THE AGRICULTURAL ENGINEER

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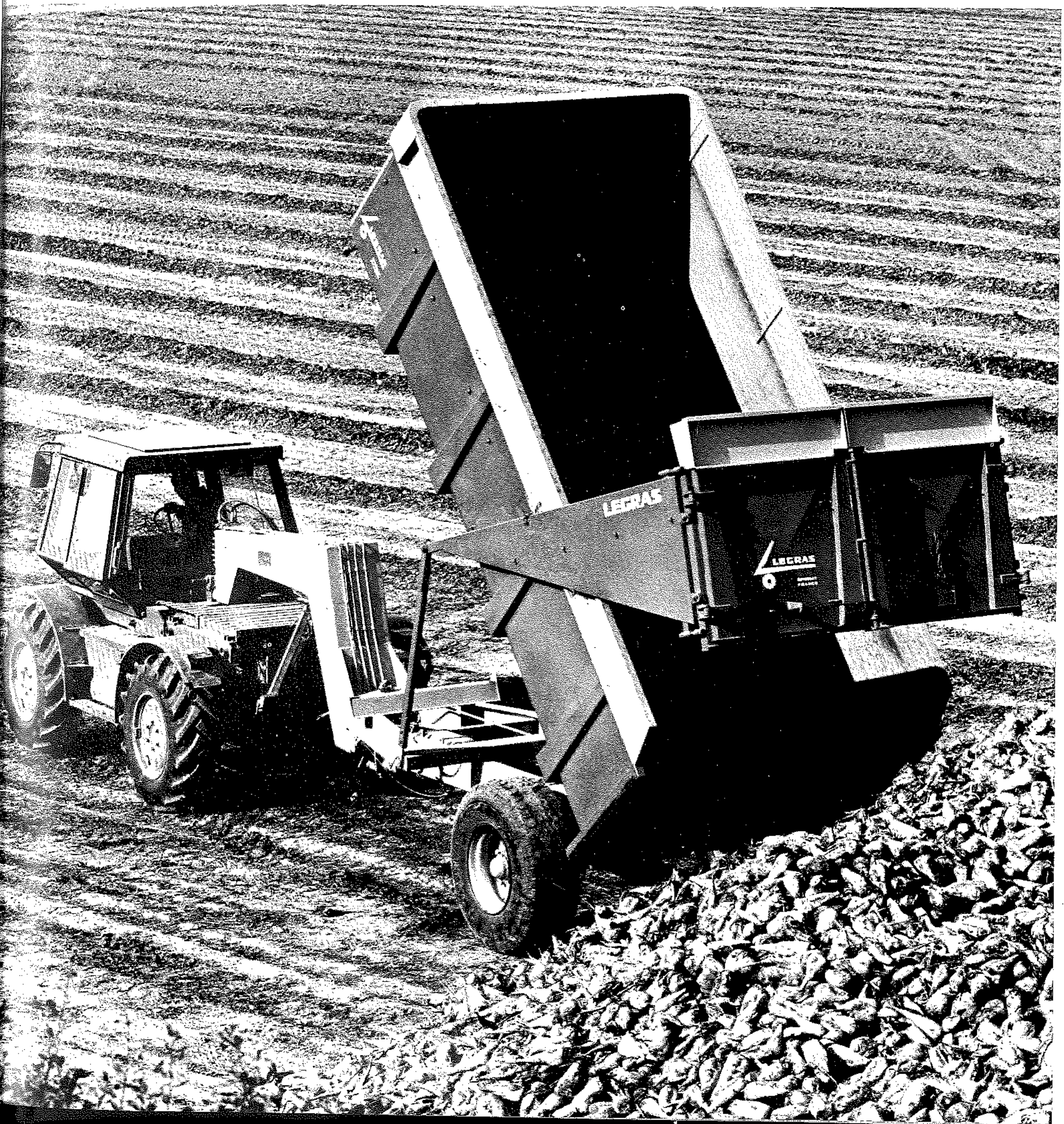
Autumn 1974 No 3



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Front cover: Intrac 2005 with platform mounted trailer (page 72).

Developments in tractor design and application

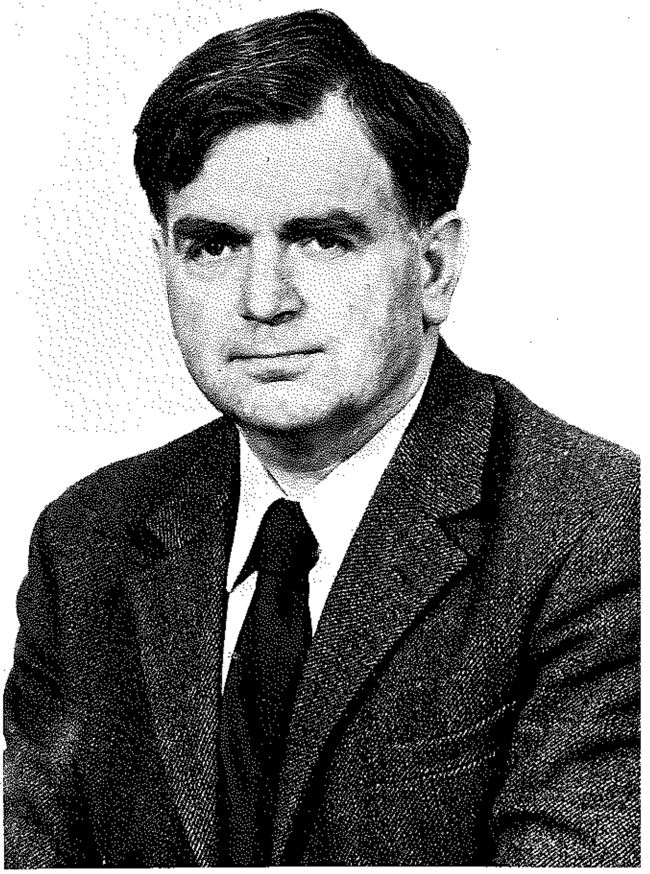
by F M Inns

WHAT progress has been made in the course of the last decade in tractor design, selection and usage? What are the prospects for the future? In the time available these questions could only be touched on at the Institution's recent annual conference; nevertheless the authors of the four papers presented were able to indicate the answers to some of these questions. The general trend in European agriculture for many years has been towards increasing the productivity of farm labour by providing the individual farm worker with more and more power. The steady rise in average tractor power confirms this trend, yet the proportion of the total installed power which is actually used, even on heavy draught operations, tends to be less as available power increases. It has been established that in many cases noise and vibration affect the operator to the extent that they limit performance. During the last few years hydrostatic drives, automatic and semi-automatic gearboxes and quick-attachment implement couplings have all achieved production and been available in the market, but have been slow to find acceptance. The cost has appeared to be high, but is it unacceptable?

Thirty years ago automatic control of the implement by draught regulation had already been widely welcomed and is now universally accepted. The full significance of this advance, resulting in an automatic control system which fully replaced one of the primary functions of the operator, has perhaps never been fully appreciated. In the intervening time what other operator functions have been replaced by automatic control systems?

Machine selection and usage are less tangible considerations than technical features of design but the disadvantages accruing from faulty decisions are perhaps even more far-reaching. Sophisticated selection procedures are feasible, through appropriately programmed computers, provided that the necessary input factors are available and reliably defined. Yet, once again, the availability of this service to the consumer may be questioned and the costs appear high.

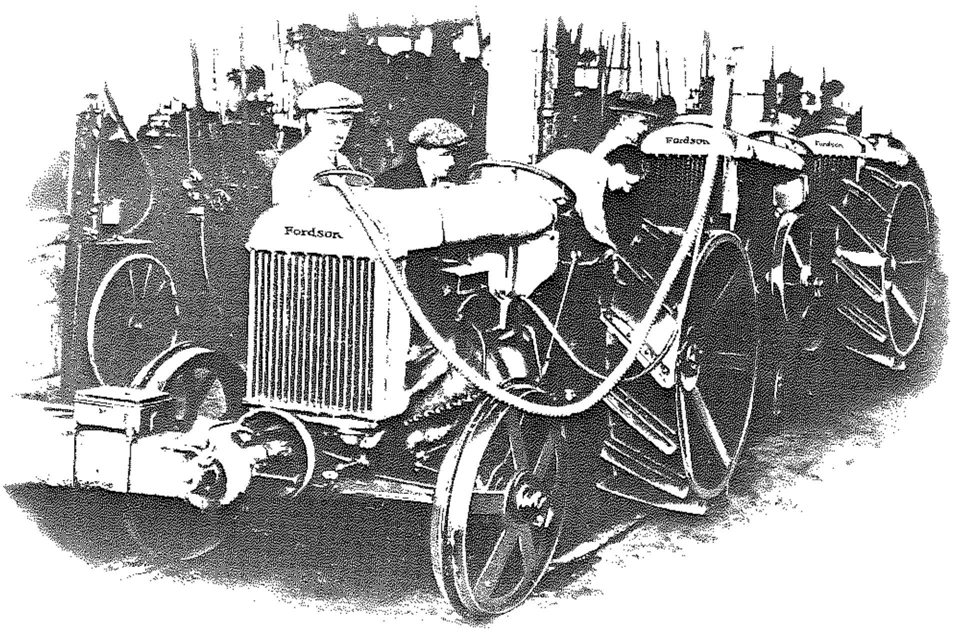
In the past decade agricultural engineers engaged in research and development have been active in the areas briefly mentioned above. Research into tractive performance by agricultural engineers has contributed to the design of the manned Lunar Roving Vehicle. Operator safety, comfort and performance have received considerable attention and the importance of these factors is now widely appreciated. The fundamental interaction between the implement and the soil is much better understood and the design of some implements has benefited. Problems of implement attachment and control have also received considerable attention.



What factors, then, inhibit the introduction of new technical features and new operational methods to the extent that, apart from the rise in size and power, today's tractor is little different from that of a decade ago? The investment in design and development, and in setting up new production equipment, is daunting indeed if very large scale production is to be achieved with resulting low prices. The costs of a change in production model are enormous and the manufacturer of an advanced or unconventional concept is in an exposed marketing situation. It may also be argued that regulations and standardisation serve to consolidate existing design and practice and allow of only slow evolution.

If it were possible to circumvent these inhibiting factors in producing a range of tractors for the next decade would the range reflect the slow evolution of the tractor over the last decade? Or is it possible for the present steady development to accelerate and achieve a worthwhile quantum jump into a new tractor concept?

F. M. Inns joined The National College of Agricultural Engineering when it was set up in 1962, and is now Senior Tutor. His experience in tractor application (in Nigeria) and tractor design (with Harry Ferguson Research Ltd.) is reflected in his continuing involvement in these problems.



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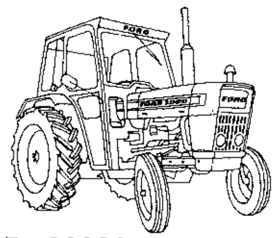

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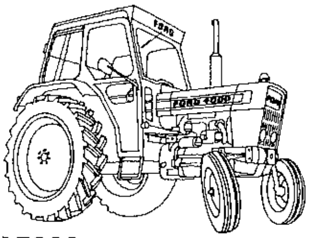

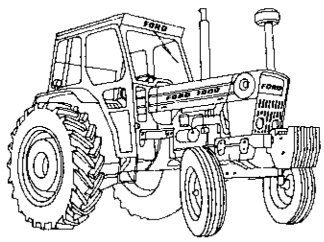

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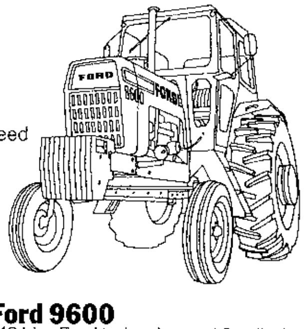

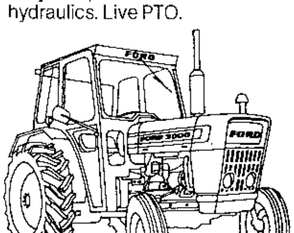

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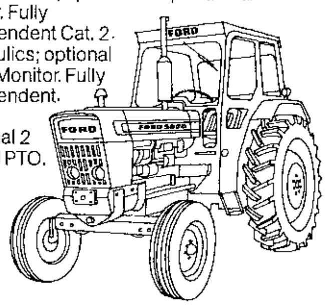

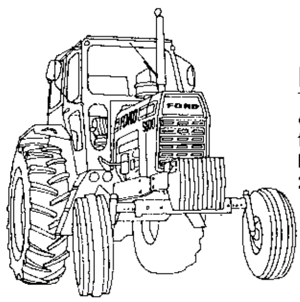

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Implement coupling and control

by M J Dwyer MSc PhD CEng MIMechE MIAgrE

Summary

THE maximum drawbar power of conventional two-wheel drive tractors which can be operated at maximum tractive efficiency with tillage implements at speeds below 2 m/s (4.5 mile/h) is 40 to 50 kW (54 to 67 hp). This limit is imposed by the difficulty of adding sufficient ballast to achieve maximum efficiency while retaining adequate steering stability. Efficiency may be retained with higher power by increasing speed but this is likely to be limited by the difficulty of retaining adequate draught or depth control. The maximum gross weight of trailers which can be effectively operated with conventional two-wheel drive tractors is 5 to 10 tonnes. This limit is imposed by the need to retain sufficient proportion of the total weight on the driven wheels. Trailers and trailed machines are likely to require more sophisticated braking and lighting equipment to conform with future regulations. Although the conventional two-wheel drive tractor is likely to remain as the most common type of tractor for the foreseeable future, it is likely that there will be an increasing market for more efficient specialised machines.

Introduction

The various forms of coupling used between tractors, implements, machines and trailers are discussed below with some indications of their limitations and suggestions for future developments, particularly in the light of the likely continuing increase in tractor horsepower.

These couplings may be classified as follows according to their function:

(i) Force transmission eg drawbars, three-point linkage, hook hitch
(ii) power transmission, eg power take-off (pto), hydraulic hoses
(iii) implement control eg top or lower link sensing elements, hydraulic lift, hydraulic rams
(iv) braking eg over-run mechanism, hydraulic or pneumatic hoses
(v) electrical connections

Force transmission

Three point linkage

The most important coupling between a tractor and implement as far as the tractor designer is concerned is the three-point linkage.

There are obviously very close relationships between tractor horsepower, working speed, soil resistance, implement width and weight and tractor hydraulic lift capacity. All designers are constrained by these relationships and inevitably the result has been a standard layout for the conventional two-wheel drive tractor. National and international standards have facilitated the interchangeability of implements and tractors manufactured by different companies in different countries eg ISO/R730 and British Standard 1495:1970.

The required hydraulic lift capacity of a tractor may be assessed as follows.

When a tractor is engaged on heavy cultivations the power available to pull the implement is typically 65% of the power transmitted to the rear axle, the remaining 35% being lost in slip and in overcoming rolling resistance. Therefore, at a typical working speed of 2 m/s (4.5 miles/h) the maximum power is developed, and therefore the highest rate of work is achieved, when the pull is 0.325 kN/kW (54.5 lbf/hp). This is generally achieved when the pull is 40% of the weight on the tractor driving wheels, including the weight of any added ballast and the weight added by a mounted implement. The pull required for a mouldboard plough varies from approximately 50 kN/m^2 (7.3 lbf/in^2) of furrow cross-section on light land to 100 kN/m^2 (14.5 lbf/in^2) on heavy land. Therefore, at a ploughing depth of 200 mm (7.9 in) the plough width required to fully utilise the available tractor power varies from 32.5 mm/kW (0.955 in/hp) on light land to 16.3 mm/kW (0.478 in/hp) on heavy land. Conventional ploughs weigh approximately 400 kg/m (35 lb/in) width and reversible ploughs approximately 625 kg/m (54 lb/in) width. Therefore, the lift force required for conventional ploughs varies from 0.128 kN/kW (21.4 lbf/hp) on light land to 0.064 kN/kW (10.7 lbf/hp) on heavy land and for reversible ploughs varies from 0.2 kN/kW (33.6 lbf/hp) on light land to 0.1 kN/kW (16.8 lbf/hp) on heavy land.

It is likely that the revision of ISO/R730 will require a minimum lift capacity of 0.3 kN/kW (50 lbf/hp) of drawbar power at 610 mm (24 in) behind the hitch points for tractors of up to 65 kW (87 hp). Thus, tractors up to this power designed to the standard should be capable of lifting mouldboard ploughs large enough to make use of their full power.

Stability and adequate control of steering and depth are also important. For adequate steering control approximately 20% of the combined weight of a conventional two-wheel drive tractor and mounted implement should be carried on the front wheels. It may be shown that conventional two-wheel drive tractors up to 65 kW require front ballast to be added at the rate of 22 kg/kW over 5 kW (36 lb/hp over 3.7 hp) in order to maintain adequate steering stability when using the full lift capacity. ISO/R730 requires a

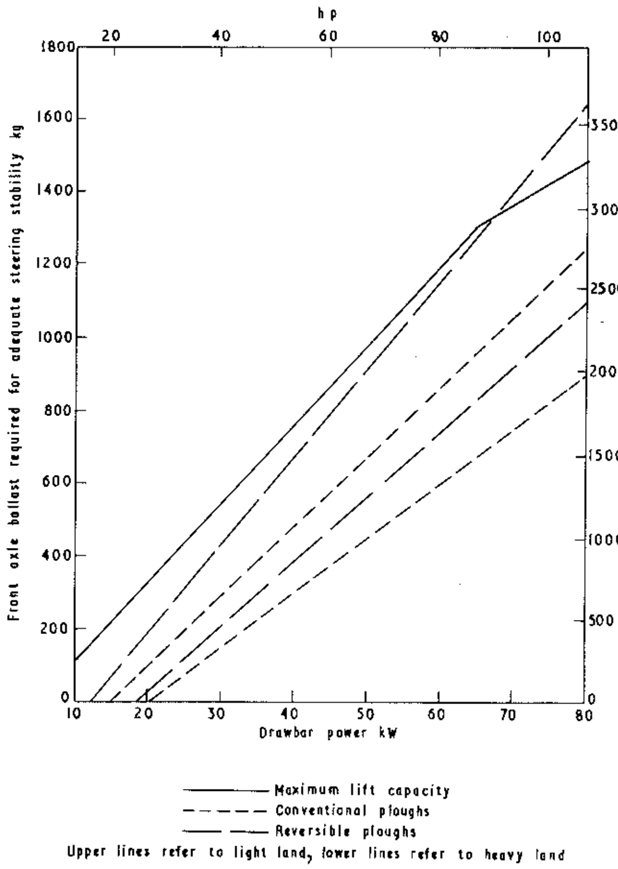

Fig 1 Front axle ballast required for adequate steering stability with maximum tractive efficiency at 2 m/s (4.5 mile/h).

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This paper was presented at the annual conference of the Institution, in London, on 7 May 1974.

reduced lift capacity of 20 kN + 0.15 kN/kW at 610 mm behind the hitch points above 65 kW and front ballast would then only have to be added at the rate of 1310 kg + 12 kg/kW (2880 lb + 20 lb/hp).

This analysis only applies when full lift capacity is used. Figure 1 shows also corresponding values when using conventional and reversible ploughs on heavy and light land.

If it is assumed that the maximum front axle ballast which it is practicable to add is 500 kg (1100 lb) the maximum drawbar power of tractors which can be operated with conventional ploughs at maximum efficiency while maintaining adequate steering stability is 41 kW (55 hp) on light land and 53 kW (71 hp) on heavy land. Corresponding figures with reversible ploughs are 33 kW (44 hp) on light land and 46 kW (62 hp) on heavy land. Tractors of higher drawbar horsepower require semi-mounted ploughs or must work at higher speeds, otherwise they will sacrifice either tractive efficiency or steering stability.

When operating semi-mounted ploughs, steering stability in work is less critical than during transport and a tractor which, with a semi-mounted plough attached, retains 20% of its total weight on the front wheels during transport is likely to retain adequate stability with the plough in work.

