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The Development of Agricultural Equipment Power Take-Off Mechanism

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SAE 800943

THIS PAPER REFERS to present SAE Standards and Recommended Practices, and it reviews some early power take-off applications, developments leading to our present standards, some more evaluations to be considered and a summary.

Standards are very important to the agricultural industry to provide safety, interchangeability, and reliability at lower cost to the user. Before power take-off standards were attempted, the optimum drive line speed of tractors and power driven implements varied widely. The vertical and horizontal distances between the tractor drawbar hitch point and the tractor output shaft varied widely among all makes. The size of the output shaft varied and drive line dimensions on implements with respect to the drawbar hitch point also varied considerably.

Because of the lack of standards, the farm equipment industry had to provide an estimated 2500 special hook-up packages to match all makes of tractors with all makes of power driven implements. Customer complications can well be imagined:

(a) in selecting proper hook-up for tractor and implement combinations,

(b) in the added cost of many packages to adapt several different makes of implements to one or more makes of tractors, and

(c) in keeping the many packages properly matched to the various tractors and implements.

During the past 30 years, most tractors and implements have been manufactured according to the standards. There is no need to provide special hook-up packages to match these tractors and implements which are according to the standards.

The present SAE Power Take-Off

ABSTRACT

A power take-off mechanism was developed for farm equipment. Its purpose was to transmit power from the tractor engine to the propelled implement. The propelled implement could then perform its functions by utilizing the tractor engine power.

The power take-off (PTO) development has involved a large variety of tractors and implements and has included recommendations and standards for safety, interchangeability, and reliability. This paper outlines some of the important steps in the power take-off evolution from the first known application to present day standards.

The power take-off has provided great versatility in the mechanization of the farm, and this has helped to lower the overall cost of food production.

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Standards and Recommended Practices for farm equipment are:

1. J1170 - SAE Standard (ASAE S203.9) "Rear Power Take-Off for Agricultural Tractors." (J1170 includes both 540 and 1000 RPM PTO standards, formerly J718 and J719). See Appendix "A".

2. J717 - SAE Recommended Practice (ASAE S333.1) "Auxiliary Power Take-Off Drives for Agricultural Tractors." See Appendix "B".

3. J721 - SAE Recommended Practice (ASAE S207.9) "Operating Requirements for Power Take-Off Drives." See Appendix "C".

4. J722 - SAE Recommended Practice (ASAE S205.2) "Power Take-Off Definitions and Terminology for Agricultural Tractors." See Appendix "D".

The American Society of Agricultural Engineers (ASAE) publishes the above standards and recommended practices in its Yearbook. ASAE also publishes some standards which affect only the implements. Implements are not considered within the scope of the Society of Automotive Engineers standards. These additional ASAE standards are:

1. ASAE S331.2 "Implement Power Take-Off Drive Line Specifications." This standard establishes 6 categories of universal joint drive lines with respect to static and dynamic torsional requirements. These 6 categories include a wide range of implements from low to high power requirements. The drive line to the tractor output shaft is the responsibility of the implement manufacturer.

2. ASAE S314 "Implement Power Take-Off and Drive Line Pedestal Shafts." This standard provides specifications for 1 3/8" and 1 3/4" PTO shafts for uniform driving means, retaining means and drive line positioning.

Since the late 1930's, most of the power take-off standards and recommended practices have been proposed by the Farm and Industrial Equipment Institute (Formerly Farm Equipment Institute) Engineering Committees. When these proposals are acceptable and approved, those affecting tractors and implements are published by ASAE in its Yearbook and those affecting tractors are published by SAE in its Handbook.

(Fig. 1) shows a typical power take-off mechanism of the late 1970's which is according to SAE J1170.

Now, let us go back to some early power take-off applications and then follow the important developments to today's PTO's.

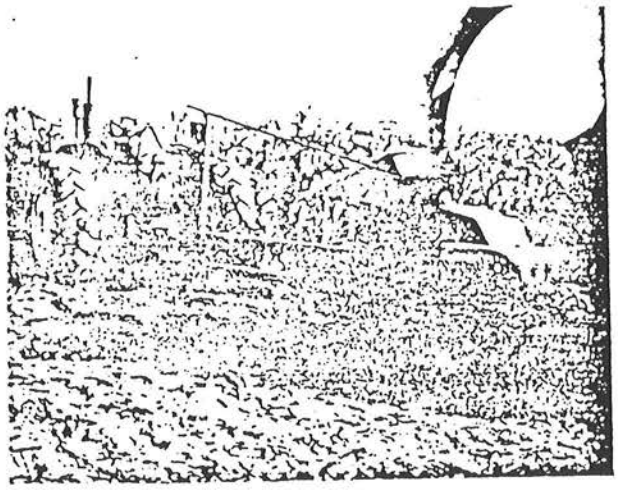


Fig. 1 - Typical application of J1170 PTO standard

EARLY POWER TAKE-OFF APPLICATIONS

(Fig. 2) shows one of the earliest known tractor rear PTO applications in the United States. It was a Jeep-like machine shipped by Renard from England in 1904 around Cape Horn to the West Coast of the United States. It had a power take-off shaft from the tractor to a driving axle on each of three trailers. The ship encountered a storm, and one of the trailers on the ship's top deck was lost at sea. Along with the "20 Mule Team", the tractor and two trailers were used for many years to haul borax from Death Valley.

The beginning of the use of power take-off and the Society of Automotive Engineers was almost simultaneous. Also, we can declare a 75th Annivers-

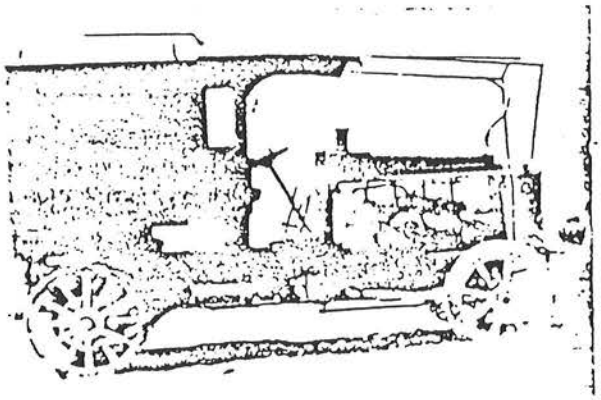


Fig. 2 - Renard tractor - 1904

ary for the power take-off.

