred in the student operator during safety

instruction. An attempt on the part of the teacher to impart safety rules by memorization may be of little value and may possibly be harmful due to developing a negative attitude in the student.

The experience and goals of the teacher will in most cases differ from those of the student. Therefore, their needs may differ. Unless the student feels a personal need for safe behavior, it will not be observed. Safety education must be built on more than informing the operator of what should be done. Safety education must be built upon a foundation based on the operator's goals. It is these goals which will provide motivation. Motivations of special value in safety education are self preservation, personal gain or reward, group membership or loyalty, responsibility, pride, rivalry, leadership. Affection from those who are important to the individual or social approval; a sense of belonging to the group he is with; to know what is going on and why things are done the way they are are psychological needs which provide the teacher with a clue to motivation.

TRAINING IN DECISION-MAKING IS AN IMPORTANT PART OF TRACTOR SAFETY EDUCATION.

Tractor safety education must include training in

making adequate decisions. The student operator must be given an opportunity to consider all conditions and arrive at an adequate decision based on his goals (8, p. 35). He must learn to anticipate the results of his actions as well as to understand his motivations for a particular choice. He probably knows that the slogan "Safety First" is not always appropriate to the situation. The operator must learn to consider the risks involved in light of the advantages of the various choices and to make his decision accordingly. This need not endanger the liability of the instructor in his responsibility for students under his instruction. He may restrict the student from operating a tractor, explaining his reason for doing so in terms of the hazards the student is creating.

TRACTOR SAFETY INSTRUCTION IS BASED UPON PRINCIPLES AND LAWS OF LEARNING. (22, p. 5-16, 5-17, 5-18)

The laws of learning provide focal points of application of the preceding information. Information is better understood when application is emphasized.

Reinforcement Reward

When learning is reinforced by reward, such as allowing only those students to operate the school's

tractor who have shown proficiency, it is more efficient, sure, and complete.

Knowledge of Results

Letting the operator find out as he performs various operations the appropriateness of his procedures will help him to analyze it while fresh in mind.

Practice

To develop safe habit patterns the operator will need to practice until routine skills become automatic. He will need to continue practice to maintain proficiency.

Whole vs. Part Learning

Whether procedures should be taught as a whole may depend upon complexity and length of the procedure. Generally, a combination of whole vs. part is best, using the whole method, but with sufficient flexibility to emphasize meaningful parts of the task wherever necessary. Stopping, starting, and steering procedures, for example, would be emphasized as parts of the whole.

Meaningfulness

Meaningfulness is an important aid to motivation,

for it indicates why an operation may more safely be done in a particular way.

Selective Learning

Out of a day's experiences those safety practices which relate most directly to the operator's needs will be most readily retained.

Frequency

The more frequently a safe procedure is performed, the more ingrained it will become.

Recency

Generally, those procedures, especially the more automatic ones, most recently learned are the ones most easily recalled.

Primacy

Attitudes and procedures formed initially will tend to persist. Thus, learning a procedure correctly initially will eliminate the need for more strenous relearning.

Intensity

Those experiences which are most vivid to the

operator will be retained the longest.

The teacher has the additional responsibility in understanding what can be done to enhance instruction. The following two principles illustrate this aspect.

INSPECTION AND MAINTENANCE IS AN IMPORTANT ASPECT OF TRACTOR OPERATOR INSTRUCTION.

A properly maintained tractor is least likely to cause injury because of breakdown. While not all mechanical failures can be anticipated, brakes, steering, and lighting equipment can be inspected, adjusted, and repaired.

SAFETY INSTRUCTION IS MOST EFFECTIVE WHEN MADE AN INTEGRAL PART OF SKILL INSTRUCTION.
(32, p. 38), (4, p. 38)

Safety instruction in itself lacks interest. A unit on safety alone is difficult for students to accept, for it tends to concentrate on hazards and restrictions rather than the more stimulating aspects which the skill tends to provide. Emphasis must be placed on the satisfactions to be obtained from the skill which would be ultimately the goal of the learner. In this context, while teaching the skill, the teacher can then indicate to the learner the possible

hazards which will interfere with satisfaction. Secondly, learning the safe procedure for operating a tractor during initial experiences removes the need for unlearning hazardous practices and provides practical and concrete applications of safety information.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

I. SUMMARY

Tractors are involved in a large portion of farm accidents resulting in deaths, injuries, and a large financial loss. One third of the fatalities occur before 20 years of age, a time approximately concurrent with opportunities for agricultural education. Programs of safety education are carried on to some degree by a majority of the agricultural agencies. This study is an attempt to develop a new approach to a relatively traditional area of subject matter.

The primary problem is that of how the agriculture teacher can be the most meaningful and direct in his safety instruction. The great fragmentation of safety rules suggests the need for identification of underlying understandings.

Therefore, the purpose of the study is the identification of safety principles which will be useful to Oregon high school teachers when teaching tractor operation to freshmen. It is assumed that the application of the principles by the operator would reduce accidents, and when the instructor uses these

principles, teaching will be more effective, efficient, inclusive, and meaningful.

The procedure of the study involves surveying the literature to draw together material with which to develop tentative principles. These principles are then reviewed by experts in psychology, agricultural engineering, teacher training, and agriculture teachers presently teaching in Oregon high schools. The revised results become the findings of this study.