It is interesting to consider the rear axle ballast required for optimum tractive efficiency. The weight added to the rear wheels by conventional mounted ploughs capable of making full use of the available tractor power varies approximately from 21.9 kg/kW (35.8 lb/hp) on light land to 10.9 kg/kW (17.9 lb/hp) on heavy land. Corresponding figures for mounted reversible ploughs would be approximately 34 kg/kW (55.8 lb/hp) on light land and 17.0 kg/kW (27.9 lb/hp) on heavy land. The rear axle ballast required for optimum tractive efficiency at a ploughing speed of 2 m/s is shown in figure 2. If it is assumed that the maximum rear axle ballast which it is practicable to add is 200 kg + 27 kg/kW (440 lb + 44.3 lb/hp) (eg 10 wheel weights plus water ballast), the maximum drawbar power of tractors which can be operated with conventional ploughs at maximum efficiency is 58 kW (78 hp) on light land and 33 kW (44 hp) on heavy land. The corresponding figure for reversible ploughs on heavy land is 42 kW (56 hp) with no practical limit on light land.

Considering semi-mounted ploughs, the static weight added to the rear tractor wheels by conventional ploughs varies from 9.02 kg/kW (14.8 lb/hp) on light land to 4.51 kg/kW (7.40 lb/hp) on heavy land. For semi-mounted reversible ploughs the corresponding figures are 14.1 kg/kW (23.1 lb/hp) on light land and 7.05 kg/kW (11.6 lb/hp) on heavy land. With semi-mounted ploughs, however, there is an

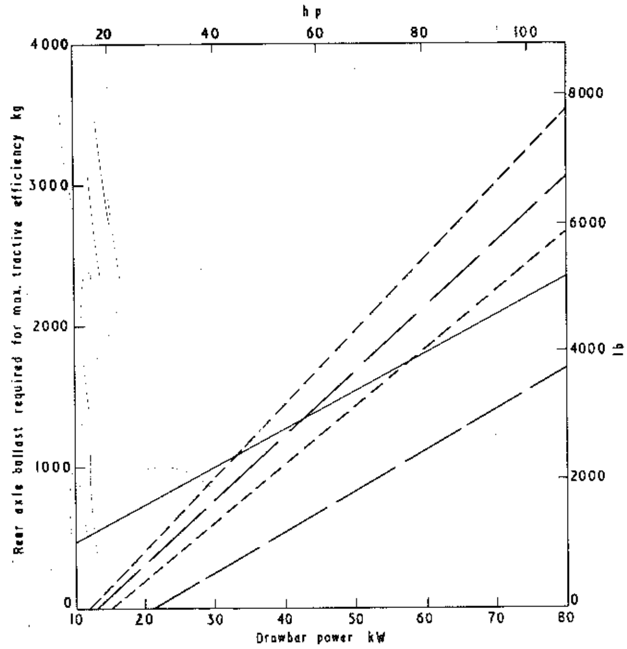


Fig 2 Rear axle ballast required for maximum tractive efficiency at 2 m/s (4.5 mile/h) mounted ploughs.

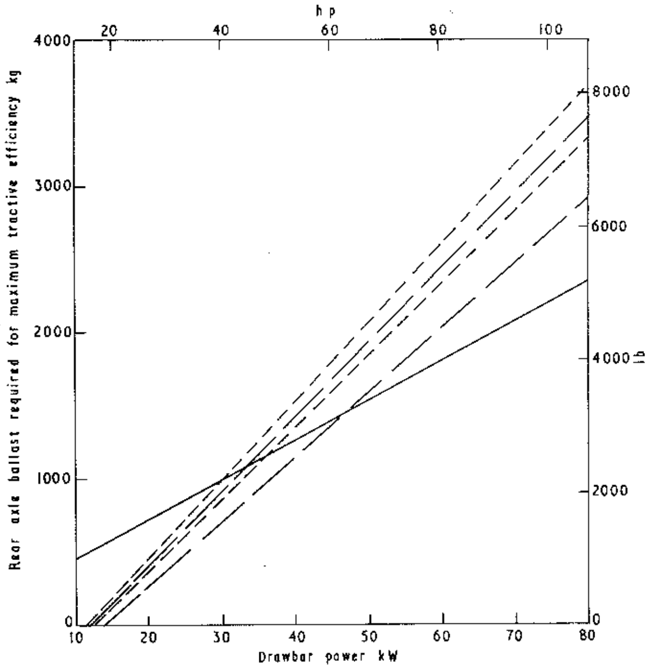


Fig 3 Rear axle ballast required for maximum tractive efficiency at 2 m/s (4.5 mile/h) semi-mounted ploughs.

additional dynamic weight transfer due to the line of pull being approximately 15% of the wheelbase above ground level, resulting in a further addition of approximately 4.8 kg/kW (7.88 lb/hp) to the driving wheels. Then the rear axle ballast required for operation of semi-mounted ploughs at maximum tractive efficiency at a speed of 2 m/s is as shown in figure 3. Making the same assumptions as before with regard to maximum rear axle ballast the maximum drawbar horsepower which can be used at maximum efficiency with conventional semi-mounted ploughs at 2 m/s is 36 kW (48 hp) on light land and 30 kW (40 hp) on heavy land and with reversible semi-mounted ploughs 47 kW (63 hp) on light land and 34 kW (46 hp) on heavy land.

Bearing in mind that this analysis is necessarily very general and approximate, the power limitations for each situation can be summarised as follows. On light land conventional mounted ploughs are limited by steering stability to tractors of less than 41 kW (55 hp) drawbar power. Semi-mounted reversible ploughs may be used up to 47 kW (63 hp) but above this power level tractive efficiency will be reduced. On heavy land conventional mounted ploughs may be used up to 33 kW (44 hp) and reversible mounted ploughs up to 42 kW (56 hp). Above these power levels tractive efficiency will again be reduced but steering stability is not likely to be a problem and no benefit is likely to be derived from switching to semi-mounted ploughs.

Another aspect of stability when ploughing is that of steering forces related to the line of draught. This is not normally a problem with tractor wheels in the furrow and ploughs less than 2 m (78.7 in) wide, since the line of draught is very close to the centre-line of the tractor. Problems only arise when it is necessary to have the tractor wheels out of the furrow to avoid compaction. There is then a moment tending to turn the tractor towards the ploughed land and as the stabilising effect of the furrow is no longer present, some form of steering aid such as that developed at the NIAE by Hilton and Chestney (1973) is desirable. As tractor horsepower increases in the future, however, and wider ploughs become necessary to make full use of that power, the situation will be reversed. Tractors pulling ploughs wider than 2 m (78.7 in) with wheels in the furrow will be subject to a moment tending to turn them away from the ploughed land and they will operate with a more central line of draught when running out of the furrow. Using the previously estimated values of the width of ploughs required for full utilisation of tractor power, 32.5 mm/kW (0.955 in/hp) on light land and 16.3 mm/kW (0.478 in/hp) on heavy land, this changeover would be likely to occur at approximately 61.5 kW (32.4 hp) on light land and at 123 kW (165 hp) on heavy land.

For cultivation implements it is essential that the driving wheels should run ahead of the implement and until recently little thought has been given to fitting a three-point linkage other than at the rear of the tractor. However, many other implements could, with advantage, be fitted in front of the tractor, particularly during harvesting operations such as mowing, where it would be beneficial for the tractor to run on the stubble rather than through the standing crop.

Automatic couplers

Various forms of automatic couplers have been developed in recent years to enable the operator to attach implements to the tractor without dismounting. Although these devices appear to offer considerable advantages in convenience and safety, they have not achieved the popularity that seemed likely some years ago. International standards have, however, specified zones of clearance around the hitch points to facilitate the use of quick-couplers and a British Standard implement headstock has been specified in British Standard 4621:1970 which can accommodate a range of quick-couplers as described by Osborne (1970). Development may be more rapid in the future if semi-mounted implements become more popular for use with larger tractors, since benefits of using quick-couplers will be greater with larger implements and their design will be simpler when only the lower links need be coupled.

Hook hitch

After the three-point linkage the force transmission coupling which imposes the most severe constraint on tractor design and use is the hook hitch used to couple large single-axle trailers, manure and fertilizer spreaders and slurry tankers. It is always situated as low as possible and as close to the rear axle as possible to reduce weight transfer between the tractor axles. The maximum static load which can be taken on the hook hitch is specified by British Standard 1495 currently under revision. The present proposal suggests 13.5 kN (3020 lb) for category 1 tractors up to 35 kW (47 hp) drawbar power and 22.5 kN (5050 lb) for category 2 tractors from 30 kW to 75 kW (40 hp to 100 hp). A value for category 3 tractors of over 70 kW (94 hp) has yet to be decided.

On conventional two-wheel drive tractors the distance of the hook hitch behind the rear axle is approximately 15% of the wheelbase. Therefore, the weight removed from the front axle when the full hook hitch capacity is used is approximately 210 kg (460 lb) for category 1 tractors and 34 kg (750 lb) for category 2 tractors. To maintain 20% of the tractor weight on the front axle, front ballast should, therefore, be added at the rate of 360 kg – 4 kg/kW (790 lb – 7 lb/hp) for category 1 tractors and at the rate of 680 kg – 4 kg/kW (1500 lb – 7 lb/hp) for category 2 tractors.

During braking of a tractor-trailer combination, deceleration of the tractor causes a transfer of load from the rear wheels to the front wheels while deceleration of the trailer causes an increase in vertical load at the hitch which transfers weight from the front wheels to the rear wheels of the tractor. If the combination is decelerated by the tractor brakes only, there is also a horizontal force at the hitch which transfers weight from the rear wheels to the front wheels of the tractor. For conventional tractors, the weight on the front axle of the tractor will always increase during braking, even when the trailer is fitted with its own braking system and there is no horizontal force at the hitch, unless the trailer is more than 12 times the weight of the tractor. The weight added to the rear tractor wheels when braking single axle trailers is very important in helping to achieve safe braking performance without wheel locking and provides an important advantage over two-axle trailers as shown by Dwyer (1970). This work indicates that provided at least 21% of the trailer weight is carried on the hitch, the tractor rear wheels will not normally lock on a good road surface when using the tractor brakes to decelerate a fully laden single-axle trailer.

An unballasted tractor can decelerate a fully laden single-axle trailer with at least 21% of its weight carried on the hitch at 2.5 m/s^2 (0.255 g) on a good road surface, provided the gross trailer weight is less than three times the tractor weight. This, therefore, was the limit specified in British Standard 4639:1970, for trailers not fitted with power or over-run brakes. Because of the limit on the weight which can be carried on the hook hitch this specification effectively limited category 1 tractors of up to 35 kW (47 hp) drawbar power to trailers below 6550 kg (6.4 tons) gross weight and category 2 tractors of 30 kW to 75 kW (40 hp to 100 hp) to trailers below 10 092 kg (10.7 tons). European countries, where two-axle trailers are more common, have never accepted the very much better braking performance of single-axle trailers and consequently the E.C.E. requires service brakes on all trailers of more than 1500 kg (1.47 tons) gross weight and trailed implements of more than 3000 kg (2.95 tons) gross weight. Trailers and implements of more than 5000 kg (4.9 tons) must have power brakes.

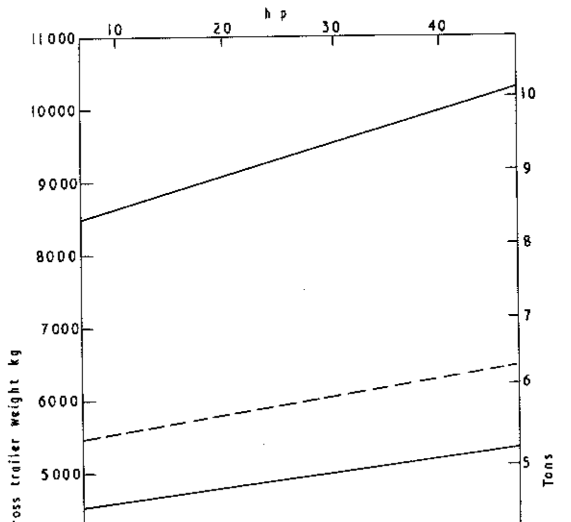
Another aspect of the efficient operation of tractor-trailer combinations is the need for a proper balance between the tractive force available at the tractor driving wheels and the rolling resistance of the undriven trailer wheels (Dwyer 1973). On level land the weight on the driven wheels multiplied by the coefficient of traction must exceed the weight on the undriven wheels multiplied by the coefficient of rolling resistance. On sloping land the weight on the driving wheels multiplied by the coefficient of traction must be increased by W sin θ where W is the gross vehicle weight and θ is the angle of the slope.

In good conditions such as a grass field the maximum coefficient of traction without excessive wheelslip would be approximately 0.6 and the coefficient of rolling resistance 0.05 so that, if 1 in 10 slopes were to be negotiated, the weight on the driving wheels should be greater than 23% of the total weight of the tractor and trailer. If 1 in 5 slopes were to be negotiated this would have to be increased to 38%.

In average conditions such as a stubble field the maximum coefficient of traction would fall to approximately 0.5 and the coefficient of rolling resistance would rise to approximately 0.1. The weight on the driving wheels would then have to be increased to 33% of the total weight for 1 in 10 slopes and 50% for 1 in 5 slopes.

In poor conditions such as after sugar beet or potato harvesting the maximum coefficient of traction could be as low as 0.4 and the coefficient of rolling resistance could rise to 0.2. The corresponding figures would then be 50% for 1 in 10 slopes and 67% for 1 in 5 slopes.

For conventional two-wheel drive tractors with single-axle trailers requiring the full hook hitch capacity this means that category 1 tractors can operate trailers of 4 to 5 tonnes in most



Upper lines refer to 1 in 10 slopes, lower lines to 1 in 5 slopes

Fig 4 Gross trailer weight which may be pulled by category 1 tractors in good ——— average – – – – – and poor —— —— tractive conditions.

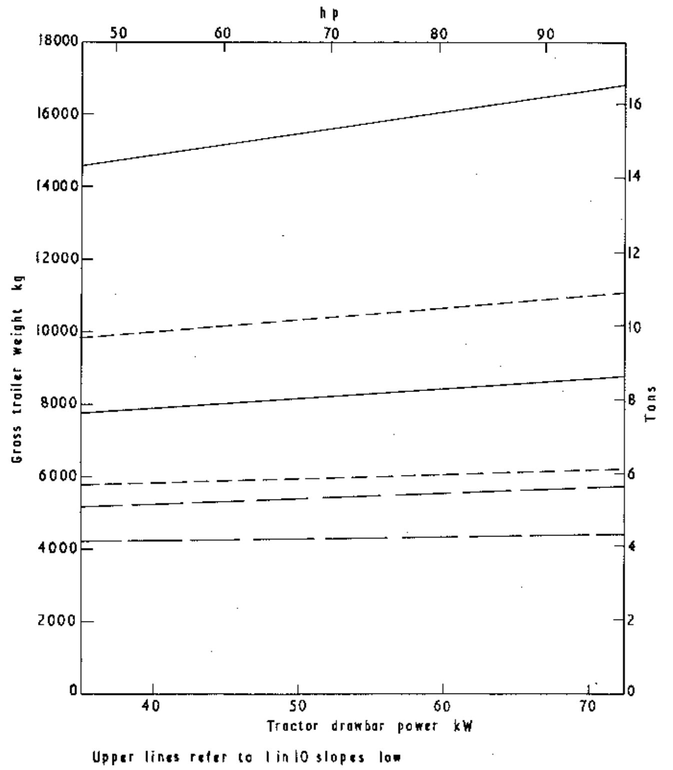


Fig 5 Gross trailer weight which may be pulled by category 2 tractors in good ——— average — — — and poor —— —— tractive conditions

conditions rising to 10 tonnes in ideal conditions and falling to 2 tonnes in the worst conditions (figure 4). Category 2 tractors can operate with trailers of 6 to 8 tonnes in most conditions rising to 16 tonnes in ideal conditions and falling to 4 tonnes in the worst conditions (figure 5). As trailers become larger, because of the limit on the load which can be carried on the drawbar, it is necessary to move the axle forward to take a larger proportion of the total weight. This has been a contributory factory in the occurrence of vertical jack-knife incidents which have received much publicity in recent months. Clearly if during tipping the centre of gravity of the trailer moves behind the axle, the force on the tractor hitch will change direction from downwards to upwards. This can happen if for any reason the contents of the trailer do not begin to discharge early in the tipping process and is more likely to occur the further forward the trailer axle is positioned. The first remedy is obviously to do all possible to ensure that the contents can be discharged as easily as possible. A second safety factor is normally available, however, since large trailers usually have tandem wheels mounted on a pivoting beam. It is then possible to restrict the movement of the beam so that, if the trailer drawbar lifts, the beam comes up against a stop and further movement will only occur if the centre of gravity of the trailer moves behind the rear wheels, which is far less likely to happen in practice.

When a tractor-trailer combination is traversing uneven ground it is clearly necessary to allow freedom of articulation at the hitch point. For this reason the proposed international standard specifies that the trailer pick-up ring should be free to rotate up to ± 20° in pitch and roll and up to ± 60° in yaw. In some countries complete freedom in roll is required to reduce the likelihood of a sideways overturning trailer overturning the tractor. In other countries it is required that the trailer becomes detached beyond a certain angle of roll.

A very interesting development of the hook hitch is incorporated in the universal tractor hitch designed by Kofoed and Christiansen (1973) which also offers automatic coupling of mounted and semi-mounted implements.

Swinging drawbar

The swinging drawbar may normally be fixed in at least two longitudinal positions, a forward position suitable for light trailers approximately 30% of the wheelbase behind the rear axle and a rear position, for pto-driven machines, specified in a proposed international standard as 400 mm behind the pto for category 1 and 2 tractors and 500 mm behind the pto for category 3 tractors.

The proposed revision of BS 1495 specifies maximum static loads on the drawbar such that the front ballast required to retain 20% of the tractor weight on the front axle would be, for categories 1, 2 and 3 respectively, 340 kg – 4 kg/kW (750 lb – 7 lb/hp), 650 kg – 4 kg/kW (1430 lb – 1 lb/hp) and 1000 kg – 4 kg/kW (2200 lb – 7 lb/hp) in the forward position and 240 kg – 4 kg/kW (530 lb – 7 lb/hp), 380 kg – 4 kg/kW (840 lb – 7 lb/hp) and 840 kg – 4 kg/kW (1850 lb – 7 lb/hp) in the rear position.

The height of the drawbar is usually variable but in the lowest position, which would normally be used for trailers, it is typically 18% of the wheelbase. Assuming as before for the hook hitch that the height of the tractor centre of gravity is 40% of the wheelbase and the height of the trailer centre of gravity is 30% of the distance from the hitch to the axle, the weight on the front axle will normally increase during braking. Even if the trailer is fitted with brakes so that there is no forward horizontal thrust on the tractor drawbar, this will still be true provided the trailer is less than four times the weight of the tractor. The main danger with swinging drawbars occurs if a trailer designed for coupling to the hook hitch is coupled to the drawbar, when a very unsafe condition arises, and it would probably be impracticable in most cases to add sufficient front ballast to retain adequate steering stability. In fact the front axle load on category 2 tractors of less than 38 kW (51 hp) is likely to be reduced to zero. The main purpose of the rear position of the swinging drawbar is for use with pto driven machines where the vertical load is likely to be comparatively low. The advantage of the rear position is that it enables the drawbar pin to be situated approximately equi-distance from the tractor pto and the implement power input coupling (pic). This means that, when the combination is turning with the pto engaged, the angle between the pto shaft and the tractor pto is the same as the angle between the pto shaft and the pic and both are a minimum for a given angle of turn. In this way cyclical variations in shaft speed and, therefore, stresses in all the rotating parts are reduced (Freeman, 1966).