In 1918, International Harvester introduced its 8-16 Kerosene tractor which had a power take-off as optional equipment. This was the first known American tractor to offer a practical rear PTO mechanism for propelling trailed implements.

(Fig. 3) shows the IHC 8-16 tractor.

In 1921, International Harvester was the first to provide the rear PTO as standard equipment on its new McCormick-Deering 15-30 tractor.

(Fig. 4) shows the IHC 15-30 tractor.

The PTO became popular in approximately 1923.

In 1928, Hart-Parr advertised the first independent power take-off on its Model 18-36. The 18-36 was tested at Nebraska, October 1926, Report #128.

(Fig. 5) shows the Hart-Parr 18-36. Hart-Parr became a part of a new company, Oliver Farm Equipment Company, in 1929. In 1970, Oliver became a part of White Farm Equipment Company, Division of White Motor Corporation.

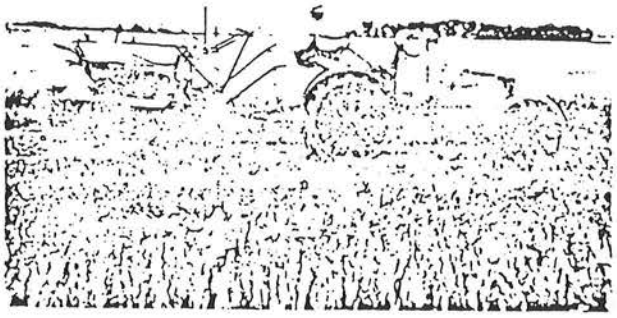


Fig. 3 - International Harvester 8-16 Kerosene tractor

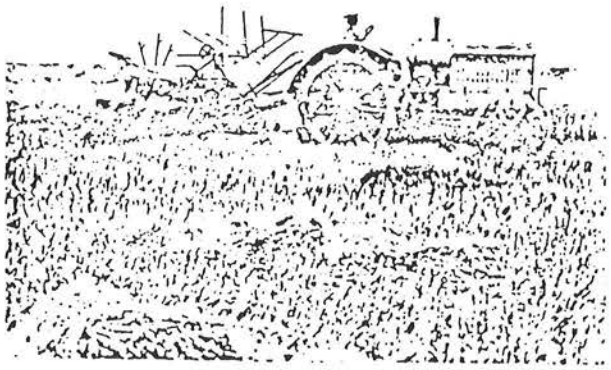


Fig. 4 - McCormick-Deering 15-30 tractor

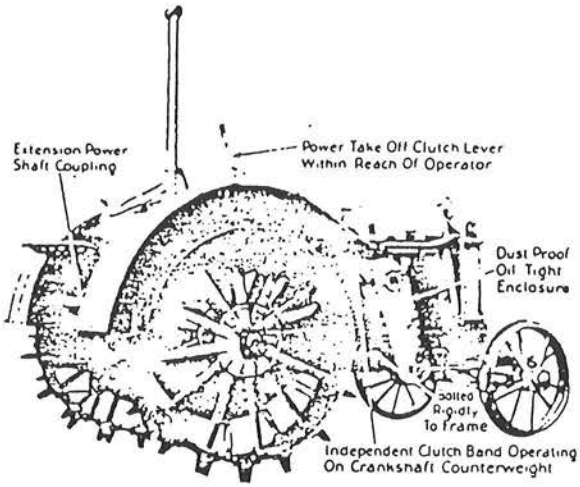


Fig. 5 - Hart-Parr 18-36 tractor

EARLY SAE PTO STANDARDS AND RECOMMENDED PRACTICES

1918 - Tractor drawbar standard height.
"Vol. 1 S. A. E. Data Sheet 55
HEIGHT OF TRACTOR DRAWBAR
S. A. E. Standard

The standard height of drawbar shall be 17 in. for both plowing and other work."

The drawbar is to become related to PTO standard at a later date.

1924 - June - A report from SAE Agricultural Power Equipment Division recommended 536 RPM as standard speed and with clockwise rotation when viewed from the rear.

"Vol. XIV June, 1924 No. 6
TRACTOR POWER TAKE-OFF SPEED

At the meeting of the Agricultural Power Equipment Division in April, the following recommendation was approved:

The normal speed of the power take-off of tractors designed for operating tractor-propelled agricultural implements shall be 536 r.p.m., the rotation to be clockwise when looking in the direction in which the tractor travels.

This recommendation was approved in view of the fact that the power take-off speed used throughout the industry has been practically constant for 30 years, this being determined by the speed of the sickles. It is be-

lieved to be advisable, however, to recognize this standard speed for the future guidance of tractor and implement designers. The Division therefore submits the proposal for adoption as S. A. E. Recommended Practice."

1924 - July - The report was approved for adoption as an SAE Recommended Practice with the addition of the tolerance of ± 20 RPM.

1924 - August - Tractor Power Take-Off Speed Recommended Practice was published.

"Vol. 1 S. A. E. Handbook E53

TRACTOR POWER TAKE-OFF SPEED

S. A. E. Recommended Practice

The normal speed of the power take-off of tractors designed for operating tractor-propelled agricultural implements shall be 536 plus or minus 20 r.p.m., the rotation to be clockwise when looking in the direction in which the tractor travels.

From the report of the Agricultural Power Equipment Division, adopted by the Society July 1924."

1929 - Recommended Practice was revised to include 6B spline, 3" long for 1 1/8" and 1 3/8" shafts.

"176

TRACTOR POWER TAKE-OFF SPEED

S. A. E. Recommended Practice

The power-take-off shaft on the tractor shall be provided with an S.A.E. 6B spline fitting. The straight length at the root of the spline shall be 3 in. Retaining means for securing the fitting shall not project more than 1 in. from the end of the spline.

The normal speed of the power-take-off shaft shall be 536 r.p.m., plus or minus 20, the direction of rotation to be clockwise when facing in the direction the tractor travels.

Two sizes of power-take-off shaft shall be used, as follows:

(1) The 1 1/8-in. splined shaft on tractors with engines developing up to 20 b-hp.