The literature indicates four major areas of consideration in dealing with tractor safety: self understanding, physiological aspects, understanding hazardous tractor situations, and education for safe operation. Self understanding is primarily a psychological approach, and has received emphasis and application relatively recently in safety education. The literature indicates that a safety program which neglects this aspect will be avoiding a major factor in the problem of safe tractor operation.

The physiological aspects of tractor safety reported in the literature involve stress due to vibration, noise, sunlight, illness and general fatigue; reaction time; and strength.

The literature developed to aid in understanding the hazards of tractor operation is segregated into

accident studies, safety rules, and explanations of the forces affecting tractor stability. Tractor accident studies are restricted to the way in which the accident occurred, but almost no studies determine the factors which caused the operator to become involved in the accident. The rules are greatly scattered through many sources, with only one listing being found relatively complete. Literature which aids in the understanding of forces which affect tractor stability is located primarily in agricultural engineering works. The explanations, mainly applications of physics, differ mostly in thoroughness of coverage.

The literature on safety education concerns goals of safety education, educational psychology, recommended inclusions in a course of study, and methods of teaching tractor safety. The goal of safety education is motivation and understanding which will result in the application of protective skills. The psychology of safety education as indicated by the literature is different from general education only in application. A course of study should be related to student problems, emphasize knowledge of construction and understanding of operation, and provide guidance. The literature emphasizes the importance of developing student motivation for safe action and urges that safety instruction

take place as a part of initial learning of a skill.

Fourteen safety principles related to tractor operation and eight principles related to tractor safety education were developed. The safety principles of tractor operation are divided into six psychological and eight physical principles. Therefore, the purpose of the study, the identification of safety principles, was achieved.

The identified psychological principles of safe tractor operation are:

1. Safe tractor operation is based upon the decision-making process controlled primarily by the emotions, limited by adequate knowledge of hazards, and the physiology of the operator primarily in reaction time and strength.

2. Distractions tend to decrease perception of possible hazards and influence the functioning of the decision-making process.

3. The speed of a reaction will increase the operator's ability to avoid an accident, providing the response is appropriate.

4. Environmental factors creating a stressful situation in the operator are a hazard to safe tractor operation.

5. A hazard is created when there is insufficient strength to perform the task or for emergencies.

6. The personal significance of a hazard tends to be reduced with time if an accident does not occur.

The identified physical principles of safe tractor

operation are:

1. Farm tractors operate mechanically in accordance with known physical laws.

2. A tractor's stability is affected by the principle of moments which states: "If a system of forces in one plane acts upon a body and keepsit in equalibrium, the algebraic sum of their moments about any point in the plane is zero."

3. Adequate tractor maintenance is an essential part of safe tractor operation.

4. Moving parts are a hazard which increases with the proximity of the operator to them and may be reduced by shielding or stopping the parts.

5. An unattended tractor is a potential hazard if it can be moved or operated by an incompetent person.

6. Heat, a hazard produced by the exhaust and cooling system, may be reduced by cooling or avoiding contact.

7. To avoid fire, sources of ignition and combustibles must be kept separated.

8. Tractor operation on roadways results in a hazard due to the proportionally greater speed of other traffic in relation to the tractor, and to the additional width and bulkiness of implements and attachments.

The identified educational principles applying to safe tractor operation are:

1. Knowledge is not sufficient to prevent tractor accidents.

2. Safety education will be effective only as it provides experiences which result in the operator's ability to use a tractor without endangering himself or others.

3. Effective tractor safety education will contribute to the desire and ability of the operator to protect himself and others within his responsibility.

4. The physical and social needs of the operator must be compensated for in his education.

5. Training in decision-making is an important part of tractor safety education.

6. Tractor safety instruction is based upon principles and laws of learning.

7. Inspection and maintenance is an important aspect of tractor operator instruction.

8. Safety instruction is most effective when made an integral part of skill instruction.

II. CONCLUSIONS

Three conclusions drawn as a result of this study are:

1. In depth, the principles of tractor safety leave education and go into the pure sciences of psychology, physiology, and physics. Deep understanding of motivations leading to accidents enters into psychology. Physiology is considered when stress is analyzed. The principle of moments is a physics concept.

2. Safety instruction is a complicated process, for it involves many variables. Not only must subject matter be considered, but also the student as an individual and in a group with all influences acting upon him.

3. If safety instruction is to be effective it must be more inclusive than simply the memorization of safety rules. Included must be the development of self understanding of the operator's motivations, attitudes, and limitations. Also, the operator must be able to understand the man-machine-environment relationships.

III. RECOMMENDATIONS

Recommendations to the teacher and for further research are offered.

Recommendations to the Teacher

As a result of this study the following is recommended to a teacher teaching tractor operation.

1. That self understanding, an aspect of safety education, be taught throughout agricultural instruction.

2. That tractor safety be taught as a part of tractor instruction, and that it be followed up all year, because habits and attitudes require time to develop.

3. That the psychological aspects of safety, as well as facts, be stressed.

4. That the physical principles be stressed to develop a basis for understanding the "do's and don'ts" of safety rules.

Recommendations for Further Study

The following recommendations are offered for further study:

1. That a program of instruction be developed which is based on principles illustrated in this study.

2. That the principle concept be expanded to include farm power and machinery in its entirety, rural electrification, shop work, farm buildings and conveniences, and soil and water management, not only in areas of safety, but in all areas where generalizations can be made.

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