Power transmission

Power take-off

The most common method of transmitting power from the tractor to another machine is by means of the 35 mm diameter 6 splined pto, designed to run at 540 rev/min at 80–90% of the rated engine speed. As pto-driven machines became larger, the torque capacity of the 35 mm diameter shaft was in danger of being exceeded. Therefore, the International Standards Organisation recommendation ISO/R500, which is being revised, only specifies this shaft and speed (type 1) for transmission of power up to 48 kW (64 hp). From 48 kW to 92 kW (64 hp to 123 hp) the same diameter shaft is specified but with 21 splines and operated at 1000 rev/min (type 2) and from 92 kW to 185 kW (123 hp to 248 hp) a 45 mm diameter shaft with 20 splines operating at 1000 rev/min is specified.

The mechanical power take-off is an efficient and relatively cheap method of transmitting the power available from the tractor engine. Its main disadvantage lies in the need for shafts and universal joints which must be adequately guarded and have adequate clearance to allow for relative movement between the tractor and implement. With mounted implements the relative movement is predominantly vertical, whereas with trailed machines it is predominantly horizontal. To allow for these movements the proposed revision of ISO/R500 specifies that there should be sufficient clearance on the tractor to allow the pto shaft to be angled from 40° above the horizontal to 21° below and to 55° on either side.

The importance of the position of the drawbar pin relative to the pto and pic on trailed machines has been discussed earlier. It is equally important to ensure that the pto and pic are as near as possible at the same height. For this reason the proposed revision of ISO/R500 specifies the height of the pic on trailed machines and the height of the tractor pto, and that, whenever possible, the pto and pic should be on the centre-lines of the tractor and machine. Three lengths of pto shaft are recommended. It is obviously essential that the pto shaft should be adequately guarded along its full length.

The greatest danger to the effectiveness of pto shaft guards is damage to the bearings due to ingress of dust and dirt and damage to the tubes and cones due to impacts. A British Standard test procedure (BS 3417: Part 5: 1969) exists to assess the durability of pto shaft guards and the last ten years has seen much improvement in guards, particularly in the use of types of polypropylene which retain good impact resistance at low temperatures. The main problem with pto shaft guards at present is probably maintaining adequate location on the shaft. The British Standard is presently being revised to introduce measurement of the axial displacement force along with other up-dating improvements.

The tractor pto has traditionally been positioned at the rear of the tractor because it is frequently used in conjunction with the three-point linkage. There may, however, be benefits in increased use of a front three-point linkage particularly for harvesting machines, as discussed previously. These are normally pto-driven and will, therefore, require a pto at the front of the tractor.

Hydraulic power

Soon after hydraulic power was introduced for lifting mounted implements on the three-point linkage, the potential for other uses was recognised and external tappings were fitted to tractors to enable hydraulic power to be applied to other machines. The two most important applications have probably been to front-end loaders and trailer tipping. Although both of these applications require fairly high loads, neither require high power, since the rate of lifting a loader or tipping a trailer is not normally critical.

The most important factors concerning the hydraulic supply to trailers and other machines with hydraulic rams is that the hydraulic pressure should be adequate and that the hoses and couplings should be suitable. A proposed revision of BS 4742 : Part 2 specifies a maximum pressure from the tractor of 160 ± 14 bar (2320 ± 203 lbf/in^2) and a maximum operating pressure for couplings of 275 bar (4000 lbf/in^2). Two types of quick-release couplings are specified.

The major disadvantage of hydraulic couplings is that, because they are connected and disconnected in the field, there is an inevitable risk of contamination of the hydraulic fluid by ingress of dirt or by mixing of incompatible fluids. In the USA, where greater use is made of semi-mounted implements which require a hydraulic ram on the implement to lift it out of work, rams are often made detachable from the implement and permanently connected to the tractor hydraulic supply. In this way the need for breaking hydraulic couplings in the field, with its consequent risk of oil contamination, is eliminated. It is necessary of course for the dimensions of the hydraulic ram and the fitting points on the implement to be standardised for interchangeability and an international standard has been proposed for this purpose.

The development of hydraulics for driving rotating machinery has been much slower than its development for operating rams, presumably because of the relatively high cost and low efficiency of the hydraulic transmission compared to the power take-off. The main advantage of hydraulic power transmission is the facility with which hydraulic hoses can be routed to motors situated in positions which would be inaccessible to shafts or belts. Therefore, machines with a low power requirement but with rotating parts in inaccessible places such as hedge trimmers, mowers and trailed fertilizer spreaders may benefit from hydraulic power transmissions.

The overall efficiency of a typical hydraulic transmission from tractor to machine is unlikely to be better than about 50% so that with present hydraulic power outputs of 5 to 10 kW (6.7 to 13.4 hp) only 2.5 to 5 kW (3.4 to 6.7 hp) is available for useful work and, worse still, a similar amount of power is converted into heat which raises the temperature of the oil. The reservoir of oil in the tractor back axle is capable of dissipating this amount of heat but clearly if hydraulic power was raised to that normally available at the pto very elaborate and expensive cooling facilities would have to be provided.

Piston pumps and motors with typical efficiencies of 95% could be used in place of gear pumps but they are more expensive and less tolerant to contamination of the oil. It is doubtful, therefore, whether the present system of connecting and disconnecting couplings in the field could be retained. A possibility which has often been suggested before is the use of a plug-in motor, similar to the rams mentioned previously which could be permanently connected to the tractor hydraulic system by means of flexible hoses and positioned on any machine in a suitable simple clamp with a mechanical connection to the driven component.

Braking

Some problems of braking tractor and trailer or trailed implement combinations have been discussed in connection with hook hitches and drawbars. It was stated that the ECE requires service brakes on trailers of more than 1500 kg (1.47 tons) gross weight and trailed implements of more than 3000 kg (2.95 tons) gross weight and that for trailers and implements of more than 5000 kg (4.9 tons) gross weight the brakes must be power operated. The braking force at the trailer or implement wheels must be at least 25% of the weight on the wheels so that trailers will have to be fitted with considerably larger brakes to comply with this requirement and a wide range of manure spreaders, slurry tankers and trailed fertilizer spreaders will also require brakes. Up to 5000 kg (4.9 tons) gross weight brakes can be manually operated by a control mounted on the tractor or operated by an over-run mechanism. For trailers and trailed implements of over 5000 kg (4.9 tons) power brakes are required and this will normally mean hydraulic or pneumatic operation from a source on the tractor.

BS 4639:1970 specifies that, for hydraulically operated power brakes, the oil pressure from the tractor should not exceed 150 bar (2180 lbf/in^2) and that the trailer or implement brakes should be capable of withstanding this pressure. A braking force equal to 25% of the gross trailer or implement weight should, however, be achieved with an oil pressure of 100 ± 10 bar (1450 ± 145 lbf/in^2). For pneumatically operated power brakes the corresponding air pressures are 8 bar (116 lbf/in^2) and 6 ± 0.6 bar (87 ± 9 lbf/in^2) respectively.

Test procedures for trailer and trailed implement brakes are specified in BS 4639 and similar procedures are likely to be adopted by ISO.

Automatic control

Before the introduction of the three-point linkage, the depth of cultivations was controlled almost exactly by depth wheels. The tractor had to be heavy enough to provide sufficient tractive force to pull the implement through the stiffest part of the field at the depth set. Draught control of mounted implements, however, automatically reduces the depth in the stiffer parts of a field, thereby enabling the weight of the tractor to be reduced to that necessary to provide sufficient tractive force to pull the implement through the majority of the field at the draught set.

It is suggested that different users in different situations may require either draught control or depth control. Where the aim is to get the maximum area of land cultivated in the shortest possible time with the cheapest tractor and evenness of depth is not vital, draught control is sufficient. However, where the aim is to cultivate to an even depth and the cost of the tractor is of secondary importance, depth control is required with a tractor having greater tractive froce in reserve for coping with the stiffest parts of the field.

At present all tractors provide draught control but non provides depth control. Fitting a depth wheel to a draught controlled implement limits maximum depth but does nothing to control minimum depth and reduces the beneficial effect on traction of the addition of the implement weight to the tractor driving wheels. One aspect of current NIAE research on implement control is the development of a true depth control which makes use of the tractor hydraulics with a minimum of modifications.

Even existing draught controls have their limitations as shown by Cowell and Len (1967) and Dwyer (1969 and 1970). Theoretical and experimental studies have shown the importance of the vertical forces produced on an implement when it moves vertically through the soil, these being either an advantage or a disadvantage depending on the circumstances. Sensitivity to vertical forces is always a disadvantage, however, in reducing the stability of control. If response is too fast vertical forces will be produced which may be large enough to cause rapid reversals of the control signal and consequent hunting. One method of overcoming this problem is to design a true draught sensing control as proposed by Cowell (1970) or as used in the Ford 'load monitor' control.

An experimental electro-hydraulic implement control was built at the NIAE to study the effect of different modes of sensing and of varying the parameters of a control such as dead-band and rate of lift. The results have been described by Dwyer, Crolla and Pearson (1974) and Crolla and Pearson (1974). They show that, although a pure draught sensing control allows a smaller dead-band to be used than in a conventional control without risk of instability, the performance is no better because the advantage of sensing vertical soil forces when draught variation inputs are caused by changes of tractor pitch is lost. Furthermore, even the pure draught sensing control is subject to instability if the dead-band is reduced too far due to the inevitable time delay which occurs between the sensing of an error signal and the response. This has been studied further by Crolla (1973) who developed a computer model which enables the performance of a draught control with given parameters to be predicted in any field condition with any implement. The simulation includes the effects on engine speed and traction and can be used for any forward speed. It is available for use by tractor manufacturers when designing draught controls to enable them to optimise the control parameters to achieve the required stable performance at a given speed.

Electrical couplings

It is likely, as a result of harmonisation of road regulations throughout Europe, that stop-lights, flashing direction indicators, and perhaps hazard warning lights and rear fog lights will be required on trailers and implements for daylight use, in addition to tail lights and rear number plate illumination at night. Proposals for international standardisation of the connections to these couplings and for the position of the female half on the tractor have already been made.

Future developments

The foregoing study of the coupling of tractors and cultivation implements by means of the three-point linkage has shown that at existing working speeds the conventional two-wheel drive tractor is likely to become less efficient at converting engine power into drawbar power as the available power is increased. The maximum drawbar power which can be used efficiently varies from approximately 40 kW (54 hp) on heavy land to 50 kW (67 hp) on light land. These drawbar powers correspond approximately to engine powers of 47 kW (63 hp) and 59 kW (79 hp) respectively. In both cases reversible ploughs provide better tractive efficiency and on light land they should be semi-mounted to retain adequate steering stability. The large arable enterprise which requires the maximum output per man-hour and which can justify extra capital expenditure on a tractor used almost exclusively for cultivations will provide a small market for more efficient tractors.

Greater efficiency at higher power may most easily be achieved by increasing working speed, but this brings problems of higher draught forces, increased ride vibration and more difficult depth or draught control. It seems likely that these problems will be gradually solved so as to allow working speeds to increase slowly as they have done in the past.

At the same time as considering the trends in tractor development it is essential to consider what is happening in the development of cultivation techniques. We are already seeing a replacement of the mouldboard plough with tined cultivators in many situations, but this is unlikely to seriously affect the factors discussed above since the size, weight and draught forces of cultivators are roughly similar to those of ploughs. There may also be a trend towards shallower cultivations for cereals.

Another development in cultivations is the increased use of pto-driven rotary cultivators and diggers. The advantage of these is that, since they do not rely on tractive force, they enable increased horsepower to be utilised by a lighter and therefore cheaper tractor, but power losses in the rotating soil-engaging parts of rotary cultivators must also be considered. Present NIAE research is investigating these problems but for the foreseeable future it is likely that there will still be a requirement for tractors to operate draught implements.

The ultimate in reduced cultivations is direct drilling which although still only responsible for a small percentage of the total acreage is gaining ground rapidly. It is too early yet to say what effect direct drilling will have on tractor design but its demands on the tractor are unlikely to be very different from those of conventional tillage implements.

The main answer to providing greater tractive efficiency at higher powers, therefore, is likely to be some increase in froward speed combined with some increase in implement size and tractor weight. To carry the extra weight it will be necessary to increase the number of driven wheels either by driving the front wheels as on a conventional four-wheel drive tractor or fitting dual wheels to two-wheel drive tractors. Dual wheels obviously cannot be fitted into a furrow and, therefore, with mouldboard ploughs this solution is probably only practicable on tractors of over 60 kW (80 hp) on light land and 125 kW (170 hp) on heavy land, when the tractor can be operated out of the furrow without being subject to large offset draught forces. The provision of a pto-drive to one or two wheels on a semi-mounted implement may also contribute to a solution. This would enable a fairly light powerful tractor to be used for a large number of other operations particularly those for which high pto power was required. Then, when high tractive forces were required the necessary weight could be provided, where it was needed, in the implement. One wheel at the rear of the implement running on the unploughed land might be sufficient or, if necessary, another wheel could be added, at the front of the implement, running in the furrow. This arrangement would have the added advantage of excellent depth control.

Probably the second most important function of a tractor, after cultivations, is transport. It has been shown that, although the conventional tractor and trailer is likely to remain adequate for most farm transport tasks, there is probably a specialist market for a more efficient transport vehicle for carrying loads of over 10 tonnes in good conditions or 5 tonnes in poor conditions. In addition, better braking and lighting is likely to be required in future for road use. The requirement to pull heavier loads in worse conditions can only be met by increasing the proportion of the total weight carried on driven wheels. Four-wheel drive is, therefore, an advantage and further advantage could be gained by adding as much as possible of the weight of the payload between the tractor axles rather than behind the rear axle as at present. For the 5 tonne payload vehicle for use in poor tractive conditions this suggests a forward control four-wheel drive tractor with containers on a tipping body mounted on the chassis. For the 10 tonne payload vehicle for use in better tractive conditions a single-axle trailer designed so that 50 per cent of its laden weight was carried on a 'fifth wheel' mounted between the axles of a four-wheel drive tractor might be more suitable.

The 5 tonne payload vehicle could also be fitted with a range of alternative bodies incorporating suitable distribution mechanisms so that it could also be used as a self-propelled sprayer, manure or fertilizer spreader, slurry tanker or seed-drill.

Other special purpose vehicles which seem likely to replace tractor-machine combinations for contractors and large farmers are high pto power tractors, of high power to weight ratio and only capable of transmitting a comparatively small proportion of their power through the driving wheels, designed primarily for operating harvesting machinery. Full power pto's and three-point linkages at front and rear would allow wide mowers and forage or maize harvesters to be mounted at the front, where they can be more easily observed by the operator. This arrangement also avoids the tractor wheels running through the standing crop. When hay-making a crop-conditioning machine may be fitted at the rear.

As tractors become larger and sound-proofed air-conditioned cabs become standard the operator inevitably becomes more remote from the implements and machines he is operating. Therefore, it is likely that there will be considerable development of automatic controls and monitoring devices. At present the only automatic control is draught control of tillage implements. However, it is possible that similar controls may be developed in the future for automatic adjustment of top-link length and of the height of the lower links relative to one another.

Monitoring of machine malfunctioning is likely to become increasingly important. The most promising devices appear to be ultra-sonic detectors connected through suitable electronic circuits to lights or audible warning devices in the operator's cab. Ultra-sonic devices are probably the most promising at present because they are unaffected by vibration and dust and comparatively cheap and robust units are available because of their widespread use as security devices.

The conventional two-wheel drive tractor will undoubtedly continue to provide the main output of the major manufacturers but the limitations imposed by attempts to transmit ever more power to an increasing range of implements and machines will inevitably lead to a reduction in efficiency. There will, therefore, in the future be a small but increasing market for high-powered specialist tractors designed to perform a smaller range of operations at greater efficiency.

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Basic considerations and experiences with the Intrac-system 2000

by A Gego

Summary

THE Intrac-System, midway between conventional tractor and self-propelled machine, is a possible answer as a mobile source of power in agriculture. The main advantages of the system are that it combines the positive features of the other two. The essential points of the basic Intrac machines are a capability for implement changing and the possibility of exploiting the front-mounting principle of the self-propelled machine.

An analysis of mobile power in agriculture and of its technology points to certain basic factors, which, to a large extent, determine the design of the Intrac machines. Layout of the workplace on the machine also exercised a considerable influence on development.

A few, detailed examples of application illustrate the high technological potential on which the Intrac-System is based.

Summing up, there are, by comparison with conventional methods, the following substantial advantages:

A healthy and comfortable workplace for the driver,
application of the principle of the self-propelled machine (front-mounting of implements),
the possibility of implement combinations,
higher transport efficiency and a better solution of the transport problem.

Hence the essentials are provided for rationalising production methods with a view to:

Improving operating conditions (increase in motivation),
reducing the specific physical effort (increase in output) and
reducing unproductive time (increase in output).

Critical juncture in the development of mobile power on the farm

Farm production in the industrialised countries is to-day largely determined by technology. By contrast to industry, mobile machines are a characteristic feature of crop production. In this connection two solutions have emerged:

The combination of tractor and implement or
the self-propelled machine (generally a single purpose machine).

The self-propelled machine as a single purpose machine is often the most logical solution to a particular problem. On the other hand, it frequently comes close to being uneconomic as its operating time per year is in many cases severely limited by the seasonal character of crop production.

Dr Ing A. Gego is from Klöckner-Humboldt-Deutz A. G. This paper was presented at annual conference of the Institution, in London, on 7 May 1974.

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By contrast, it is possible with a conventional tractor to extend the operating time over the year by using different implements for consecutive operations and so making the overall operation of the tractor economic. The conventional tractor has, however, the disadvantage that it is designed primarily for use with rear-mounted implements — an analogy with the earlier draught function of horses on the farm is still recognisable to-day. Its major disadvantage is that its design is not determined by the technological requirements in agriculture but largely by the arrangement of engine and transmission. The more appropriate principle of the self-propelled machine ie of operating front-mounted implements, is excluded on design grounds.

The conventional tractor also has drawbacks in so far as the location of tanks eg spray tanks, is concerned. This often leads to the adoption of non-standard mounting points on the tractor (eg spray tanks beside the engine) which in turn creates problems for the driver, such as impaired visibility and difficulty in getting to the tractor seat as well as the problem of mounting the equipment (non-productive time).

The result has been that tractors of ever increasing horsepower have in recent years yielded specific operations to self-propelled machines despite the fact that the latter involve a heavy investment and fail to attain an annual operating time that is economic. A further problem with self-propelled machines is that their manufacture is normally only on a small scale and technical development and reliability in service are frequently inadequate.

As workplace requirements become more exacting (resistance to overturning, cab, noise reduction, air conditioning, ergonomics) the minimum operating time per year for the self-propelled machine will further increase if the requisite investment is to be an economic one.

Now that the average engine horsepower for new tractors is more than 50 in Europe and considerably exceeds 70 in North America, the time seems ripe to consider a variant to the solutions hitherto applied to the question of a mobile power source in agriculture.

Basic ideas on the design of a 'System tractor'

The operations in crop production can be set down diagrammatically in the form of a 'control' sequence (fig 1). From it two deductions can be made:

(a) The range of operations in planting is suitable for combinations of implements,
(b) loading and transport play an important role in the sequence of operations.

The aims of all endeavour in agriculture and agricultural engineering must be broadly the combination of the traditional, separate operations in crop planting into one operation and the further rationalisation of transport operations.