(2) The 1 3/8-in. splined shaft on tractors with engines developing up to 40 b-hp.

These ratings are based on the use of material having a minimum torsional yield-point of 65,000 lb. per sq. in.

From the report of the Agricultural Power Equipment Division, adopted by the Society July 1924. Revised February 1929."

1938 - The PTO Recommended Practice became a standard in January 1938. Also, it was revised to include shaft dimensions, 1 3/4" splined shaft, 3¼" spherical clearance radius, drawbar relationship to output shaft, shielding of drive line and a reference to adaptor parts to hitch implements to standard tractor PTO.

In 1937, the American Society of Agricultural Engineers (ASAE) adopted the PTO Standard but included another shaft size of 1 3/4" diameter and additional data as to the location of PTO shaft with respect to drawbar and other requirements. Since this time, ASAE and SAE have coordinated and published basically the same PTO standards. The complete 1938 Standard is Appendix "E".

This was the first SAE report in the PTO development concerning shielding of the drive line. "The tractor manufacturer shall adequately shield the power take-off shaft and tractor universal joint, and provide protection for the operator against the telescoping member attached thereto, assuming connection between tractor and implement is according to recommended practice."

"The manufacturer of a power take-off driven machine shall furnish the power drive parts up to the tractor spline shaft, the necessary hitch parts to attach to the recommended drawbar location, and all shields, except the one attached to the tractor, covering the spline shaft fitting or universal joint."

"The tractor power take-off drive shall be provided with a throw-out clutch, operating independently of the tractor travel, of a design safe against accidental engagement and with a control located conveniently to the operator."

During the 1920's PTO drive lines were generally unprotected.

(Fig. 6) shows a typical PTO drive line in the 1920's.

During the early 1930's, some inverted "U" tunnel type telescoping

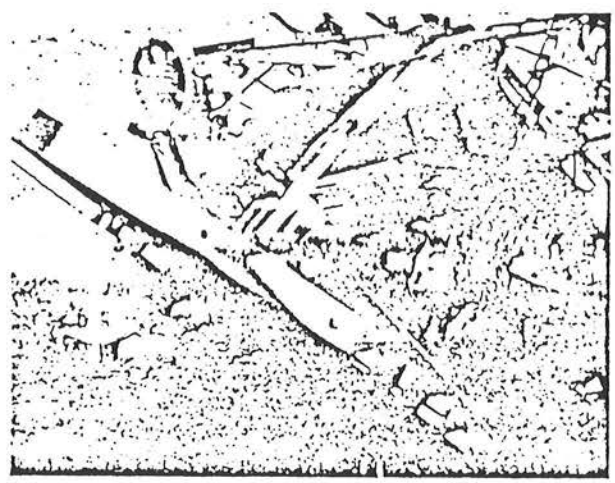


Fig. 6 - PTO shaft on grain binder of 1920's

shields were adopted.

(Fig. 7) shows the tunnel type shields and how they were attached with a latch to a tractor master shield and the implement shield. The tractor master shield was included in the 1946 SAE Handbook printing.

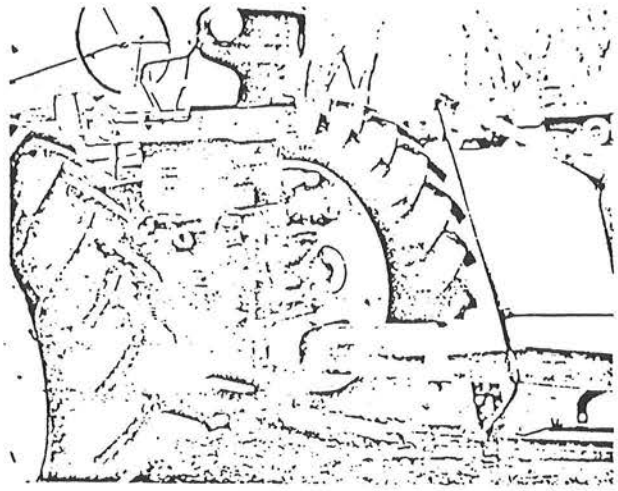


Fig. 7 - Inverted "U" tunnel type shield

IN 1946 - (Fig. 8) shows the revised standard to include views and dimensions of PTO master shield.

(Fig. 9) shows the agricultural tractor drawbar standard which established more precise drawbar and PTO output shaft relationship.

(Fig. 10) shows a drawing of PTO shaft and hub or coupling. Drawings

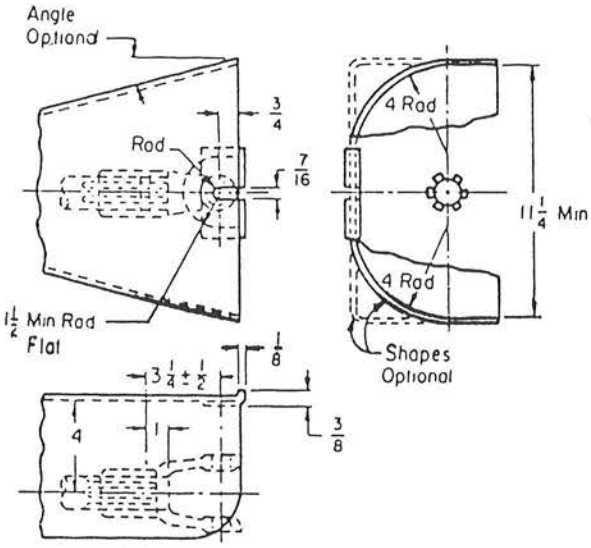


Fig. 8 - Tractor PTO master shield

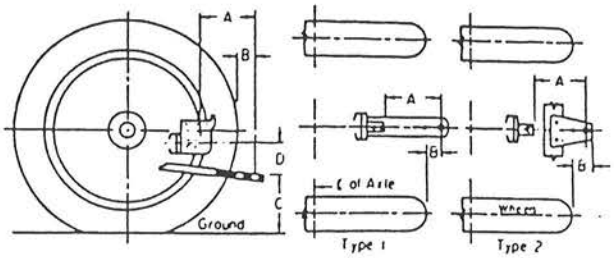


Fig. 9 - Tractor PTO output shaft and drawbar relationship

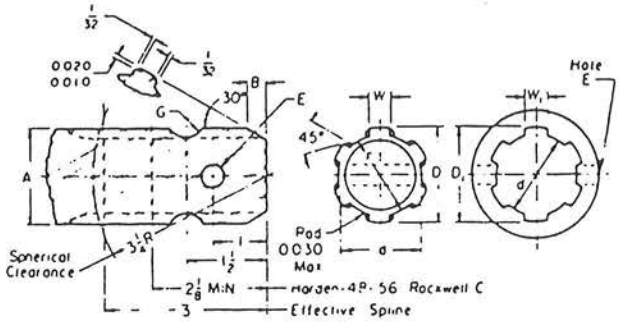


Fig. 10 - Outline drawing of 1 3/8" 6B splined shaft and coupling

of the power take-off and drawbar relationship were included in the drawbar standard. 1 1/8" shaft standard was discontinued. See appendices "F" and "G".

ENGINE POWERED DRAWN EQUIPMENT

By 1946, pull type implements, such as combines and hay balers, were driven by a separate engine on the implement and were pulled behind a tractor. An example is shown in (Fig. 11).

This photo of Allis Chalmers tractor and New Holland baler was taken in approximately 1948.

The reason for the separate engine was to permit stopping and starting of the forward travel without interrupting the power to the implement. When a sudden overload of material to the implement was encountered, it was necessary to stop forward motion so that the overload could be cleared without clogging the implement.

The extra cost and complications of adding an engine to the implement prompted the re-introduction of the independent PTO.

INDEPENDENT POWER TAKE-OFF

The independent PTO provided the

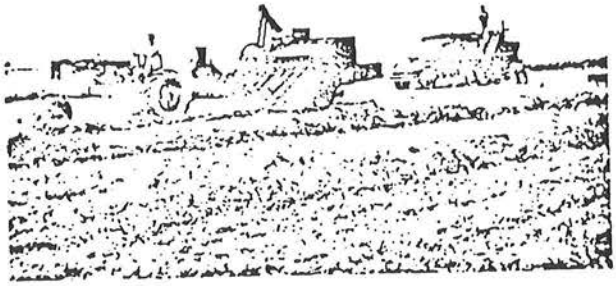


Fig. 11 - Baler with engine to drive its baling mechanism

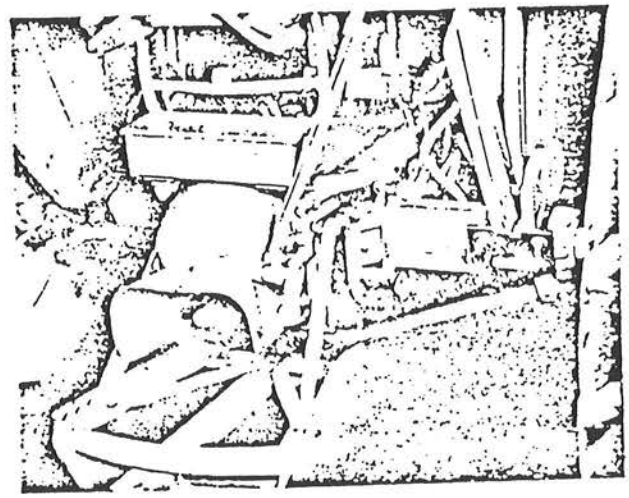


Fig. 12 - Oliver's tractor independent PTO

ability to stop and start the forward motion without interrupting the power to the implement. Thus, the separate engine on most implements was no longer needed.

In approximately 1946, Oliver Corporation and Cockshutt provided their new lines of tractors with independent PTO. Other tractor manufacturers followed suit soon afterwards.

(Fig. 12) shows the general configuration of Oliver's independent PTO.

(Fig. 13) shows a cross section of the Oliver independent PTO and its drive.

FURTHER 540 RPM POWER TAKE-OFF DEVELOPMENTS

In approximately 1950, the standard was changed from 536 ± 10 RPM to 540 ± 10 RPM.

The 540 RPM PTO standard has continued much the same since 1948. There have been some dimensions added, some editorial changes, and some improvements in safety. Some of these developments will be reviewed later in this paper.

In 1953, SAE J721 - SAE Recommended Practice "Operating Requirements for Power Take-Off Drives" was approved. The purpose of this Recommended Practice was to provide guidelines for the design of drive lines between the tractor and the implement. It includes:

a. Instructions to the operator.

b. Implement hitch and power line design requirements.

c. Maximum bending load limitations for power take-off drives employing v-belts and chains.

d. Power line protective couplings and maximum torsional load limitations for power take-off shafts.