Transport efficiency and the rate of work depend on the following factors:

Operating or transport speed	V_F	(km/h)
width of work	B	(m)
number of operations per pass	m	
quantity transported	G	(t)
hopper capacity	G_V	(m³)
effective operating time	t_{eff}	(h)
non-productive time	t_t	(h)

The rate of work, F, is affected by a number of factors and a major one is non-productive time:

$$F = B.V_F.\frac{t_{eff}}{t_{eff} + t_t}\ .\ 10^{-2}\ \text{(ha/h)} \qquad (1)$$

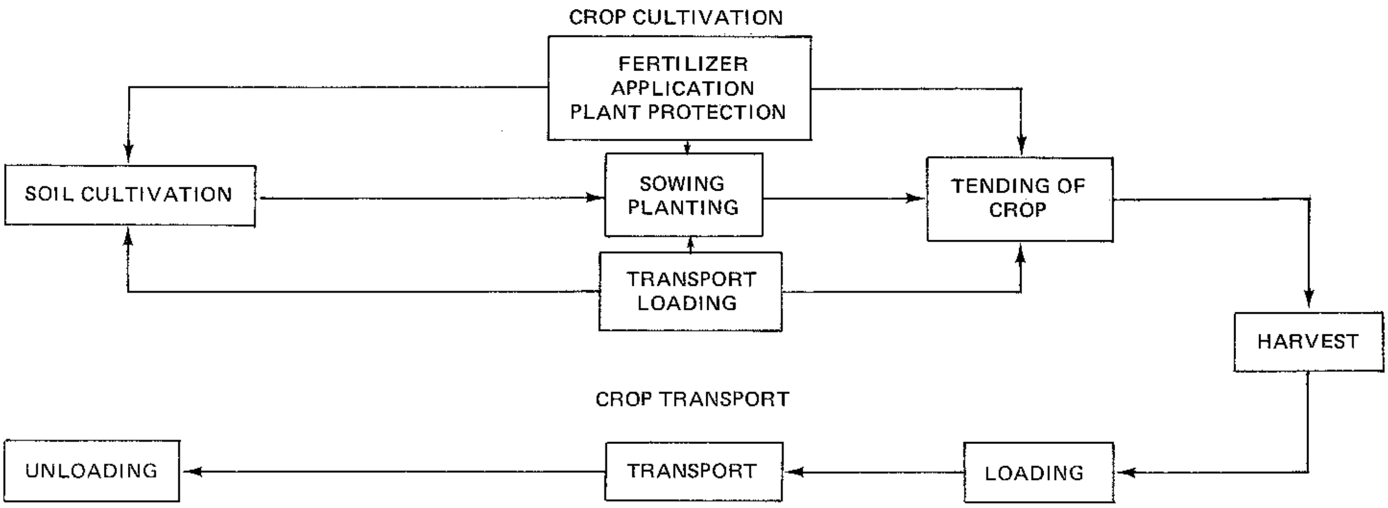


Fig 1 Diagrammatic representation of sequence of operations in crop production

Transport capacity, T, is calculated similarly:

$$T = G.V_F.\frac{t_{eff}}{t_{eff} + t_t} \text{ (t. km/h)} \qquad (2)$$

A list of some of the sources of unproductive time (fig 2) shows that their extent can easily be underestimated. An important aspect of any new development must therefore be to reduce to a minimum any such times which are dependent on design (eg implement changing) and, if possible, to eliminate them completely (eg machine maintenance). Unfortunately these aims can only be reached at a very slow pace.

Fig 2 List of unproductive operations

Hitching and unhitching of implements	Turning and reversing
Adjusting to transport position	Transport to farmyard
Transport to field	Unhitching
Setting machine	Machine maintenance
Filling hoppers	Getting on and off machine
Stoppages	Refilling hoppers
Raising and lowering of implement	Emptying hoppers
Engaging and disengaging of drive	Emptying transport vehicles

When thinking of the initial, general criteria for a variant to the

Fig 3 Analysis of operations in crop production

Soil relationship	Category of work	Operation or function	Power requirement Draught	Pto	Normal mounting point
Dependent on soil	Working in soil	Soil cultivation with trailed implements (eg plough, heavy cultivator)	High	—	Rear
		Soil cultivation with pto-driven equipment (eg power harrow, rotary cultivator)	Low	High	Front, mid or rear
		Harvesting of root crops (eg beet)	Medium	High	Rear
		Drilling, tending of crops, fertilizer application	Low	Low to Medium	Front or rear
	Working above soil	Distribution (eg fertilizer)	Low	Low to Medium	Front or rear
		Harvest (eg maize, beet tops, cereals)	Medium	High	Front, mid or rear
Independent of soil	Supply of materials (hopper)	Drilling, fertilizer application, plant protection	Low	Low to Medium	Behind driver (in other respects open to choice)
	Collection and transport (hopper)	Harvest (eg potatoes)	Medium	Medium	Behind driver (in other respects open to choice)

conventional tractor and the self-propelled machine, the positive characteristics of the two should, as far as possible, be retained ie:

The long operating period per year through using different implements (conventional tractor) and

application of the principle of front-mounting (self-propelled machine).

The following deductions can be made from an analysis of the operations performed by different machines in crop production (fig 3):

(a) Only a few of the operations (eg ploughing), characterised by an extremely high draught requirement, are typical operations for rear-mounted implements (physical reasons);

(b) operations involving the use of the pto and those where relatively small pushing or pulling forces are required (eg beet hoeing) leave the choice of mounting point open and may therefore be suitable for front-mounted implements,

(c) only operations which are dependent on the soil involve the use of the power lift.

The following essential functions for farm tractors (fig 4) stem from the foregoing:

Adequate overall power output,
optimum visibility,
operator comfort,
automatic coupling.

The analysis shows that, in addition to draught, other types of power are involved, particularly the output at the pto and hydraulic power, both of which are growing in importance whereas draught, relatively speaking, is losing ground.

As there are as yet no economic answers to the question of the automatic tractor and as none appears likely in the near future, the visibility from the driver's seat and operator confort (effect on performance) are of special importance in the design of new machines. This is even more true when the importance of retaining in agriculture the qualified personnel needed to operate to-day's complicated equipment is considered.

When new developments are examined, the operator, his workplace and optimised operational techniques must now be regarded as top priorities. The idea of the ascendancy of engine and plough as the criterion for everything in 'tractor engineering' must be banished to the past. Due to the more efficient use of energy, the pto-driven machine is frequently to be preferred to the trailed one.

Automating implement coupling is not solely a matter of reducing non-productive time but is, above all, concerned with accident prevention (risk of labour shortage at times of peak demand) and freedom from dependence on additional personnel.

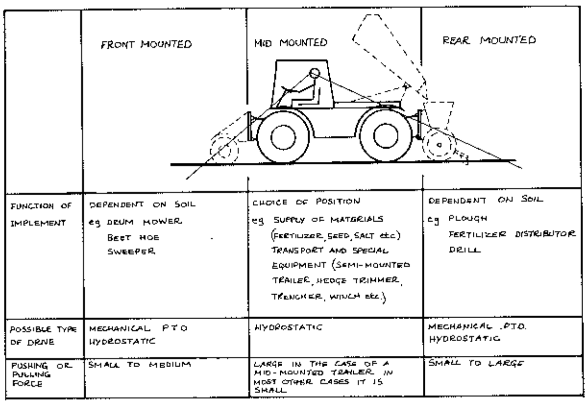


Fig 5 Design of tractor with a number of operational features

The viewpoints expressed above lead to a tractor design (fig 5) which is characterised by the following:

4-wheel drive (front and rear wheels of the same size),
vehicle suspension and longitudinal frame,
3-point lifts at front and rear with A-frame couplings that

Main requirements	Aspects	Comments
1. Power output (overall)	Drawbar horsepower	Optimum position at rear of tractor } High outputs
	P.t.o. power Hydraulic power	Choice of position is open
	Electric power Pneumatic power	Relatively small outputs for servos
2. Optimum vision	View of guide lines (road, plant row, furrow, edge of crop, line traced in soil by marker etc)	Top priority, logical part of design, decisive for quality of work and rate of output
	View of tractor wheels	Control of slip, contact with soil
	View of coupled equipment	Operational control, partially automated in its simplest form
3. Operator comfort	Cab Comfortable seat Optimum layout of controls Heating Ventilation Air conditioning	Important factor for driver's health, safety and operating efficiency
4. Automatic hitching devices	Trailed, mounted and semi-mounted implements	Short-term aim because strenuous physical effort has hitherto been required
	Mechanical pto Hydraulic coupling Electric socket Pneumatic coupling	Long-term aim as physical exertion is slight; cost would not be justified at present

Fig 4 Main functions of farm tractors

can be operated by remote control from the tractor seat,
full power at the front and rear pto's
a safety cab located at the front in such a way that the driver's seat is behind the front axle,
space behind the cab (eg for mounting supply hoppers),
hydraulic lift for containers.

As far as possible the driver should be located between the axles, as a position near the centre of gravity of the machine is relatively favourable from the point of view of vibrations. Furthermore, this position affords the best visibility.

Sighting of a guide line (fig 4) takes absolute priority over other points to be kept in view (eg rear-mounted implements) and hence the cab can only be at the front since a supply hopper located ahead of a rearward positioned cab would make it impossible to perform this operation. The cab must be located at the front so that a good view of front wheels and front-mounted implements is possible. In this regard it differs substantially from the road truck.

Lengthwise, the ends of the vehicle body should be within the tyres at front and rear so that front and rear lifts are as close as possible to the axles (axle loads).

In view of the asymmetric position of many implements, most of which are located on the right (eg mower, baler), the driver sits on that side.

Turning to the engine and transmission, there is, from the point of view of farm operations, an unnecessary, wasted space between the driven axles, ie in the side view shown in fig 5, the space roughly between the upper edge of the tyres and the minimum ground clearance line.

The need for track width adjustment is frequently unjustified and, with 4-wheel drive tractors, in time-consuming. This raises the question of a possible standard track width, making changes superfluous.

An analysis of track widths used in Europe (fig 6) shows that in the range between 40 and 100 cm almost 20 different row widths are employed. The need for this number is not justifiable in logic or for crop cultivation, and many of the widths are so close to each other that assimilation is possible. This has been proved in the field. The row width can be varied within relatively wide limits for many crops without having a negative effect on yield, provided that the number of plants per unit area is kept constant.

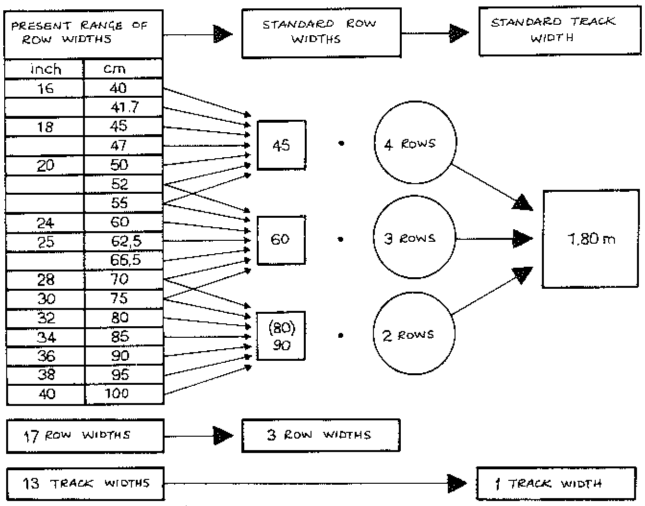


Fig 6 Standardising the track width of tractors.

This may be achieved by varying the seed or plant spacing.

If row widths are consolidated to 45, 60 and 90 cm (fig 6), a standard track width of 1.80 m is possible. This has already been proposed and justified (References[1 2 3]). Discussions are currently taking place in the pertinent standards' committees with a view to introducing on an international basis a standard track width of 1.80 m for larger tractors – alongside one of 1.50 m for smaller tractors.

Engineering aspects of the new system tractors

The design of Intrac 2005 (fig 7) is based on the foregoing analysis. Descriptive details on points not covered in other publications are given below.

In addition to what has been mentioned earlier, the machine has the following characteristic features:

Low-slung tanks, close to the frame, for fuel and oil,
hydraulic tappings at front and rear.

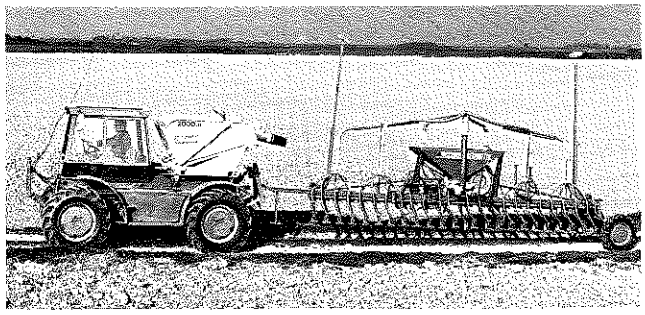


Fig 7 Intrac 2005 with pneumatic drill in the transport position.

The unit, consisting of the engine and the hydraulic and mechanical components of the transmission, is resiliently mounted at three points between the two longitudinal, box sections of the chassis and below the upper edge of the frame (fig 8).

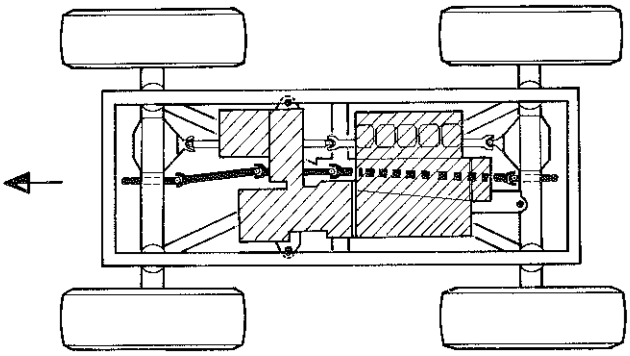
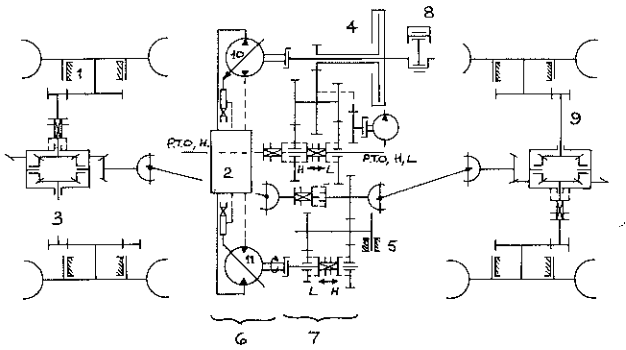


Fig 8 Layout of transmission and pto drive for Intrac 2005 (plan view).

The air-cooled, 5 cylinder diesel engine is located behind the driver's cab and, when the cover has been raised, access is easy. Cooling air is drawn through this cover behind the cab To reduce height the engine is tilted at an angle of about 53°.

The axles are rigidly attached to triangular links and, through these, are connected centrally to the chassis in flexible mountings. Transverse forces are absorbed by approximately horizontal stabilisers providing a flexible link between axle and chassis.

Details of the transmission are shown diagrammatically in fig 9.



1 SERVICE BRAKES
2 AUXILIARY UNITS FOR CLOSED CIRCUIT, REGULATION AND CONTROL
3 FRONT AXLE
4 P.T.O. CLUTCH
5 PARKING BRAKE
6 HYDROSTATIC MOTOR (SEPARATE PUMP AND MOTOR)
7 MECHANICAL TRANSMISSION COMPONENT PNEUMATICALLY OPERATED
8 DIESEL ENGINE
9 REAR AXLE
10 75 cm³/REV.
11 140 cm³/REV.

Fig 9 Hydraulic circuit diagram for Intrac 2005.

There is a direct drive from the diesel engine to a hydraulic pump, which operates a hydraulic motor. Pump and motor are infinitely variable, axial piston units on the Thoma principle. The hydraulic motor drives front and rear axles through a pneumatically operated, 2-speed gearbox and Cardan shafts. To increase ground clearance the driven axles are designed as Portal axles.

Through a single-plate, dry clutch the diesel engine drives the pto gearbox which provides two standard speeds for the rear pto and one for the front. The pto's are mounted in the Portal axles. Torque is transmitted to front and rear through a gearbox and Cardan shafts. This is omitted for the sake of simplicity in fig 9, but is indicated in fig 8.

To exploit the operational simplicity possible with hydraulic transmissions, the vehicle is also equipped with a control system for normal travel (fig 10). When driven on the road, the effect is much the same as that obtained with an automatic gearbox in a saloon car. The control variable for the hydrostatic drive units is a pressure head produced by an auxiliary pump. This pump, whose speed is dependent on the diesel engine, operates against an adjustable throttle valve. This type of control provides smooth starting and stopping and, by comparison with the diesel engine, a slower response of the hydrostatic units.

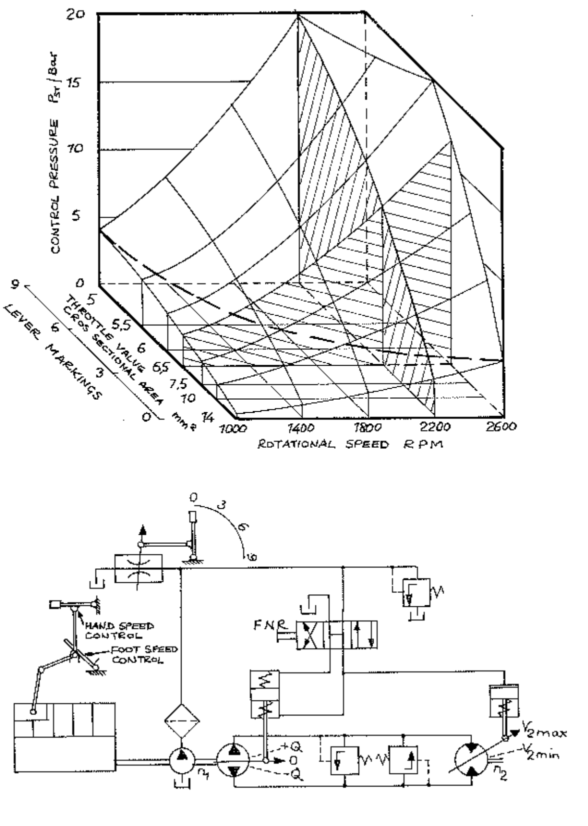


Fig 10 Throttling valve control principle used on Intrac 2005.

When working at constant engine and pto speed, the forward speed can be controlled by hand operation of the throttle valve.

To avoid overloading the engine, the tractor is also fitted with a torque limiting device (not shown).

The lower efficiency of hydrostatic transmissions ie by comparison with mechanical transmissions, is of subsidiary importance when the engine output is divided for purposes of draught, pto and remote power. In cases where a high tractive effort is required, the drawbar horsepower comparison with a mechanical transmission is less favourable but the fall in efficiency is to some extent compensated by the infinitely variable nature of the hydrostatic transmission. The ease in reversing the drive and the consequent advantages in turning and reversing the tractor also help to balance the disadvantage.

The vehicle is fitted with pneumatic power-assisted service brakes which operate on drums on all four wheels. The independent hand brake operates on the rear transmission.

The Intrac 2002 is a smaller model but designed on a similar system. It has a mechanical drive, different sized wheels at front and rear and optional rear-wheel or 4-wheel drive. Vehicle data on Intrac 2002 and Intrac 2005 are given in fig 11.

In the development of these machines particular attention was paid to the design of the driver's workplace and the cab (fig 12).