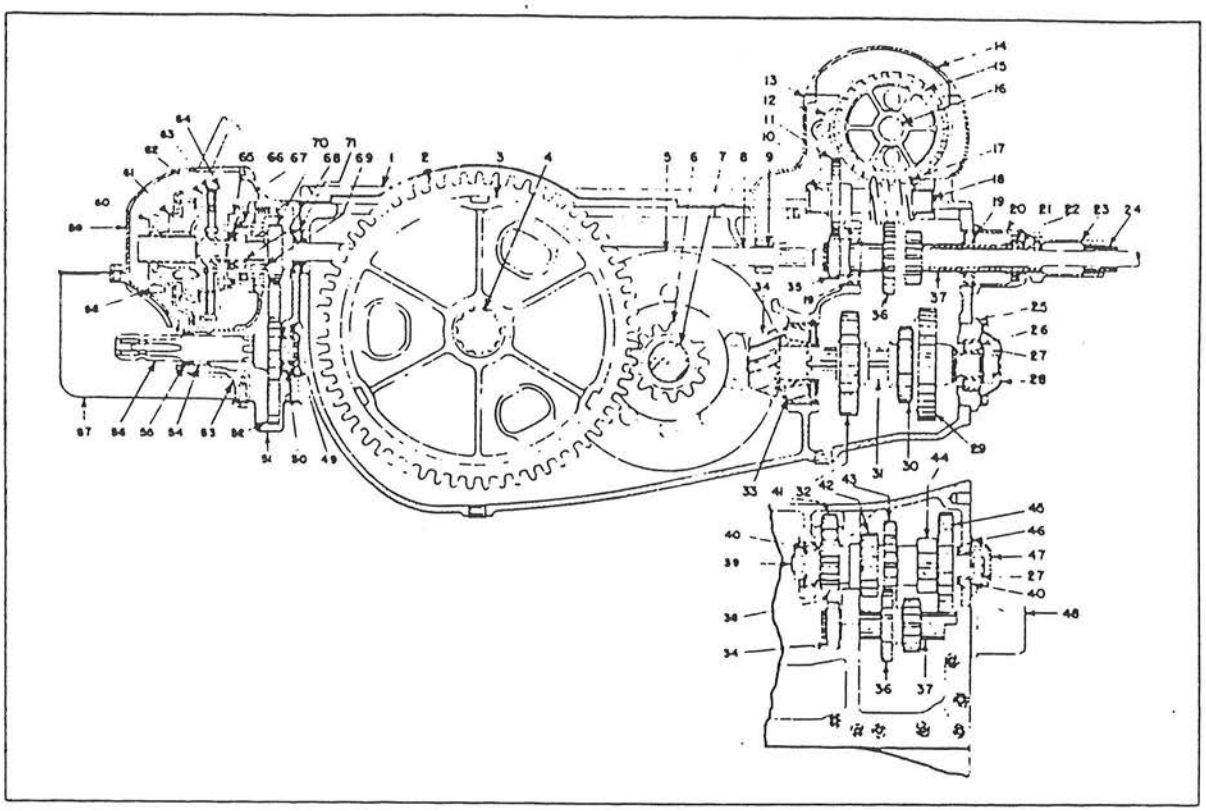
During the late 1940's and early 1950's, many new PTO driven implements, such as mounted corn pickers, became quite common. The drive was often by a sprocket and chain or a belt from the tractor PTO shaft. These applications and the independent PTO caused some new problems. The radial type loading on the tractor PTO shaft was not anticipated early in the development of the PTO standards.

Transmission driven PTO's were normally engaged smoothly through the tractor main clutch. The independent PTO could be engaged quickly without an apparent "jolt" to the operator. Such quick engagement could cause extreme shock loads on PTO mechanism. Radial loaded shafts were often bent from these shock loads. Also, the independent PTO "opened the door" to introduction of high power receiving implements, such as forage harvesters.

The variety of tractor shaft to drawbar vertical relationship and adjustment of the implement pedestal bearing height permitted very poor drive line alignment in field operations. The poor alignment often resulted in early failures of universal joints and other drive line components.

These problems and new PTO driven implement applications prompted the development of J721.

This Recommended Practice has had many editorial changes to keep it up-to-date. One significant change was



1. Platform and Bull Gear Cover
2. Bull Gear
3. Bull Gear Spider
4. Rear Axle
5. Bevel Drive Gear
6. Differential Bull Pinion
7. Differential Spider Shaft
8. Power Take-Off Drive Shaft
9. Power Take-Off Drive Shaft Bushing
10. Power Lift Worm Shaft Bushing
11. Power Lift Drive Gear
12. Power Lift Trip Arm
13. Power Lift Housing
14. Power Lift Housing Cover
15. Power Lift Worm Gear
16. Power Lift Shaft
17. Power Lift Worm
18. Power Lift Worm Shaft
19. Transmission Input Shaft Bearing
20. Input Shaft Front Bearing Retainer
21. Input Shaft Front Bearing Oil Seal
22. Clutch Coupling Spacer
23. Input Shaft Coupling
24. Clutch Shaft
25. Bevel Pinion Shaft Bearing Cage
26. Bevel Pinion Shaft Front Roller Bearing
27. Countershaft Nut
28. Bevel Pinion Shaft Bearing Cage Cover
29. Bevel Pinion Shaft Idler Gear
30. Transmission Sliding Gear
31. Bevel Pinion Shaft
32. Transmission Sliding Gear
33. Bevel Pinion Shaft Rear Roller Bearing
34. Bevel Pinion
35. Power Lift Drive Pinion
36. Transmission Sliding Gear
37. Transmission Input Shaft
38. Reverse Pinion
39. Countershaft
40. Countershaft Roller Bearing
41. Reverse Idler Gear
42. Countershaft Gear
43. Countershaft Gear
44. Countershaft Gear
45. Countershaft Gear
46. Countershaft Bearing Cover Shim
47. Countershaft Bearing Cover
48. Shifter Rod End Cover
49. Power Take-Off Front Bearing Cover
50. Power Take-Off Front Bearing
51. Power Take-Off Lower Cover
52. Power Take-Off Gear
53. Power Take-Off Housing
54. Power Take-Off Rear Bearing
55. Power Take-Off Shaft Oil Seal
56. Power Take-Off Shaft
57. Power Take-Off Shield
58. Power Take-Off Clutch Release Fork
59. Power Take-Off Cover
60. Power Take-Off Clutch Release Bearing
61. Power Take-Off Clutch Washer Plate
62. Power Take-Off Clutch Pressure Plate
63. Power Take-Off Drive Plate
64. Power Take-Off Clutch Housing
65. Power Take-Off Clutch Mounting Sleeve
66. Power Take-Off Drive Shaft Oil Seal
67. Power Take-Off Clutch Mounting Sleeve Oil Seal
68. Power Take-Off Clutch Mounting Sleeve Rear Bearing
69. Power Take-Off Front Bearing
70. Power Take-Off Pinion
71. Power Take-Off Drive Shaft Bearing

Fig. 13 - Cross section of Oliver's tractor transmission, differential, final drive and independent PTO

the addition of a table showing vertical drawbar load limitations with various size classes of tractors. See Appendix "C".

In 1954, SAE J722 - Recommended Practice "Power Take-Off Definitions and Terminology for Agricultural Tractors" was approved. This Recommended Practice defines the various types of power take-off including:

a. Clutch, master
b. Power take-off, tranmsission driven
c. Power take-off, continuous running
d. Power take-off, independent

It establishes a uniform terminology within the industry for the various types of PTO's. See Appendix "D".

In 1955, J717 - SAE Recommended Practice "Agricultural Tractor Auxiliary Power Take-Off Drives" was approved. The purpose of this Recommended Practice was to establish speed, shaft dimensions, and direction of rotation for mid and side PTO's. There was some interest in auxiliary mid, right and left side, tractor power outlets. This Recommended Practice provided guidelines to avoid future problems, such as non-interchangeability.

This Recommended Practice has remained much the same except for editorial changes to keep it up-to-date and to add location information and shielding recommendations. See Appendix "B".

In 1958, the integral rotating power take-off drive line shield was proposed.

(Fig. 14) shows the integral rotating shield. It was accepted and put into general use in early 1960's. The 1 3/4" shaft changed from 1 3/4" 6 B spline to 27 teeth 16/32 diametral pitch involute spline.

The tunnel inverted "U" type shield, shown in (Fig. 7), was not a good answer. It got bent easily if a rear tire interfered with it on turns. Any dents or rust caused problems to telescope the shield and to connect it to the tractor master shield. Such malfunction and other reasons prompted the user to remove the shield and never re-install it. The farm equipment industry recognized the hazards and the problems when the shield was omitted. During the late 1940's and early 1950's, some companies started to provide an assembly whereby the shield was journaled on the telescoping drive line shaft. The telescoping shield had a smooth outer surface. The shield could be held while the shaft inside

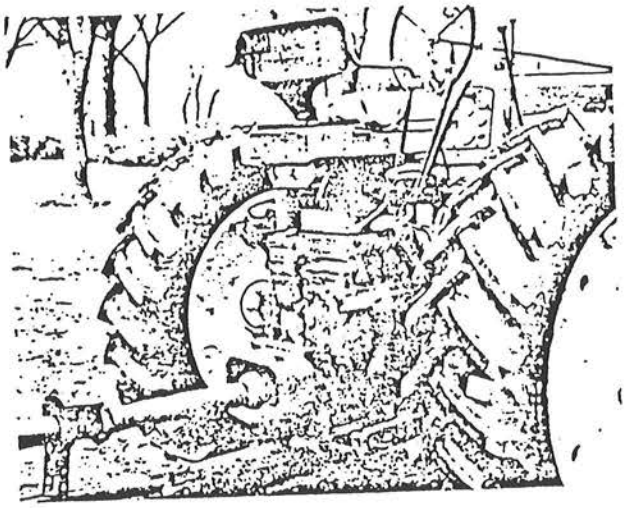


Fig. 14 - Integral rotating shield on PTO telescoping drive line

was turning. It had the advantage that it was a part of the PTO telescoping drive shaft assembly and was not easily removed. This afforded much better long term protection for the user.

Other means of shielding the drive line have been considered, such as a fully shielded assembly, which was used for a period of time by some and has been discontinued for reliability reasons. This was SAE J955 Recommended Practice "Full Shielding of Power Drive Lines for Agricultural Implements and Tractors". SAE J955 (ASAE S297T) was cancelled in approximately 1974. See Appendix "H".

1000 RPM POWER TAKE-OFF DEVELOPMENT

By the early 1950's, it became apparent that tractors would continue to become more powerful and exceed the capacity of the 540 RPM standard.

The Farm Equipment Institute (now Farm and Industrial Equipment Institute - FIEI) Power Take-Off Sub-Committee was assigned the task of studying and proposing an additional standard. Their proposal included 1000 RPM PTO with 1 3/8" involute spline.

In April 1957, Oliver Corporation, Charles City, Iowa, was host to the FEI PTO Sub-Committee. Special Oliver tractors were prepared to check-out drive lines for tractor and implement relationships of proposed 1000 RPM power take-off.

(Fig. 15) shows the special tractor adaptation.

The front wheels of an Oliver row-crop tractor were removed. In place

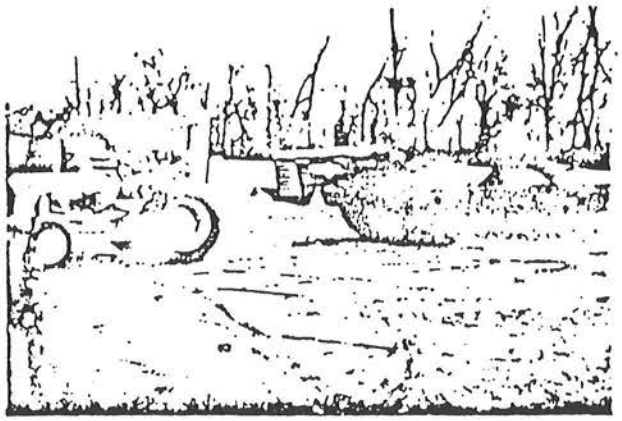


Fig. 15 - Special tractor combination for studying PTO's

of the front wheels, a special adaptor was attached to tractor front frame and to the forks of a fork lift tractor. The purpose of this special arrangement was to provide a means of simulating a tractor and PTO driven implement negotiating ditches and rough terrain and while turning. With respect to the level ground, the tractor front end could be lowered approximately 17° before the front adaptor touched the ground. The tractor front end could be elevated approximately 20 to 24° before the standard 15" high drawbar and implement hitch touched the ground. A protractor mounted on the side of the tractor provided quick readings of the tractor's vertical incline.

(Fig. 16) shows how the tractor was angled with respect to the implement. When in the inclined and turned positions, they simulated extreme operating conditions. This set-up permitted much to be learned with regard to drive shaft telescoping capabilities and universal joint applications.

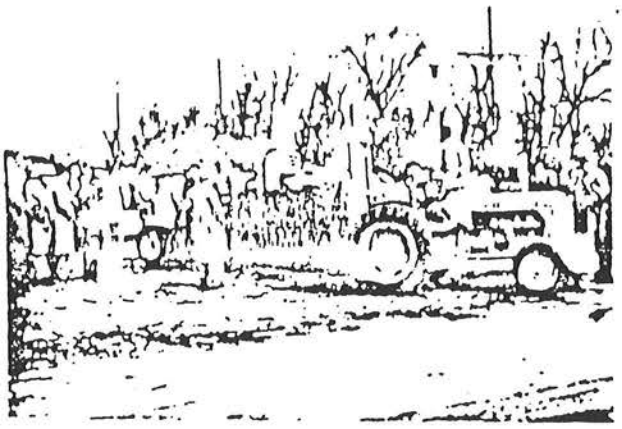


Fig. 16 - Study of PTO drive line while turning and tractor front end elevated

These tests indicated that the 540 RPM standard of 14" horizontal distance between drawbar hitch point and tractor output shaft and 14" horizontal distance from hitch point to implement power shaft did not permit operation over extreme rough terrain. The telescoping shaft could bottom on a short coupled tractor and implement combination when the front end of the tractor was inclined upward approximately 15° and during a sharp turn. The telescoping shaft could almost separate on a short coupled tractor and implement combination when tractor was straight ahead and tractor front end inclined downward approximately 17°.