MODEL	2002	2005
Engine hp (DIN)	51	92
Number of cylinders	3	5
Transmission	Mechanical	Hydrostatic
Pto speed		
front min^{-1}	1000	1000
rear min^{-1}	540/1000	540/1000
Wheelbase mm	2200	2500
Track width mm	1500/1800	1800/2000
Max. speed km/h	25	25 or 40
Unladen weight kp (operating condition)	3400	4300
Max. permissible gross weight kp	5200	7500

Fig 11 Data on Intrac 2002 and 2005

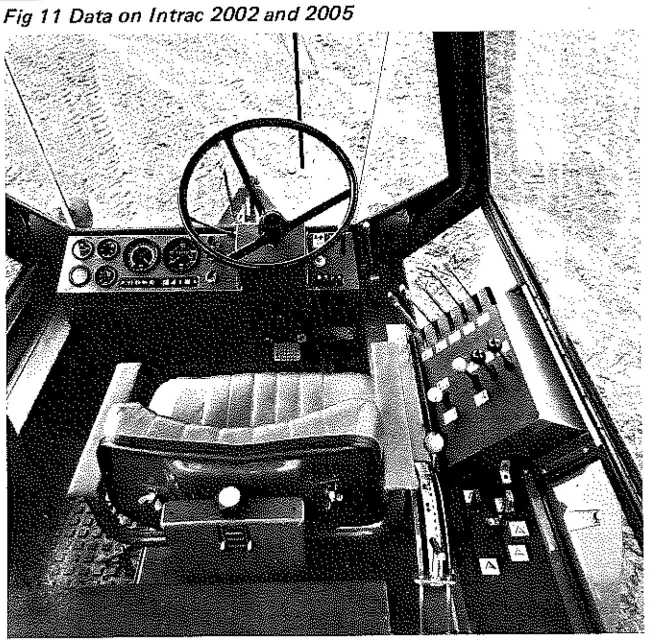
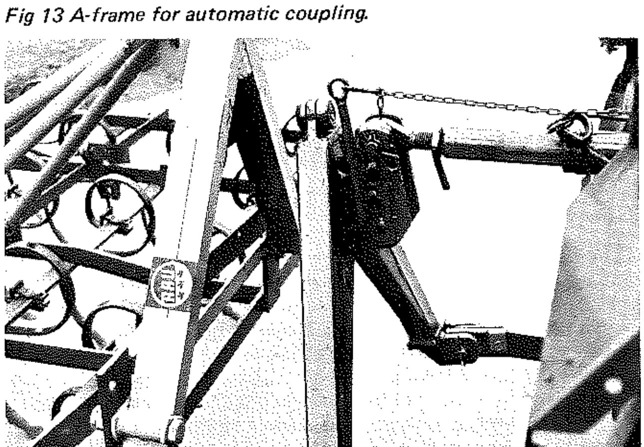


Fig 12 Operator's position on Intrac 2005.

The driver's seat is located about 150 mm to the right, when facing in the direction of travel, of the centre line of the tractor, as most implements, at least in agriculture, operate on the right. In other applications, too, (eg work for municipal councils) there are arguments for a workplace offset to the right: equipment for mowing grass on slopes and for washing guide markers on roads should operate on the right to enable the machine to move forward in the direction of the traffic.

Fig 13 A-frame for automatic coupling.



Entry to the cab is from the left. A sliding door, which can be locked in both end positions is fitted to make it easier to operate where side clearance is restricted and to afford the possibility of driving with the door open.

Hand controls are mainly to the right of the driver while the instrument panel is located in front of him. In side view, this panel is located, in relation to the lower line of vision of the driver, in a way that visibility is not impaired.

For normal operation only two pedals are required – speed control pedal and foot brake – as no clutch is required with a hydrostatic transmission.

The construction of the vehicle is such that the driver can see all four wheels.

The windows to the righthand side of the driver and behind him are of the sliding type. The cab roof can be opened for additional ventilation.

The cab is heated and ventilated and, optionally, can be fitted with an air conditioning unit. Safety has not been overlooked. The cab is designed as a safety cab and meets the international impact test requirements. To reduce noise, anti-vibration mounts are fitted between cab and chassis.

The hitching and unhitiching of front- and rear-mounted implements is effected by means of a single-phase, A-frame coupler (fig 13) with a telescopic top link. These operations can be made by the driver without leaving his seat.

Possible applications of new 'System' tractors

There is an interesting range of possibilities for using the machines described above in conjunction with farm implements and for transport purposes.

Front-mounting and rear-mounting of implements are clearly not new but power lifts with identical hitching devices at front and rear in conjunction with automatic couplers that can be easily observed by the driver are a new development. This also applies to the lift for mid-mounted equipment.

Front- and rear-mounted implements and automatically filled hoppers can, for the first time, be taken up or set down at any suitable point without the assistance of a second person.

As the example of sugar beet drilling (fig 14) indicates, it is often possible to use all three mounting points simultaneously. The implement at the front is effecting the final soil preparation while the seed drill is mounted at the rear. At the same time a band of herbicide, 15 to 20 cm wide, is being sprayed along the row. The herbicide is carried in the mid-mounted spray tank which, in the case of the smaller Intrac model, has a capacity of 1000 litre. At a working width of 3 m the rate of work is roughly 0.6 ha/h.

Fig 14 Seedbed preparation/drilling combination for sugar beet (Intrac 2002 A).

In the case of 6-row, beet harvesting on the French pattern, topping and lifting are performed as one operation with results which were previously attainable only by self-propelled, single-purpose machines. This combination of operations is particularly promising from the technical aspect. The rate of work varies from 0.7 to 1.0 ha/h.

A further development into a single operation is shown in fig 15. In this case, instead of being windrowed, the beet are transferred by elevator to transport vehicles running alongside. The power required for this combination of operations is about 120 hp.

The presence of a mid-mounting point and a vehicle chassis offers transport possibilities based on platform mounting (fig 16), a system characterised for its suitability for cross-country work (traction is increased by the load applied at the centre of the vehicle) and for road operations, and also for ease of handling. The useful load is 8 t with a single axle and 12 t with tandem wheels. The trailer is tipped hydraulically by remote control from the tractor. The tail gate opens and closes automatically.

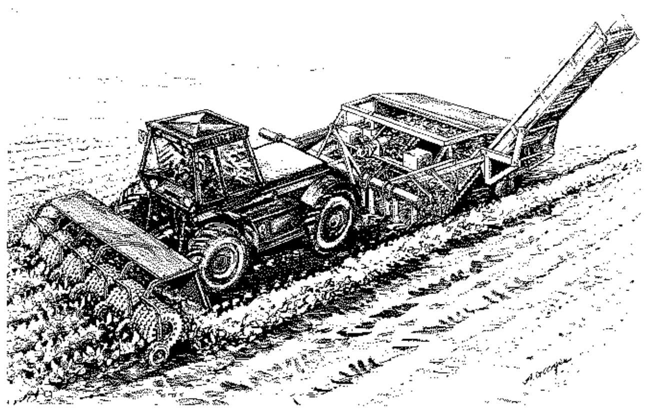
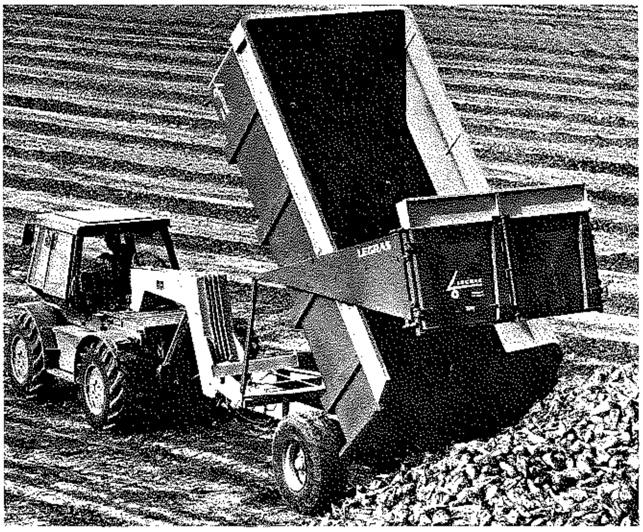


Fig 15 6-row harvesting of sugar beet in one operation.

Fig 16 (below) Intrac 2005 with platform mounted trailer.



For the sowing of cereal crops (fig 17) wide, pneumatically operated distributors (fertiliser application, drilling of seed) can be used in conjunction with a tipping supply hopper which, in the case of Intrac 2005, holds about 2 t of fertiliser or seed. If a suitable, pto-driven implement for soil cultivation is mounted at the front, the Intrac system is ideal for the 'once over' technique.

Fig 17 Planting of cereals (fertilizer application, drilling, spraying with Intrac tractor.

Lift and pto at the front can be used for the operation of a front-mounted harvester for silage maize (fig 18) ie the principle of the self-propelled machine can be applied.

Typical applications for Intrac 2002 are shown in fig 19 and 20 Further examples are the front-mounted drum type mower, front-mounted hoe and sprayer.

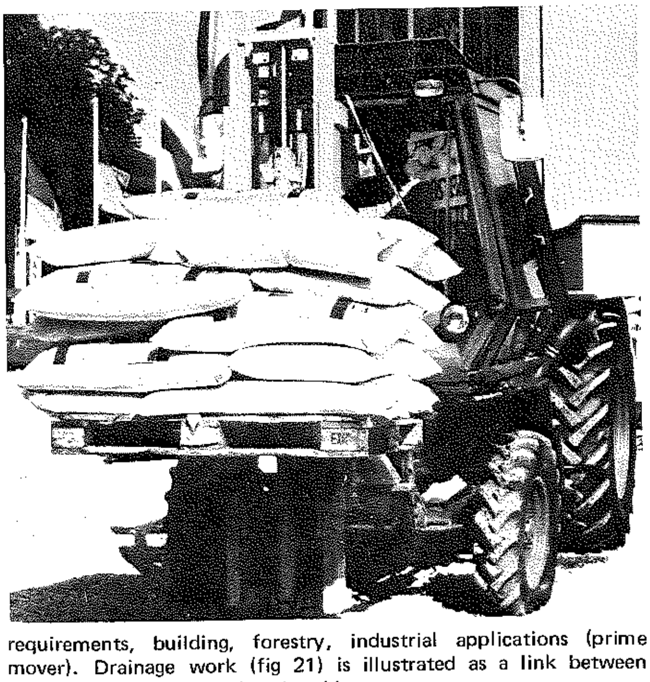
Apart from the many possible uses of these machines in crop production there are further applications in many other spheres where a mobile source of power is needed, eg municipal authority

It is essential that all members of the Institution of Agricultural Engineers keep the Secretary informed at all times of any change in their address.

Fig 18 Intrac 2005 with front-mounted 2-row maize forage-harvester.

Fig 19 (below) Combination of windrower and self-loading trailer in the harvesting of forage crops (Intrac 2002A).

Fig 20 (below) Fork lift mounted on Intrac 2002A.



requirements, building, forestry, industrial applications (prime mover). Drainage work (fig 21) is illustrated as a link between agriculture and municipal undertakings.

The potential applications of this system are so varied that only a few selected ones can be shown here.

Experience with the Intrac system

We now have several years of practical experience in western Europe with machines, which have been sold, and with test machines and a report on this is given below.

The connection of the Intrac machines with current agricultural engineering practice (on farms, with contractors, in farm co-operatives) has proved to be the important condition for introducing the Intrac system. In other words, all the present-day techniques for

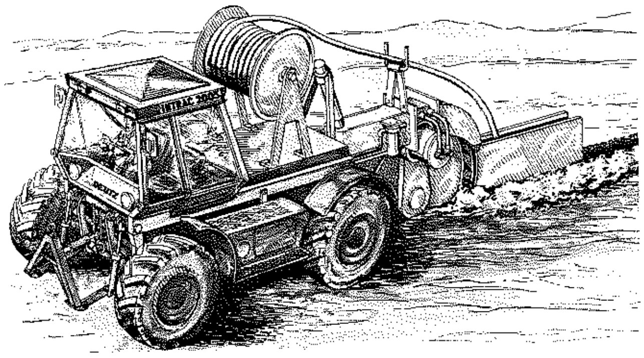


Fig 21 Drainage operations (Intrac 2005).

rear-mounting can continue to be applied within the framework of the particular tractor hp class:

3-point linkage implements,
semi-mounted or,
trailed implements.

Implements mounted on the 3-point linkage can be used with or without the A-frame coupler (Deutz hitch). When an Intrac machine is acquired, the decision is taken on many farms to fit the Deutz hitch to all tractors and 3-point linkage equipment.

Good all-round visibility and firm contact with the soil are features which have proved of positive value in practice.

The drum type mower and swather, key machines for the Intrac system in the harvesting of forage crops, can be operated in conjunction with suitable rear-mounted machines (rotary tedder baler, self-loading trailer).

In the cultivation of maize, sugar beet, vegetables and potatoes, important front-mounted equipment includes spacing drills hoes and other implements for tending the crops.

The front-mounted pto-driven machine for soil cultivation is an important element in minimum tillage (once over technique). When rear-mounted drill and supply hopper are used in combination with such a machine, 25 to 35 hp is required per metre of working width.

When operated in combination with rear-mounted sugar beet drills, front-mounted (pushed) implements for soil cultivation (fig 14) can have the effect of increasing field emergence of seedlings by several per cent. This is of particular interest (reduction of risk) when drilling early and drilling to a stand.

In the harvesting of silage maize and sugar beet, technical solutions, which were not feasible with conventional tractors are possible with the Intrac system (fig 16 and 17). It can even be claimed that self-propelled machines were required for these operations because the methods that could be applied with conventional tractors were unsuitable. By contrast with the self-propelled machine, the system tractor has, however, the advantage that, apart from harvesting, it can be used on other operations during the year so that its working time per annum is appreciably longer and its profitability higher.

By comparison with traditional transport methods, the platform mounting of trailers has a number of advantages:

Better traction and, as a result, improved performance of the tractor on arable land,
handling of the tractor is easier,
automatic opening of the tail gate and application of the principle of longitudinal flow,
good performance on road.

Quite apart from the platform-mounting aspect, a major performance benefit derives from the much higher top speed of 40 km/h ie when compared with many conventional tractors (25 km/h in the EEC). This higher speed is also an asset when moving in traffic on the road. The sprung suspension is of value on the road without being troublesome when the power lifts are in use in field work.

Tractor drivers tend generally to prefer the Intrac machines because the workplace is considerably superior to that of most conventional tractors.

To conclude, the Intrac system has the following substantial advantages over the conventional tractor:

A healthy and comfortable workplace for the driver,
application of the principle of the self-propelled machine (front-mounting of implements),
the possibility of implement combinations,
higher transport efficiency and a better solution of the transport problem.

Guide to membership of the Institution of Agricultural Engineers

Agricultural engineering

AGRICULTURAL engineering is the application of engineering to agriculture, horticulture and forestry. Agricultural engineers are concerned with the design, development and maintenance of machines and systems of mechanisation which can improve and increase crop and animal production, with greater economy of manpower and money. In a world in which the production of food and other materials is already grossly inadequate, the contribution which agricultural engineering can make to the survival of hundreds of millions of people, now and in the future, is literally vital.

The need for agricultural engineering and mechanisation is ever-growing, not only in the highly industrialised countries where labour is scarce and expensive, but also in those developing regions where hand labour alone, however plentiful, cannot produce sufficient food for populations expanding at an alarming rate.

The work of agricultural engineers includes the design and construction of machines for use on farms; the design and installation of water supply, drainage and irrigation works; soil conservation, land clearance and reclaimation; the design of farm buildings and equipment within buildings; advisory and development work on systems of mechanisation and on the selection of machines; teaching in Universities and Colleges; and the selling, maintenance and management of farm machinery and equipment, including that used on agricultural contracting work.

Agricultural engineering technology involves a vast range of engineering and scientific skills, new ones being continually developed. New materials such as plastics, new sciences like electronics and automatic control; new techniques of component and systems analysis and design using computers, are all powerful tools being used by agricultural engineers.

The British agricultural engineering industry has built up an enviable record of design, production and export of tractors and farm machinery British agriculture, in its widest context, supported by the design, production and maintenance of tractors and machinery, mechanisation and other ancillary services is one of the most efficient in the world. The Institution of Agricultural Engineers is dedicated to give the fullest possible support to those whose work supports these industries.

Aims and objects of the Institution

The general advancement of agricultural engineering and mechanisation.

The promotion of high educational standards in agricultural engineering and mechanisation.

Classifying membership of the Institution into grades, regulating entry thereto and bestowing upon members status appropriate to their grades of membership and sponsoring them, when appropriate to the Engineers Registration Board.

Conferring and co-operating with educational, legislative, public, charitable and other bodies on agricultural engineering matters.

Initiating and facilitating the exchange of information and ideas on agricultural engineering and related subjects.

Publishing technical papers and other literature of interest to agricultural engineers.

Benefits of membership

Membership of the Institution provides a status that has won widespread recognition throughout the world as a necessary career qualification. This is understandable when it is remembered that the Institution is the natural focus for agricultural engineering endeavour, linking specialists in all branches of engineering and mechanisation with the needs of agriculture and horitculture in Great Britain and overseas. Furthermore it is only through the Institution that agricultural engineers can register as Technician Engineers or Technicians, with the Engineers Registration Board. This is vital for those who wish their attainments to be recognised in relation to other technical qualifications, both in the UK and in other parts of the world.

The Institution organises programmes of national conferences, open meetings and regional activities. The facilities provided by the progressive branch network do much to promote the common interest and further the objects of the Institution as a whole. A member of the Institution can belong to a branch without paying an additional subscription. Reports of the proceedings at many national and branch meetings, also other matters of technical and current interest are published quarterly in the Institution's journal entitled THE AGRICULTURAL ENGINEER, which is supplied post free to all members.

Grades of membership

Fellow

The senior grade of membership, applicants should be well established in a professional position and normally hold qualifications at least equal to a degree in agricultural engineering or mechanisation.

Companion

This grade of corporate membership is open to those of proven ability and considerable experience in agricultural engineering who hold senior posts but whose academic qualifications do not precisely meet those necessary for the Fellow grade. Also eligible are those who are qualified at degree level in a subject other than agricultural engineering or mechanisation but who are, or have been employed in agricultural engineering or mechanisation in a position of professional responsibility.

Member

The corporate grade of membership appropriate to those, normally qualified to a standard approximately equivalent to a Higher National Certificate, who are established in the mainstream of their careers.

Technician Associate

This grade provides a career status for those working at technician level and normally qualified to City & Guilds Part II level. Technician Associateship also provides recognition for those who are still continuing with their studies, with a view to attaining corporate membership, who require immediate recognition of their technical achievements.

General Associate

This grade is appropriate for those, who may not hold qualifications in agricultural engineering, who wish to be associated with the Institution's activities and to make use of its services.

Graduate

This grade is for those who are qualified academically for Member grade but who have not yet had appropriate industrial experience.

Student

This grade is intended for those who are following courses which will lead to one of the recognised grades of membership. It enables young people to make use of the facilities which the Institution offers, for a contribution which is well below the actual cost of the services offered.

An applicant who is not certain of the grade of membership for which he should apply may leave blank the section referring to grade of membership applied for and the applicant will be offered an appropriate grade of membership or given specific advice, as appropriate.

Details of academic and other requirements for the various grades of membership are given in Appendix A.