The 1000 RPM PTO drive line at 14" horizontal distance from tractor PTO output shaft to hitch point and during sharp turns vibrated more than the 540 RPM PTO drive line. Further studies were conducted using 16" and 18" horizontal distances. A 16" horizontal dimension from the tractor output shaft to the drawbar hitch point provided much better telescoping under these extreme conditions. The 16" horizontal dimension was established for the 1 3/8" involute splined shaft at 1000 RPM.

Tractor front end stability, clearance with rear tires during turns, weight of implement tongues on tractor drawbar and many others were considerations to limit how far the drawbar hitch point could be located rearward of the tractor.

Another interesting situation occurred during this special set-up. When a standard drawbar was hitched to a standard implement clevis and a recommended hitch pin size was used, the pin would bend when the tractor front end was inclined approximately 5°. In order to provide the flexibility for the tractor and implement evaluation, a special drawbar with 3 point hitch ball was prepared and used for the demonstrations.

In August 1957, a field demonstration was planned near Morton, Illinois, to test and demonstrate the 1000 RPM PTO units from various companies.

(Fig. 17) shows a typical field demonstration of 1000 RPM PTO.

The demonstration consisted of tractors from most companies and implements which were representative of various types from small and short coupled as shown in (Fig. 18) to long coupled units as shown in (Fig. 17).

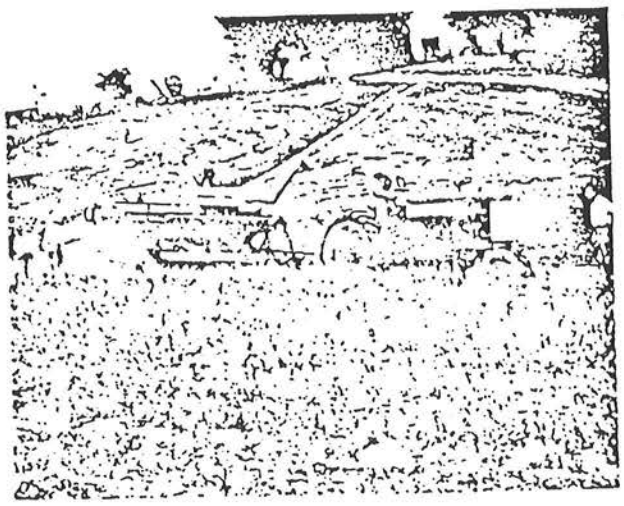


Fig. 17 - 1000 RPM PTO field evaluation

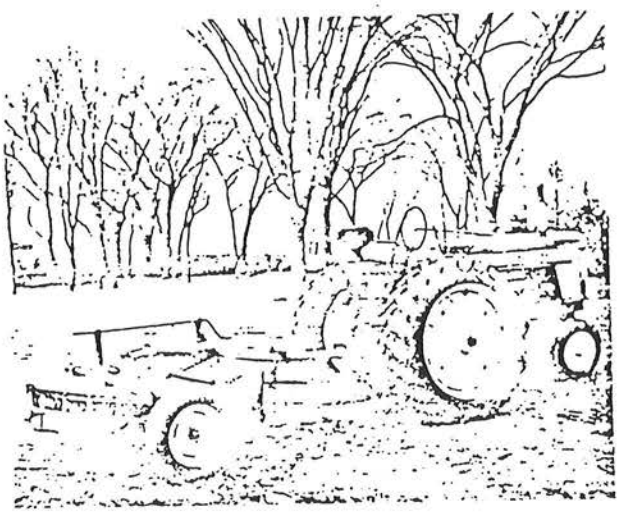


Fig. 18 - Typical short coupled tractor and PTO driven implement

These tractors and implements were equipped with the company's proposed 1000 RPM PTO. The designs were generally refined, based upon what was learned in April 1957, at Charles City, Iowa. The designs were further refined based upon the results of the field review and tests at Morton, Illinois, in August 1957. Additional 1000 RPM PTO standards review meetings were conducted during 1957.

In April 1958, the SAE Tractor Technical Committee approved the 1000 RPM PTO Standard J719 - with 1 3/8" dia. 21 teeth, 16/32 diametral pitch involute splined shaft.

The industry wide participation in the 1000 RPM PTO evaluations revealed many other considerations to provide an effective future Power Take-Off program.

OTHER CONSIDERATIONS

EXCESSIVE PTO SPEEDS - During the 1950's, tractor engine speeds were increased. The overall configuration of some tractors did not permit a greater reduction to the PTO output shaft. The engine governed speed for drawbar work was higher than the engine speed to drive the PTO implement.

A survey was conducted and it was learned that some early implements would be subject to failure and safety hazards if over speeded. In June 1959, this subject was reviewed and later an editorial change was approved. J1170 paragraphs 2.4 and 2.5 limit the over speeding of 540 and 1000 RPM PTO driven implements. See Appendix "A".

The non interchangeable spline and adequate decals were means of greatly reducing the possibility of propelling a 540 RPM implement at 1000 RPM.

CONVERSION OF TRACTORS AND IMPLEMENTS FROM 540 to 1000 RPM PTO'S - Each company was responsible for providing information to the field on tractors and implements that could be converted from 540 to 1000 and 1000 to 540 RPM PTO.

LOW FRICTION TELESCOPING DRIVE LINE - High power receiving implements, such as roto tillers and field silage harvesters, experienced early drive line failures caused by high end thrust when operated at continuous full power over rough terrain and during sharp turns. Some experimental ball recirculating telescoping drive lines which were tested in 1958 solved the problem. This experience led to the recommendation to provide low friction telescoping drive lines for implements capable of utilizing continuous torque in excess of 3000 lb. in. (34.6 kg-m). The low friction telescoping drive shaft is to be incapable of transmitting an axial thrust in excess of 1500 lbs. (680 kg). See SAE J721 Appendix "C".