Appendix A

Academic and other requirements for grades of membership

(details of Part I & Part II A & B qualifications are given in appendix B)

Grade of membership	*Age*	*Academic/special requirements*	*Other requirements*
Fellow (FIAgrE)	35+	Part II B list 1 Part III assessment	8 years total experience including training 5 years in position of professional responsibility 2 years in agricultural engineering or mechanisation
	35+	Part II B list 2 Part III assessment	8 years total experience including training 5 years in position of professional responsibility in agricultural engineering or mechanisation
	33–35	Part II B list 1 Part III assessment Outstanding applicant	8 years total experience including training 5 years in position of professional responsibility 2 years in agricultural engineering or mechanisation
	40+	Part III assessment Outstanding applicant Member continuously since 17 June 1970	8 years total experience including training 5 years in position of professional responsibility in agricultural engineering or mechanisation
Companion (CIAgrE)	30+	Outstanding candidate	10 years in position of responsibility in agricultural engineering or mechanisation and at the time of application in a position of considerable responsibility
	23+	Degree, or similar, in a discipline other than agricultural engineering or mechanisation	5 years training and experience at an appropriate level 2 years in a position of responsibility associated with agricultural engineering or mechanisation
Member (MIAgrE) eligible for sponsorship to Engineers Registration Board as Technician Engineer TEng (CEI)	23+	Part II A or B	5 years training and experience in agricultural engineering or science 2 years in a responsible position in agricultural engineering or mechanisation
	23+	DWSO Grade I Non corporate member continuously since 17 June 1970	10 years continuously as DWSO Grade II or equivalent prior to 17 June 1970
	30+	Part I Part III assessment	7 years total training and experience in agricultural engineering or mechanisation 2 years in a responsible position in agricultural engineering or mechanisation
	30+	Non corporate member continuously since 17 June 1970 Part III assessment	Currently Technician Associate 7 years training in agricultural engineering or mechanisation 2 years in a responsible position currently in a position of responsibility commensurate with the grade of Member
	30+ on 17th June 1970	DWSO Grade I or II Non corporate member continuously since 17 June 1970 Part III assessment	Currently Technician Associate 7 years training and experience at an appropriate level 2 years in a responsible position
	35+	*Interim procedure until 1.12.74. non corporate member continuously since 17 June 1970* *Mature candidate (Yet to be approved by ERB)*	*Either 15 years experience in agricultural engineering or mechanisation in posts of increasing responsibility or 10 years continuously DWSO prior or equivalent prior to 31 December 1973*
		Full procedure *Part III assessment* *Currently non corporate member*	*15 years experience in agricultural engineering or mechanisation in posts of increasing responsibility*

Appendix A — *continued*

Grade of membership	Age	Academic/special requirements	Other requirements
Technician Associate (AIAgrE)	21+	Part I	3 years training and experience in agricultural engineering or mechanisation
NB eligible for sponsorship to Engineers Registration Board as	30+	Non corporate member continuously since 17 June 1970 DWSO Grade II	10 years continuously as DWSO Grade II or equivalent prior to 17 June 1970
Technician Tech (CEI)	21+	Non corporate member continuously since 17 June 1970 General Grade Associate	10 years continuous employment in agricultural engineering or mechanisation
Technician (AIAgrE) Associate	*35+*	*Mature candidate Interim procedure until 1.12.74 non corporate member continuously since 17 June 1970 (Yet to be approved by ERB)*	*Position of responsibility comparable with technician associate 15 years in agricultural engineering or mechanisation 10 of these being in a technical capacity and continuous prior to 31 December 1973*
		Full procedure	*15 years in agricultural engineering or mechanisation 10 of these being in a technical capacity and continuous prior to 31 December 1973*
General Associate (AIAgrE)	21+	No specific requirements	Bona-fida farmer, or in a profession, industry or trade associated with agricultural engineering
Graduate	21+	Part II A or B	
Student	17+	No specific requirements	Following a course leading to a Part I or Part II A or B qualification

Appendix B

Academic qualifications satisfying the requirements of Part I

Degree in agriculture or horticulture of an approved university;

HND or OND in agriculture;

National Diploma in agriculture;

HND or OND in horticulture;

National Diploma in horticulture;

Ordinary National Certificate or Diploma in engineering;

City & Guilds 015 (ex 260) (Agricultural Mechanics) plus 029 (ex 261) (Agricultural Engineering Technicians') certificates;

City & Guilds 255 (ex 293) (Mechanical Engineering Technicians') (Part II) Certificate;

City & Guilds 030 (ex 405) Part 1 plus Part 2;

Any qualification acceptable by the Engineers' Registration Board for sponsorship to Tech (CEI);

Any other qualification approved from time to time as suitable pre-entry training for courses leading to qualifications under Parts IIA and IIB.

Academic Qualifications satisfying the requirements of Part IIA for Grade of Member

CNAA Diploma in Engineering;

City & Guilds 030 (ex 465) Agricultural Engineering Technicians Certificate No. 030 Part 3 with credits in six subjects;

National Diploma in Agricultural Engineering;

College Diploma in Agricultural Engineering of the West of Scotland Agricultural College;

Advanced Diploma in Machinery and Building with Management from Writtle Agricultural College;

IAgrE Part II(A) Examination for candidates of 30 years and over in the year of entry to the examination;

BSc(Agr) (Honours in Farm Mechanisation) from Universities of Newcastle or Reading;

Degree or Diploma or Associateship in Engineering or Engineering Technology of an approved University or College;

HND or HNC in Engineering;

Post-graduate certificate of grade not less than GOOD, of NCAE, based on underlying Part I qualification;

Other qualifications which, in the opinion of the Membership Panel are equivalent to any of the above.

Satisfaction of the requirements of Part IIB qualifications for Fellowship (see below) will be deemed *per se* to satisfy the requirements of Part IIA. This is especially applicable to candidates under 35 who, being under age for the grade of Fellow, may be eligible for the grade of Member.

Academic Qualifications satisfying the requirements of Part IIB for the Grade of Fellow

1. **British Isles**
   (a) Parts I and II of the CEI Examination (subject to IAgrE stipulating options under Part II *or* subject to the candidate being a practising agricultural engineer for a period of not less than two consecutive years);

   Associateship of the National College of Agricultural Engineering;

   BSc from the National College of Agricultural Engineering;

   BSc (AgrEng) from Universities in UK;

   MAgrSc (Farm Mechanisation) or (Agricultural Buildings) from the University of Reading;

   MSc (AgrEng) or (AgrBuildings) from the University of Reading;

   MSc (AgrMech) or (AgrEng) from the Universities of Dunelm or Newcastle;

   Post-graduate certificate of grade not less than GOOD, of NCAE, based on underlying Part IIA degree-level qualifications;

Appendix B — *continued*

(b) At the discretion of the Council, *and* provided the candidate is a practising professional agricultural engineer for a period of not less than two consecutive years;
CEng via corporate membership of any CEI Constituent Institution.

Appendix C

Notes for the guidance of candidates submitting a Part III Review

1. General

1.1 The fee for submitting a Part III Review, which is non-refundable, should accompany the review document.

1.2 Three copies of the document, which should be type-written, should be sent to the Secretary of the Institution of Agricultural Engineers.

1.3 There are no formal rules which relate to the length or format of the document. It is desirable, however, that each report be submitted in a folder, with the individual pages stapled at the top left-hand corner.

1.4 Once received the reports become the property of the Institution and after examination by the Membership Panel a copy will be retained in the candidate's file. Full confidentiality will be observed.

1.5 The last page of the report should bear a statement of authenticity, which should be signed by a responsible person, eg one of the candidate's seniors, such as his Managing Director, Technical Director, Chief Engineer, Professor or Principal, who where possible should be a corporate member of the Institution. A statement of the following type is recommended:

'I certify that I have read the Part III Review submitted by............................and confirm to the best of my knowledge that it is a true and accurate statement.'
Signed........................(giving designatory titles including Grade of Membership of this or other Institutions)
Institution/Company.......................
Position..................................

2. Content

In preparing the report the applicant should remember that its purpose is to convey an accurate impression of his technical responsibilities and accomplishments to people who do not know him. It must be more than a catalogue of jobs; the assessors should find it possible to derive from it an idea of the candidate's understanding of engineering principles as applied to the work on which he has been engaged. He should try to be accurate and explicit without going into unnecessary detail; he should not assume that the readers are familiar with his organisation or make use of jargon or abbreviations which are not generally understood.

Content and suggested format for presentation:

2.1 A review of the applicant's training giving names of institutions attended, durations of courses and the title of the qualification and date obtained. Where the qualification or institution may not be well known a brief description of the course of study would be advantageous.

2.2 A brief review of the appointments held (including if applicable any postgraduate work) which can be said to have contributed to the applicant's development as an agricultural engineer.

The information should include the name of the employer, duration of employment, a brief description of the nature of the job and the level of responsibility.

2.3 A detailed account of the current appointment which allows the Membership Panel to adjudge the level of responsibility the candidate has in his job.

It should contain an account of:

the type of work the applicant is doing (eg design, product development, production planning); the main products with which he is involved (or alternatively, the subject of research or teaching); how long he has been actively working on the above.

He should try to bring out any particular characteristics of the work in hand which would test the abilities of an agricultural engineer. It is important to state clearly what the candidate's own personal role is in the work on which he is engaged and to try to make it clear how far he is expected to go on his own responsibility. In the case of an applicant holding a Part IIB qualification other than in agricultural engineering or mechanisation special attention must be given in this section of the report to show that he has completed a period of at least five years in a position of professional responsibility in agricultural engineering or mechanisation.

2.4 Any other relevant information concerning his career or related interests which might help the assessors to draw up their recommendations. A list of publications and papers which have been read at meetings or conferences, and the names of committees or working parties of well-known bodies upon which the candidate has served would come within this category.

If published literature or notes about mechanisms or machines designed or schemes supervised are enclosed to endorse the candidate's application only *ONE* copy of these need be sent.

3. Method of processing Part III Reviews

The secretariat will acknowledge the receipt of the Part III Review. The Review will be examined by the Membership Panel, which may in certain cases request further details from the applicant. The time required to deal with applications involving a Part III Review is likely to be between three and six months.

COSTS OF MEMBERSHIP

Annual Subscription	United Kingdom £p	Abroad £p
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FURTHER DETAILS AND APPLICATION FORMS MAY BE OBTAINED FROM THE SECRETARY.

The full and correct postal address of the Institution of Agricultural Engineers is:

**The Secretary,
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2. Overseas

The degrees of a number of overseas colleges are recognised by the Institution as satisfying the requirements of Part IIB. This is continually being updated and it is impractical to publish it. Applicants with degrees from overseas colleges are advised to give full information regarding type and content of degree.

Factors affecting the width and speed for least cost tillage

by Frank M Zoz

Summary

EQUAL productivity can be obtained with various combinations of width and speed. Investment costs increase with slow speeds while operating costs tend to increase at higher speeds. An optimum width and speed exists for given conditions.

Tractor performance and plow draft predictions are made. Tractor and plow prices are estimated, total costs (fixed and variable) are determined and the optimum width and speed is calculated to give the *least total cost per acre.* While an optimum point can be determined, the cost function is not extremely sensitive to change and a wide range of widths, speeds, and power levels allows operation within a few percent of the minimum cost.

There are many factors which affect the optimum design for minimum cost. Some of these factors, including fuel and labor costs, tractor annual usage, acres plowed per year, and plow draft requirements (soil type) have been given additional study. While the tillage operation has been studied in detail, also of prime importance are the *tractor hourly costs* as these costs must also be assessed against the other tractor operations. When total annual tractor costs are considered, the tractor's design travel speed will exceed that which gives least cost tillage.

Frank M. Zoz is Senior Engineer of Product Test & Evaluation, John Deere Waterloo Tractor Works, Waterloo, Iowa 50643 USA.

Paper given at annual conference of Institution, in London, on 7 May 1974.

→ *concluded from page 73*

Hence the essentials are provided for rationalising production methods with a view to:

Improving operating conditions (increase in motivation),
reducing the specific physical effort (increase in output) and
reducing unproductive time (increase in output).

It may be expected that the Intrac system will become increasingly important in a future planned production in agriculture.

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Introduction

Primary tillage has always been one of the larger power consuming operations on a farm. As such it is the operation that most influences the size of the power unit required for the total farm operation. Over the years the moldboard plow has been the most accepted primary tillage tool, only recently being challenged by various systems offering types of reduced tillage. Reasons for this are varied but a primary stimulus is the desire to increase productivity and minimize cost.

Increases in productivity in field operations can be accomplished in at least three ways: (1) increasing size and width of machine, (2) increasing travel speeds, or (3) combining operations to limit the number of trips across the field.

For an analysis of total farm system, alternative number 3 can be very important. However, for purposes of this paper we are limiting considerations to the first two alternatives – increasing size and increasing speed. Productivity of the tractor primary tillage system is usually limited by the power available from the tractor. With an increase in power either may be a satisfactory alternative to increase productivity. What are some of the advantages and disadvantages of each approach?

Increasing width

It is a relatively simple engineering matter to scale up the tractor implement combination to increase the unit size. No new technology is involved. Remaining at the same travel speeds creates no new functional problems in the field. With increasing farm size and some increase in field size, field efficiency should not be adversely affected.

However, the larger implements are much more difficult to transport when farm operations are spread out geographically as is often the case. Larger implements can be expected to increase in cost at least in proportion to their width and likely more due to heavier frames required for the larger machine. If the ground is level no operational problem is likely to result from increased width. However, in the normal situation or in the special case where terraces are involved, an excessively wide implement may not have the required flexibility to follow the contour of the ground. Larger implements also require larger components at the tractor implement interface and result in more difficulty in hitching. Tractor weight and ballast required is directly proportional to the size of the implement. Increasing width not only requires a heavier and thus more expensive tractor but also one with design to transmit high power at low speeds (also resulting in increased cost).

Increasing speed

History has seen a gradual increase in plowing speeds in spite of some disadvantages that may result from it. The cost per unit of implement width may increase if higher speeds are utilised because of functional and durability requirements. Under certain soil conditions, accelerated wear may occur on the soil engaging elements unless better and more expensive materials are used. High speed operation in rocky soil may be impossible without the extra expense of automatic resetting bottoms or spring cushion standards. Fatigue life may be decreased because of the higher frequency of loadings at increased speeds. New technology may be required to obtain satisfactory function and durability. Operator ride and control factors become more critical items at higher speeds.

Utilisation of increased power by higher travel speeds does have several important advantages. Since machines usually cost in proportion to their weight, the smaller size plow and tractor required for higher speed operations have a lower investment cost. The tractor may have lower cost per unit of power. The smaller size not only results in a more maneuverable tractor-plow combination but results in a tractor more adaptable to other farm operations where power may not be the biggest requirement.

There are, of course, both economic and non-economic factors involved in determining the optimum width and speed for a given situation. Economics will not always be the most important factor. However, for most farms, it is important and for the industry as a whole, it is the single most important factor involved in the design of future tractor implement systems.

In a recent ASAE paper by the author[1] procedures were shown for determining the optimum width and speed for least cost tillage under given (normal or average) conditions. It is the purpose of the present paper to further study some of the factors which might affect the optimum tillage speed with emphasis upon UK conditions.

As shown in previous paper[1] the following steps are necessary to predict the economics of the tractor tillage systems:

(1) Prediction of tractor performance,
(2) prediction of implement draft requirement,
(3) matching of tractor and implement,
(4) prediction of the productivity (acres/hour),
(5) estimation of tractor and implement investment costs,
(6) determination of fixed and variable costs and optimization for least total cost/acre.

Predicting tractor performance

Methods for predicting the performance of tractors in the field were outlined in a previous paper by the author[2] and were combined with the work of Luth and Wismer[3] to provide the approach used here. Luth and Wismer[3] have established methematical relationships for performance of tires in soils whose strength is specified by Cone Index[11]; they have also suggested design points for optimising vehicle performance.

These design points are very much in line with the author's experience and in line with UK values provided by personal communication with Mr John Matthews, NIAE, for this paper. The design points establish the optimum tractive efficiency, dynamic ratio (ratio of drawbar pull to dynamic weight on the drive wheels) and travel reduction for the performance prediction under given tractive conditions. Tractor weight distribution and implement-tractor weight transfer characteristics must also be considered in making the performance prediction.[1,2].

Figure 1 can be used to predict the performance and weight requirements for two-wheel drive tractors over a range of two to nine miles per hour on soils ranging from 50 to 200 psi Cone Index. The curves are based upon the design points. A travel speed and a tractive condition established a point on the chart from which values of pull, weight, and drawbar horse-power can be determined (in terms of pto hp). For figure 1 it was assumed that the axle horse-power was equal to about 96% of the pto horse-power. This can be considered typical for simple gear type transmissions. Values can be adjusted for other types. The design travel reductions are those that give near maximum tractive efficiency for the given soil strength on single R1 tires, loaded to about (less than) 90% of their maximum weight carrying capacity.

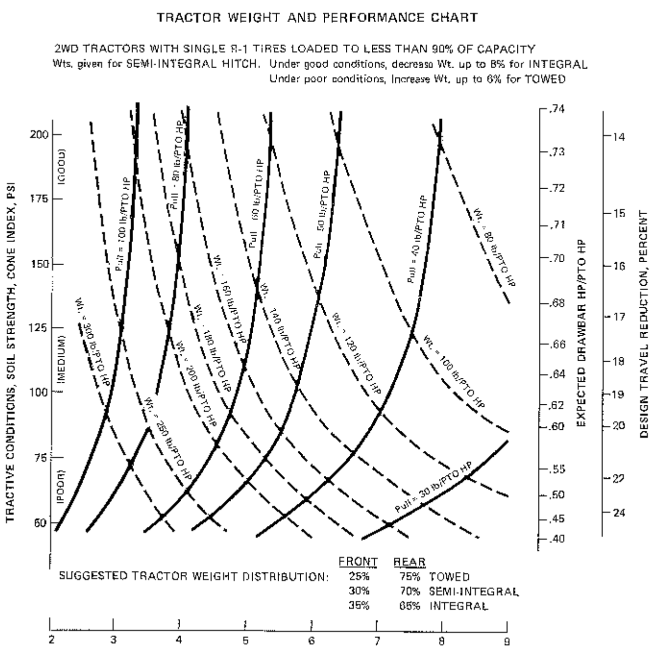


Fig 1

Implement draft requirements

Typical moldboard plow draft curves are shown in fig 2. These curves recognize the generally known fact that the draft of nearly all soil engaging tools increases with travel speed and that for moldboard plows the draft generally varies with the square of the travel speed. Tests show that a relationship of the following type can be used:

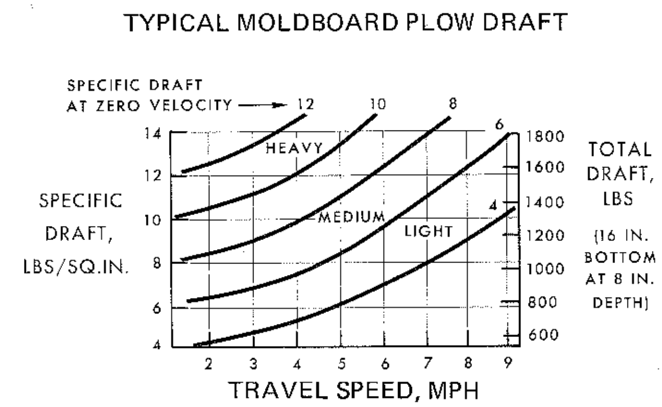


Fig 2

Specific draft = XK1 + XK2 $(SA)^2$

Where:

Specific draft = Draft per square unit of furrow cross section (lbf/in^2)

XK1 = Specific draft at zero velocity (lbf/in^2)

XK2 = Velocity coefficient

SA = Actual travel speed (miles/h)

Considerably less draft data are available for chisel plows. Generally, the draft per unit of width is less for a chisel plow because the entire volume of soil is not being disturbed. The draft can be expected to vary with the square of the depth since a triangular section of soil is normally being worked. The speed effect is less pronounced than for a moldboard plow and the draft appears linear over the normal speed range, increasing somewhat with travel speed.

Matching of tractor and plow; prediction of productivity

Tractor and implement are matched on the basis of the implement draft requirement and tractor pull capability. The power limited travel speed is determined and is combined with the implement width and estimated field efficiency to predict the productivity in acres/hour.

$$APH = \frac{(SA)\ (W)\ (FE)}{8.25}$$

Where:

APH = Acres/hour

SA = Actual travel speed (miles/h)

W = Width (ft)

FE = Field efficiency ratio

The combination of tractor, implement and productivity relationships is shown graphically in figure 3 for moldboard plowing under typical UK conditions. This method resulted from unpublished work by Luth. It shows the interaction of plow size, tractor horse-power, tractor weight and travel speed and the resulting productivity. The curves are only valid, of course, for the constants shown. Any two values locate a point on the graph. For example, in figure 3, point 1, four bottoms (16 in) at 5.0 miles no-slip travel speed results in 4.1 miles/h actual travel speed, requires about 160 lb tractor weight per pto hp, about 85 pto hp, 9500 lb, on the tractor drive wheels (2WD) and will result in about 2.1 acres per

MOLDBOARD PLOW PRODUCTIVITY

APPROXIMATE TRACTOR WEIGHT TO PTO HORSEPOWER RATIO REQUIRED, LB/PTO-HP

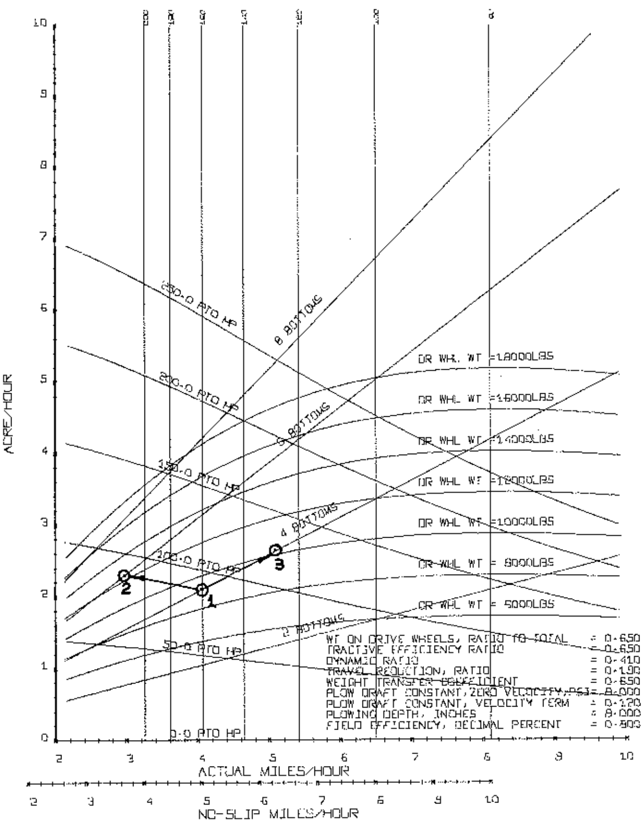


Fig 3

hour. From a given point any value can be held constant and another point determined. For example, if a constant 85 pto hp is followed going down in travel speed, we would find (point 2) that six bottoms could be pulled at about 3.0 miles/h with an increase of about 0.2 acre/h. This combination requires 12,000 lb on the tractor drive wheels, and expensive design for high strength in the lower gears. A better and perhaps more economical alternative might have been to remain with 4 bottoms, increase the power level to 125 pto hp with resulting 5.1 mile/h travel speed (point 3). Greater productivity increase results from this change.

Tractor and plow price relationships

Specific price information is available for any given implement or tractor. However, for this analysis it was necessary to determine implement and tractor costs in general terms, particularly in terms of the performance parameters of width, travel speed, power, and weight. Price information for tractors currently on the market can be used to establish price relationships at current travel speeds.

Recognising that manufacturing cost varies with weight, the following type of relationship has been used to project purchase price of the tractor (2WD) over a range of travel speeds:

$$PURT = \frac{C_1 \text{ (PTOHP)}}{\sqrt{SA}} + C_2$$

Where:
PURT = Purchase price of tractor, \$
C_1 and C_2 = Constants
SA = Actual travel speed (miles/h).

Travel speed and operating weight are related as shown in figure 1. The constant C_2 represents items such as cabs and operator stations whose cost is not directly related to the size, power or weight of the tractor.

The tractor cost function used in this paper is shown graphically in figure 4. Tractor total cost, cost/lb and cost/pto hp are shown as a function of the tractor design operating weight and pto hp.

The price relationships for plows are not so well defined as that for tractors. In general, there is less need for precision in plow price estimates as it is a relatively low contributor to the total costs. Plow prices have been determined to be a function of the width, and a speed factor is applied to allow for probable increase in cost per unit

GRAPHIC REPRESENTATION OF TRACTOR COST FUNCTION

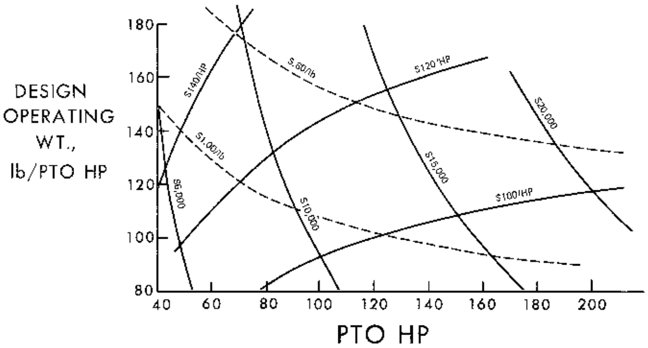


Fig 4

width for satisfactory life at increased speeds. The following type of relationship has been used:

$$PURP = C_3 \; (W(\sqrt{SA})$$

Where:
PURP = Purchase price of plow, \$
W = Width of plow (ft.)
SA = Actual travel speed (miles/h)
C_3 = Constant

Values of the constant have been selected to provide purchase prices representative of tractors and plows presently on the market at current travel speeds.

Cost determinations and optimization

After the performance and purchase prices have been predicted, the fixed and operating costs can be calculated. Optimisation is really the process of determining the trade-off between fixed and operating costs to determine the best combination of width and speed for the least total cost per unit of area plowed. The higher investment costs of slow speed operations are balanced against the higher operating cost at increased speeds. Cost factors considered are:

1. Depreciation — straight line depreciation is used. The total costs are the average over the life of the tractor and plow.
2. Interest — calculated at current annual rates.
3. Taxes, insurance, shelter — estimated as a percentage of purchase price.[7]
4. Labor — current on-farm hourly rates.
5. Fuel — current cost/gallon. Consumption is calculated, based on pto hp required.
6. Repairs and maintenance — estimated as a percentage of the purchase price.[7]

Nominal values of the variables were agreed upon in personal communication with Mr John Matthews, NIAE, to be representative of UK conditions. It was comforting to note that the values relating to performance were not greatly different than those used in author's previous paper.[1]

The following are the primary variables used in the optimisation shown in following figures. Nominal Values are given:

Tractive efficiency ratio — TE = .65
Dynamic ratio — DR = .41
Travel reduction — TR = .19, (19%)
Ratio of drive wheel weight to total weight — RWR = .65
Dynamic weight transfer coef. — DWC = .65
pto to axle hp ratio — PTAXE = .967
Specific draft at zero velocity (medium draft soil) — XKI = 8 psi; also varied.
Plowing depth — DE = 8 inches
Field efficiency — FE = .80, (80%)
Tractor use — tractor is used 600 hours per year exclusive of plowing. Plow hours are added to obtain the total; also varied.
Tractor life — life of tractor is 4000 hours or 5 years, *whichever comes first*. Plowing hours are calculated, added to the tractor hours and life is calculated.
Tractor fuel efficiency — tractor pto hp-hr/gal = 15 (US gallon); 18 (Imp. gallon).
Plow life - assumed to be 10 years.
Interest rate — annual rate of 12% is used.
Salvage values — tractor — 40% after 5 years (or 4000 hours). Plow — 10% after 10 years.

Plow use — 200 acres/year are plowed; also varied.
Fuel cost — $.30/US gallon (15 p/imp. gallon); also varied.
Labor cost — $2.00 (83 p)/hour; also varied.

A computer program was developed to calculate the performance of the tractor and the requirement of the plow, to predict the productivity, to calculate the individual cost items, and to plot on a width and speed coordinate system. The optimum point (least total cost/acre) is determined and contours of equal cost, at percentages greater than the minimum, can be plotted.

Figure 5 shows an example of the program output using assumed inputs previously listed. For this set of variables, the minimum cost/acre was determined to be at 5.2 ft wide and 5.0 miles/h. Other values are 116 pto hp, 2.5 acres/hour, approximately four 16 inch bottoms and required tractor weight of 130 lb/pto hp. For these variables the minimum cost was determined to be $5.35 per acre. The contour shown represents total costs/acre 5% greater than the minimum. In other words, all the area inside the contour is within 5% of the minimum cost. It is interesting to note the size of the area, showing the relative insensitivity of the total cost function to changing widths, speeds or power levels. A 200 pto hp tractor at over 7 miles/h can have total plowing costs equal to a 100 pto hp tractor at about 3 miles/h (both 5% over the minimum).

TYPICAL COST OPTIMIZATION MOLDBOARD PLOWING

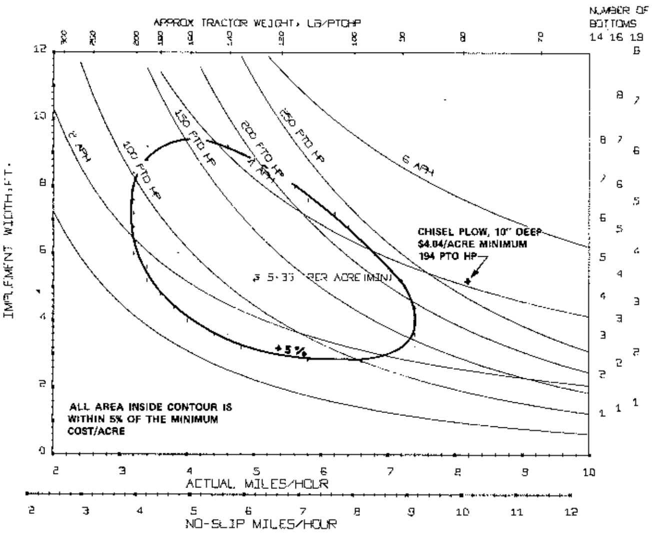


Fig 5

Also shown in figure 5 is an optimum point derived for chisel plowing under similar conditions. More study of the relationships for chisel plowing is required before valid conclusions can be reached. There are perhaps factors other than economics that are tending to keep field speeds lower than shown as optimum.

Effect of changing input variables

There is nearly an infinite combination of the variables that can be analysed. The work to this point has been directed toward a select grouping that have been considered average or normal. It is of interest to study some of the variables in more detail to see their effect on the optimum design. The following have been given further study:

1. Area plowed annually, acres per year,
2. tractor annual usage (other than plowing), hours per year,
3. Plow resistance (specific draft) (lbf/in²),
4. Cost of fuel, $/gallon,
5. Cost of labor, $/hour,
6. Plowing depth,
7. Rate of interest.

Each one of these variables has an effect upon the design optimum width and/or speed as well as an effect upon the magnitude of the cost/acre.

Figure 6 shows the general effect that each of the above variables individually has on the optimum width and speed. All other variables were held at the nominal value while one was varied. Increasing plowing depth and plow draft (soil type) tend to reduce the design optimum travel speed with little effect on the width. Increasing the tractor annual usage (other than plowing), the number of acres plowed per year, or the labor cost have the greatest effect on the design width.

Changing the rate of interest has no effect on the optimum

EFFECT OF SELECTED VARIABLES ON OPTIMUM WIDTH & SPEED
(MOLDBOARD PLOWING)

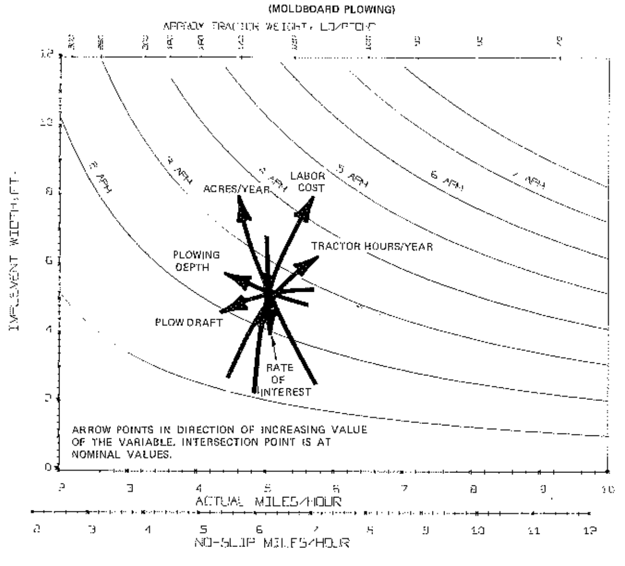


Fig 6

speed. While not specifically studied here it is to be expected that inflation of the purchase prices would have a similar effect.

Additional analysis of the effect of changing the input variables has been made. A method has been developed where they can be studied in pairs. The following figures show effects of changing five variables:

figure 7 Plowing resistance and acres plowed per year.
figure 8 tractor annual usage and acres plowed per year.
figure 9 fuel cost and labor cost.

In figures 7 and 8 the optimum (lowest) cost per acre, pto horse-power level, and tractor weight to power ratio are shown as a function of the two given variables. Design travel speeds are also shown. Figure 9 shows how the tractor hourly costs can be expected to change with increasing fuel and labor costs.

EFFECT OF TRACTOR USAGE & ACRES PLOWED ON THE OPTIMUM DESIGN FOR LEAST COST PLOWING

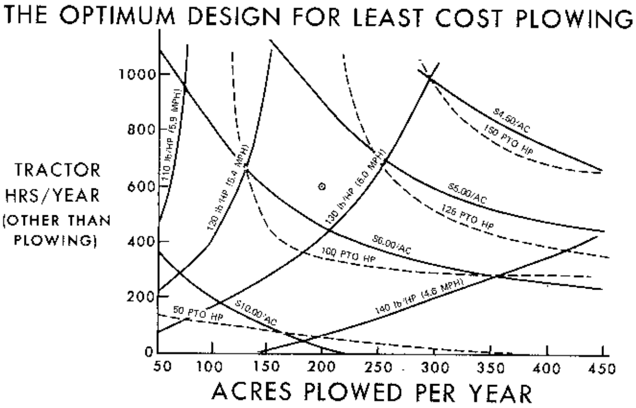
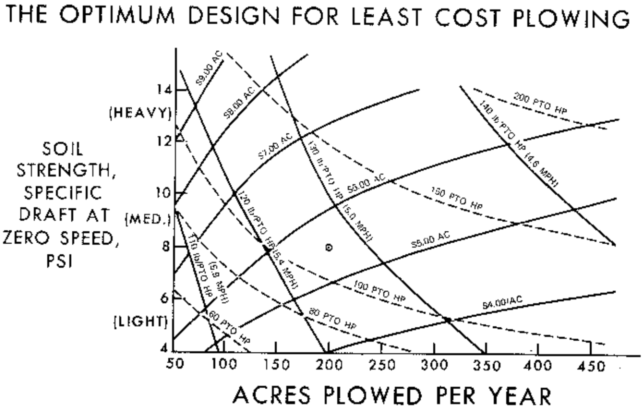


Fig 7 (above)

Fig 8 (below)

EFFECT OF PLOW DRAFT & ACRES PLOWED ON THE OPTIMUM DESIGN FOR LEAST COST PLOWING



EFFECT OF FUEL & LABOR COST ON THE OPTIMUM DESIGN FOR LEAST COST PLOWING

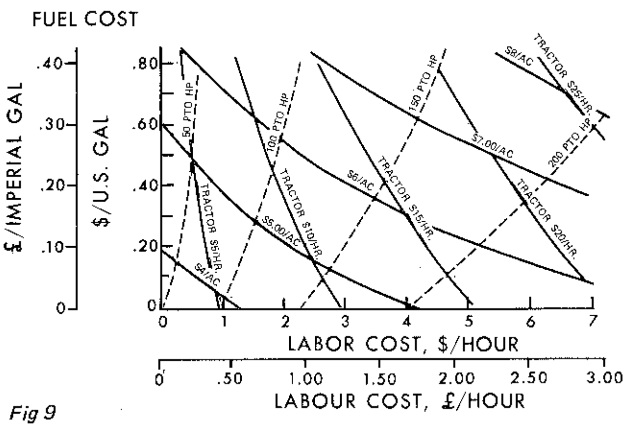


Fig 9

Each of the curves (figures 7, 8, 9) requires detailed study to understand the interaction of the variables. The nominal point is indicated on each figure. For example, in figure 7, the nominal plow resistance value was 8 lbf/in^2 with a nominal 200 acres plowed per year. This resulted in 116 pto hp and $5.35 per acre plowing cost with about 126 lb/pto hp tractor weight for 5.2 miles per hour plowing speed. When studying the effects of the variables in figures 7, 8 and 9 it is well to keep in mind the relative insensitivity of the total cost function to change of width and speed around the optimum point. This was shown by the large 5% area in figure 5. The optimum point should serve only as a guide to the effect of changing the variables.

In figure 8 we can see a significant decrease in the cost of plowing as the tractor hours per year (exclusive of plowing) are increased. For example, a tractor plowing 200 acres per year exclusively (zero tractor hours per year other than plowing) shows a minimum cost of $10 per acre with a 40 pto hp tractor. This can be reduced to $6 per acre simply by using the tractor 450 hours for other work, with the bonus that the optimum power level is now over 100 pto horse-power. This supports the concept of a general purpose tractor design, one which can be used for a large number of operations on the farm.

For these other operations to be economically performed, it is necessary that the *tractor hourly costs* be kept to a minimum.

Figure 10 shows both the total plowing cost/acre and the *tractor cost per hour* for a 116 pto hp tractor (UK optimum?) over a range of design travel speeds.

EFFECT OF SPEED ON TRACTOR HOURLY COST & TOTAL PLOWING COST

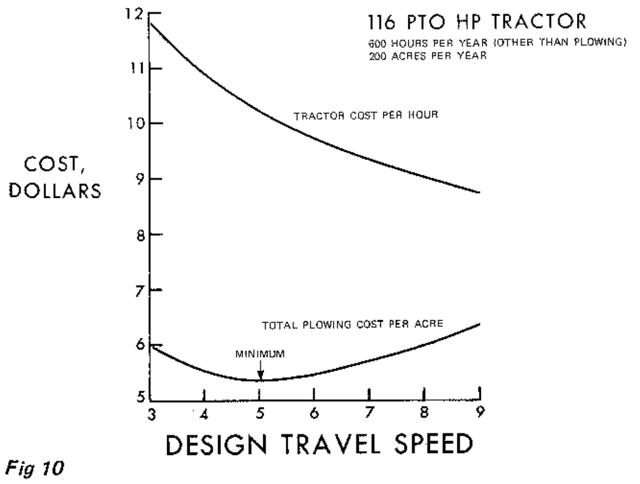


Fig 10

While it is beyond the scope of this paper, the ultimate in optimising tractor and machinery costs would mean not only designing for minimum plowing costs but for minimum total machinery costs. Since the tractor can be a major cost item, reducing the tractor hourly costs could significantly reduce the total machinery costs. For this reason, evidenced by figure 10, the true optimum tillage speed may be even higher than has been shown in this paper.

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A systematic tractor range

by A Grečenko

Summary

IN order to rationalise the production and operation of tractors it appears expedient to specify the parameters of particular types of tractors in such a way they would constitute a coherent range with regard to field performance without undesirable gaps or overlaps.

A tractor range must be formed in a certain system whose constituents are the classified quantity and the method of classification. In particular the system based on engine power is considered to be well adapted for tractor applications, its classified quantity being the rated engine power graduated to conform to the rate of work in ploughing.

This paper includes a new theory of the performance of a tractor and plough or similar traction combination, defining exactly under what conditions the combination would attain the highest output. The theory provides the basis from which to derive the method of classification of the power-system.

A typical power-range of wheeled tractors is given as an example. Subsequently the tractors of this range are evaluated with respect to design concept, unification of engines and several operational aspects.

1. Introduction

The programmes of production of many significant tractor manufacturing firms include complete lines of models with power rating approximately between 20 and 120 kW. Sometimes these production lines consist of more than 10 models with a minimum difference in engine power less than 10 kW.

If the sales organisation is well established, such a choice of models makes it possible to put on the market tractor types with properties and performance well adapted to diverse requirements of farmers. It may be concluded that a large assortment of models can help the firm to compete with other manufacturers.

On the other hand from the point of view of production efficiency and tractor maintenance costs there is a pronounced tendency towards steady rationalisation of production programmes. This means, in addition to other measures, that a maximum quantity of assembled units of the same type should be achieved by reducing the number of different types and through unification of their basic components eg by fitting highly unified engines with different output into tractor bodies of similar design.

There should exist a certain succession of different tractor models whose number would be appropriate from the view of economy of production and at the same time, in combination with implements and machines, this range of tractors would provide the desired performance and economic features. The problem is to specify the rules for establishing such a range, that is to say to form a system.

Economic aspects play an important part in considerations about tractor/implement operating qualities. The total costs per unit area and their relation to the performance of the tractor have been intensively studied for instance by Netík (1967) and by Zoz (1973) with most valuable results. However it would be extremely difficult to formulate a general system of tractors on the basis of production and operation economics because the corresponding relationships are subject to continuous and uncertain changes.

More likely, a system of tractors may be established on the basis of operation properties of tractor/implement (machine) combinations, recognising the fact that the model of a tractor range will not only be a result of applied theory but a matter of opinion and convention as well.