Some tests indicated that at 50 HP, statically, it took 19,000 lbs. end thrust to telescope a conventional square shaft assembly. A ball recirculating shaft assembly only required 420 lbs. Also, the ball recirculating telescoping drive shaft was quieter and had much less vibration during sharp turns.

IMPROVED DRAWBAR HITCH POINT FASTENING - A simple drawbar ball hitch and some proposals for fast hitching were reviewed in 1958. The intent of

these proposals was to provide more flexibility to avoid binding and bending of the hitch pin. None of these appeared too satisfactory in view of the millions of PTO implements, in customer's hands, which would cause hitching problems if these proposals were adopted.

IMPROVED FASTENING OF FORWARD UNIVERSAL JOINT TO TRACTOR PTO SHAFT - Considerable early failures of retaining pins on universal joints were reported in 1958. Most of these were caused by excessive end thrust on the drive line from operating over rough terrain and under load on sharp turns. Several experimental attempts were made to solve this problem through a different attaching means. None of these appeared to solve the problem.

PTO TELESCOPING DRIVE SHAFT ASSEMBLY STANDARD - An attempt was made, starting in 1959, to provide a standardized ball recirculating telescoping shaft assembly. The objectives were to solve many types of drive line failures and to provide an economical assembly. One of the objections to the ball recirculating type was its high cost. If a standard telescoping drive line could be provided, then instead of having a telescoping shaft assembly on each implement, one low friction telescoping shaft could be provided for several implements for any one tractor.

This proposal was dropped because of interchangeability problems with implement drive lines on millions of implements already in the hands of customers.

IMPROVED SHIELDING OF FORWARD UNIVERSAL JOINT - Since the 1920's, there has been a continuous effort to improve the drive line shielding. In 1959, many ideas were proposed. Some experimental ones were made and tested. These considerations resulted in the Recommended Practice SAE J955 "Full Shielding of Power Drive Lines for Agricultural Implements and Tractors" approved in 1966 and was discontinued in approximately 1974.

GROUND SPEED PTO FOR IMPLEMENTS AND TRACTORS - There were considerable discussions about providing a ground speed PTO for rakes, seeders, planters, fertilizers, etc. This requirement was primarily for European countries and was being considered for an International Standards Organization (ISO) standard. The proposal was for 19½" ± 1" for each ground speed PTO revolution.

This subject was tabled for lack of interest by United States industry and customers.

OTHERS - In 1967, 1 3/4" dia. 20 teeth, 12/24 diametral pitch was approved for 1000 RPM PTO.

In 1978, the 540 RPM SAE Standard J718 and the 1000 RPM SAE Standard J719 were combined into the new J1170 Standard.

J1170 included the addition of a larger tractor master shield for the 1 3/4" 1000 RPM PTO shaft. A larger shield is necessary for clearance with the larger universal joints needed for drive lines transmitting power in excess of 100 HP.

Also, J1170 refers to J208 SAE Standard (ASAE S318) "Safety for Agricultural Equipment". The reference is in regard to safety when tractor master shield is omitted for any reason. See Appendix "I".

In 1980, there is now some concern about unequal angles of universal joints during sharp turns. Some designs for 1 3/8" 1000 RPM drive line have a horizontal dimension from tractor PTO shaft to drawbar hitch point of 16" and from drawbar hitch point to implement shaft of 18" or more. These unequal angles cause excessive vibration during sharp turns and particularly if there is end thrust on the drive line.

SOME INDUSTRY EVALUATIONS TO BE CONSIDERED

GROWTH OF TRACTOR SIZE AND POWER - Tractors and implements have grown in size at a rapid pace since the late 1950's. To keep up with effective standards has been a major task and has required continuous committee efforts. These efforts must continue as long as there is growth.

The 540 RPM standard is capable of transmitting an approximate maximum of 50 PTO horsepower continuously.

The 1000 RPM 1 3/8 involute shaft standard is capable of transmitting an approximate maximum of 100 PTO horsepower continuously.

The 1000 RPM 1 3/4 involute shaft standard is capable of transmitting an approximate maximum of 200 PTO horsepower continuously.

MATCHING OF TRACTORS AND IMPLEMENTS - The matching of large tractors to small power requirement implements, such as a mower equipped with 540 RPM capability, can be a serious problem. The other extreme, such as small tractors to forage harvesters, can also be a problem.

Careful instructions and non-interchangeable drives assist in proper match of PTO speeds. There was an estimated quantity of 4 million 540 RPM

PTO driven implements in the hands of U. S. customers when the 1000 RPM PTO standard was approved.

END THRUST ON DRIVE LINE DURING TURNS UNDER FULL POWER - Excessive end thrust on the drive line can occur on some tractor and implement combinations. An example is a field silage harvester which can absorb full power of the tractor while turning. Excessive end thrusts and early drive line component failures can result if such a combination is not equipped with a low friction telescoping drive line. The conventional square shaft and square tube tends to lock up and not telescope when submitted to continuous high torque load. A very high percent of field failures of PTO universal joints, drive lines, etc. are caused by excessive end thrust.

DRAWBAR HITCHES FOR TRACTOR AND IMPLEMENTS - Many different designs have been considered which would improve the drawbar hitches. The present standard lacks flexibility for negotiating rough terrain with short coupled implements. The hitch pin tends to bind and bend. Also, one man hitching is often difficult to accomplish.

SUMMARY

During the last 75 years, the application, safety, versatility, capability and quality of power take-off drives have improved continuously. The PTO has resulted in one of the greatest practical innovations on farm equipment.

The committees who have worked diligently to keep up with the evolution of farm equipment PTO applications are to be complimented. The history of PTO standards and recommended practices indicate the efforts required to effect safety, interchangeability and reliability in a field which is rather complex. These efforts will need to continue as long as there is growth in power of tractors and size of implements and wider scope of applications. There is still much to be considered.

No doubt, the cost of food production is greatly reduced through the use of the versatile PTO Drives.

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