In the meantime the tractor manufacturers have a longstanding practical experience with the structure of lines of their models. This paper is meant to be a contribution to the present state of the art, in the sense that it tries to formulate principals on which to determine a rational system of tractors as one of the factors for deciding about the systematic tractor range which may come into production.

2. Considerations about tractor systems

2.1 For the purpose of this paper a system means a set of rules which can be used to form a rational line of products. In a strict sense it refers to a system of tractors, in a wider sense with regard to future evolution it acquires the meaning of an integrated system of tractors and self-propelled machines.

With respect to the level of organisation and integration of manufacture a system may have a more general acceptance (national or international) or rather specialised validity (particular firms). Accumulated experience and the development of agricultural production requirements will probably assist a gradual convergence of both these variants.

In order to be exact, that is to give for certain conditions unambiguous values of all the members in the range, a system must have two precisely defined components:

(a) Classified quantity CQ,

(b) method of classification MC.

The classified quantity is a basic technical parameter which represents the whole machine and provides a basis for deduction of other parameters. The classified quantity must have a physical meaning, a simple definition, and be measurable.

The method of classification is a procedure to determine the succession of values of the classified quantity. This succession has not necessarily the regularity of a mathematical series; however it must abide by a definite law.

Some of the principal tractor systems are the following:

1. traction system;
   CQ . . . nominal drawbar pull;
   MC . . . drawbar pull;
   tractor range with traction classes;
2. power system;
   CQ . . . rated engine power;
   MC . . . rate of work (in tillage);
   tractor range with power classes.

2.2 The well-known traction system was worked out in the mid-fifties by Trepenenkov (1963) and then refined especially from the point of view of the MC, for instance by Parfenov (1968) and again Trepenenkov (1970).

2.3 In the power system, the engine power is a universal quantity which specifies the field performance of a tractor/implement (machine) or tractor/trailer combination expressed by means of rate of work (field area or soil volume worked per unit of time) or transport capacity (transported mass per unit of time). In operations where traction is predominant, the concept of power (eg drawbar or tractive power) includes both the drawbar pull and working speed since the drawbar power equals the product of these quantities.

The rated engine power (or perhaps the power transmitted through the power take-off shaft) is exactly defined and can readily be measured. It seems to be useful also for an integrated power system for tractors and self-propelled machines because these machines are often equipped with adapted tractor engines and other components. Thus the common features of tractors and self-propelled machines are with respect to design mainly the engine power and with respect to field operation mainly the field performance.

The method of classification could perhaps be based on the limits of acceptable engine loading (for instance 60—90%) but the discussed field performance as MC appears to be far more advantageous and significant.

The most suitable approach to derive the method of classification both formally and logically is to use the field performance (rate of work) in primary tillage, namely in ploughing, which is the most energy-absorbing operation. This field performance has direct bearing upon the lay-out of a tractor/plough combination (traction combination) and thus on the design of a tractor itself.

The next section will deal with this problem.

3. Theory of performance of traction combination

3.1 For ploughing the rate of work by volume W_V in the main

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productive time (ie 100% field efficiency) may be expressed by the following alternative formulae*:

$$W_V = S.v = \frac{F_X.v}{p} = \frac{P_f}{p} = b_p.d_f.v = W_S.d_f \tag{1}$$

where

$$P_f = P_e.\eta_f = P_m.\alpha_p.\eta_f \tag{2}$$

The specific soil-plough body draught (further on simply specific draught) depends on the speed of ploughing as follows:

$$p = p_0 + \epsilon(v - v_0)^2 = \frac{F_X}{S} \tag{3}$$

where the term v_0 expresses the fact that most measurements of draught of a plough indicate the minimum draught at a speed $v_0 >$ 0.

The function according to formulae (1) and (3)

$$P_f = W_V[p_0 + \epsilon(v - v_0)^2] \tag{4}$$

for a constant value of the rate of work W_V will be referred to as the performance function. This may be plotted by means of a network of velocity equi-potential lines $v = P_f/F_X$ = const (see Grečenko 1968) into the co-ordinate axes of a traction characteristic $[F_X; P_f]$ as presented in fig 1. The performance function belongs with regard to specific draught to a certain type of plough body in a certain soil.

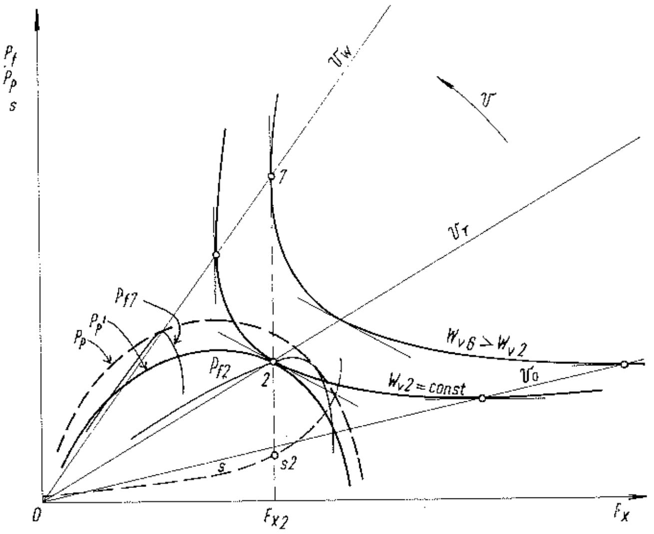

Fig 1 Performance of tractor/plough combination.

The general magnitude of the slope of the performance function is:

$$\frac{dP_f}{dF_X} = \frac{dP_f}{dv}\cdot\frac{dv}{dF_X} = \frac{2(v - v_0)\ .v^2}{v^2 - {v_0}^2 - p_0/\epsilon} \tag{5}$$

which indicates that the wanted slope depends only on working speed and on properties of the soil-plough body system. A certain velocity line intersects all the performance function curves at the same angle.

Further analysis of the performance function reveals that its minimum corresponds to the velocity $v = v_0$ and that for the velocity denoted as v_W:

$$v_W = \sqrt{({v_0}^2 + \frac{p_0}{\epsilon})} \tag{6}$$

the slope reaches the infinite value.

The speed v_W is significant for further development of the theory for reasons which will now be explained.

A tractor may be designed in such a way that its part load curve of potential power $P'_p = \alpha_p.P_p$ (where the full load curve of potential power P_p is the envelope of drawbar power curves P_f, see Grečenko 1968) just touches the performance function for W_{V2} at the tangent point 2 with the abscissa F_{X2} and corresponding slip s_2. The relevant velocity v_T will be simply called tangential velocity. A properly chosen gear ratio will provide the drawbar power P_{f2} passing through the tangent point 2 so that this point represents a working mode of a tractor with a plough whose width of cut b_p equals $W_{V2}(d_f v_T)$.

It is evident that the performance function for W_{V2} that has a common tangent with the curve of potential power P'_p at the point 2, represents the maximum rate of work in ploughing which the respective tractor can achieve at the desired engine loading. The tangential velocity v_T should be kept within the limits indicated by the plough manufacturer to observe the quality of ploughing.

Let us suppose, however, that it is permitted to surpass this speed. In this case increasing the engine power of a tractor with constant mass makes for shifting of the working mode point up the vertical with the abscissa F_{X2} towards higher speeds and performances until it reaches the point 7 at the speed v_W with the respective rate of work W_{V6}. Further increase of engine power with consequent shift of the working mode point still upwards would be useless because the rate of work after exceeding the velocity v_W would begin to decline.

Therefore the performance function for W_{V6} represents the absolutely highest field performance of a certain tractor/plough combination. This assertion may be checked directly by calculating the condition for the extreme of the rate of work by volume at drawbar pull F_X = const. Again the solution is $v = v_W$ as in the formula (6).

In fact, ploughing at the speed v_W would be of poor quality and uneconomic since the energy E_V required to cut and turn the unit volume of soil

$$E_V = \frac{P_e}{W_V} = \frac{p}{\eta_f} = \frac{p_0 + \epsilon(v - v_0)^2}{\eta_f} \tag{7}$$

increases with the square of velocity. Ultimately an effort to compensate for this phenomenon through improvement of tractive efficiency would not be effective.

3.2 The next task is to determine and analyse the properties of the tangent point 2 (fig 1). The common tangent of the curves P'_p and W_{V2} = const must have a slope satisfying the condition:

$$\frac{dP'_p}{dF_X} = \frac{dP_f}{dF_X} \tag{8}$$

The inevitable mathematical procedure will only be outlined to the extent of providing a basis for eventual recomputation. For this purpose the scheme of a tractor with forces and dimensions in fig 2 is given as a complement to the list of symbols.

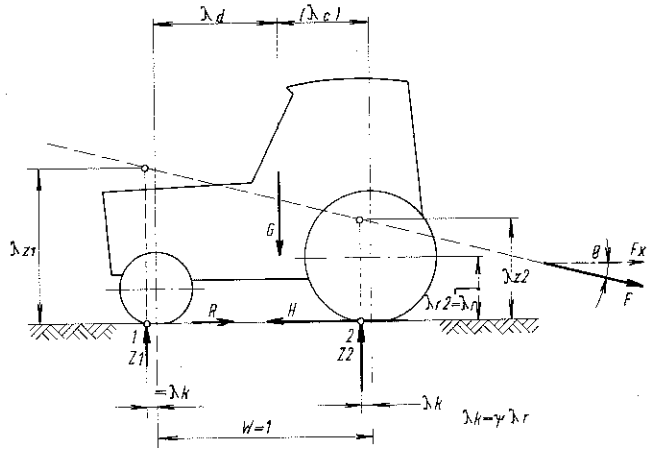

Fig 2 Scheme of a tractor.

The author on principle, for driving wheels, relates zero slip $s = 0$ with zero thrust force $H = 0$ where the thrust force equals net traction force plus rolling resistance of these wheels (ASAE R 296).

The sum of rolling resistances of all the wheels of a tractor is denoted R. In this way the respective definitions are:

2WD tractors: $H = \mu.Z_2;\ R = \psi(Z_1 + Z_2)$

4WD tractors: $H = \mu(Z_1 + Z_2);\ R = \psi(Z_1 + Z_2)$

The slope of the curve of potential power P'_p is to be computed on the basis of its equation:

$$P'_p = P_p.\alpha_p = P_m.\alpha_p.\eta_f \tag{9}$$

**A list of symbols is given at the end of the paper.*

where the tractive efficiency equals:

$$\eta_f = \eta_t \cdot \eta_s \cdot \eta_r \tag{10}$$

The transmission efficiency η_t is considered constant, the travel reduction η_s is a function of the coefficient of thrust μ

$$\eta_s = 1 - s\ (\mu) \tag{11}$$

and may be expressed by means of the binomic slip-thrust equation (Grečenko 1967) based on the principles of terramechanics:

$$s = \frac{s_t}{2} \cdot \frac{3\alpha - 2\alpha^2}{1-\alpha} \tag{12}$$

or reciprocally

$$\mu = \frac{\mu_m}{4}\left[2\frac{s}{s_t} + 3 - \sqrt{[(2\frac{s}{s_t} - 1)^2 + 8]}\right] \tag{12a}$$

where

$$s_t = \frac{jk}{l};\ \alpha = \frac{\mu}{\mu_m};\ \mu_m = \frac{c}{p_c} + \tan\phi$$

The force ratio η_r as a function of the gross traction ratio $\rho_f = F_x/G$ (ASAE R296) equals:

$$\eta_r = \frac{F_x}{H} = \frac{\rho_f}{\rho_f(1+\psi \cdot \tan\theta) + \psi} \tag{13}$$

The auxiliary formulae (14, 15), defining relations between the coefficient of thrust and gross traction ratio, are given in table 1.

Table 1 Relations between thrust coefficient and gross traction ratio

Tractor	$\mu = f(\rho_f)$	$\rho_f = f(\mu)$	*Equation number*	*Remarks*
2WD	$\mu = \frac{\rho_f(1+\psi\tan\theta)+\psi}{\lambda_{dk}+\rho_f\cdot\lambda_{z1}}$	$\rho_f = \frac{\mu\cdot\lambda_{dk}-\psi}{1+\psi\cdot\tan\theta-\mu\lambda_{z1}}$	14	$\lambda_{dk} = \lambda_d + \lambda_k$
4WD	$\mu = \frac{\rho_f(1+\psi\cdot\tan\theta)+\psi}{1+\rho_f\cdot\tan\theta}$	$\rho_f = \frac{\mu-\psi}{1-(\mu-\psi)\tan\theta}$	15	

With the given fundamentals the computation can be done in this way:

$$\frac{dP_p'}{dF_x} = \frac{dP_p'}{d\rho_f} \cdot \frac{d\rho_f}{dF_x} = \frac{dP_p'}{d\rho_f} \cdot \frac{1}{G}$$

$$\frac{dP_p'}{dF_x} = \frac{P_m}{G} \cdot \alpha_p \cdot \eta_t \cdot \frac{d}{d\rho_f}\left[\eta_s(\rho_f) \cdot \eta_r(\rho_f)\right]$$

It may be noted that the member P_m/G can be expressed through the specific power ρ_p of the tractor:

$$\rho_p = \frac{P_m}{m} = \frac{g \cdot P_m}{G} \tag{16}$$

so that the former equation becomes:

$$\frac{dP_p'}{dF_x} = \rho_p \cdot \frac{\alpha_p \cdot \eta_t}{g}\left[(1-s) \cdot \frac{d\eta_r}{d\rho_f} - \eta_r \cdot \frac{ds}{d\mu} \cdot \frac{d\mu}{d\rho_f}\right] \tag{17}$$

For a certain value of slip, given parameters of tractor and other values, the complex member in brackets from equation (17) has the meaning of a coefficient and will be denoted u so that:

$$\frac{dP_p'}{dF_x} = u \cdot \frac{\alpha_p \cdot \eta_t}{g} \cdot \rho_p \tag{17a}$$

Further on the expression on the right hand side can be converted to a function of velocity with help of the formula:

$$\rho_p = \frac{g}{G} \cdot P_m = \frac{g}{G} \cdot \frac{P_f}{\alpha_p \cdot \eta_f} = \frac{g}{G} \cdot \frac{F_x \cdot v}{\alpha_p \cdot \eta_f} = \frac{g \cdot \rho_f \cdot v}{\alpha_p \cdot \eta_t \cdot (1-s) \cdot \eta_r} \tag{18}$$

By inserting the formula (18) into the equation (17a) the resulting formula for the slope of the P_p' curve is obtained in the simplified form:

$$\frac{dP_p'}{dF_x} = u \cdot \frac{\rho_f}{(1-s) \cdot \eta_r} \cdot v = t \cdot v \tag{19}$$

The slope of the curve P_p' under conditions as for the formula (17a) depends only on the velocity v. This is a similar conclusion as with slope of the performance function given by the formula (5).

The formal condition (8) of the equality of slopes can therefore be expressed through equations (19) and (5) in this way:

$$t \cdot v = \frac{2(v - v_0) \cdot v^2}{v^2 - {v_0}^2 - p_0/\epsilon}$$

The solution yields the resultant formula for the tangential velocity v_T at the point 2 (fig 1):

$$v_T = \frac{v_0 + \sqrt{[(t^2 - 2t) \cdot ({v_0}^2 + p_0/\epsilon) + {v_0}^2]}}{2-t} = \frac{v_0 + \sqrt{[(t^2 - 2t) \cdot {v_W}^2 + {v_0}^2]}}{2-t} \tag{20}$$

This formula proves the existence of the common tangent point in the interval of values of the coefficient t:

$2 < t \leqslant 0;$

a practical meaning having the values $t < 0$ and the corresponding values of the velocity v_T which is then greater than v_0.

3.3 As an application to the foregoing theory there will be instanced the results of computation of some tractor/semi-mounted plough combinations on a rather heavy soil with medium aptitude for traction. The given values are listed in table 2 and some of the

Table 2 Tractor/plough combination, given values

Subject	*Symbol*	*Dimension*	*Value*	*Remark*
Slip	s	—	0.18	
Thrust conditions	μ_m	—	0.78	Loam soil stubble
	s_t	—	0.082	Estimate of average value
Coeff. of rolling resistance	ψ	—	0.08	
Specific draught	p_0 ϵ v_0	N/m² kg/m³ m/s	68.70 × 10³ 5.72 × 10³ 0.56	Compacted soil
Effect of a plough on a tractor	$\tan\theta$ λ_{z1}	— —	0.27 0.56	Semi-mounted plough with depth wheel at the rear end
2WD tractor	λ_d λ_k α_p η_t	— — — —	0.65 0.03 0.85 0.87	
4WD tractor	η_t	—	0.85	

results in table 3. These results will also be used later on to demonstrate the tractor range.

It is worth noting (table 3) that the velocities v_T appartaining to the maximum field performance of the combination are not too high and certainly lower than the maximum speed recommended by the manufacturer.

Table 3 Tractor/plough combination, computed results

Symbol	*Dimension*	*Formula*	*Value* 2 WD	*Value* 4 WD	*Remark*
μ	—	12	0.58	0.58	Fig. 1, point 2
ρ_f	—	14, 15	0.45	0.58	point 2
η_r	—	13	0.833	0.862	point 2
η_f	—	10, 11, 13	0.596	0.601	point 2
u	—	17, 17a	−0.336	−0.449	point 2
t	—	19	−0.221	−0.369	point 2
v_T	m/s	20	1.39	1.64	
v_W	m/s	6	3.51	3.51	
ρ_p	W/kg	18	12.13	18.23	
p	N/m²	3	72.64×10^3	75.37×10^3	For v_T
			118.5×10^3	118.5×10^3	For v_W

4. Tractor range

4.1 The proposed method of classification by field performance is based on the theory presented in the preceding part of this paper. The substance of this method will be explained by means of fig 3. The capacities of tractors are represented by their curves of potential power.

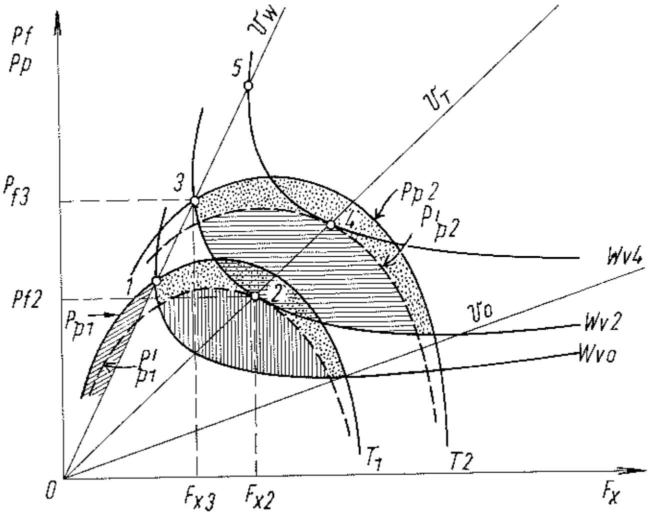

Fig 3 Representation of two members of a tractor power-range.

The tractor designated T1 would ideally attain the maximum rate of work W_{V2} when ploughing at the speed v_T with the engine load 100. α_p%. The relevant working point is marked 2. Another performance function for W_{V0} intersects the potential power curve P_{p1} at the point 1 with corresponding velocity v_W. The performance function for W_{V0} jointly with the curves P'_{p1} or perhaps P_{p1} delimits the area where an increase of working speed at constant force of pull will cause unambiguously the increase of rate of work as well. The area to the left from the line of velocity v_W, small as it may be, brings about a contrary effect.

It follows from this reasoning that the area delimited by the performance functions W_{V0} and W_{V2} can be considered an operating sphere for the tractor T1 at least from the point of view of constituting the neighbouring types in a range.

In order to eliminate an eventual gap in field performance of neighbouring tractor models, the performance function for W_{V2} must play for the next more powerful tractor type denoted T2 the same part as did the performance function W_{V0} for the tractor T1. From this follows the location of the point 3 as of the point of intersection of the performance function for W_{V2} with the line of velocity v_W, further on the relevant design parameters of the tractor T2 and then once again the point 4 at the line of velocity v_T.

The result of this systematic procedure being repeated several times in the same way gives the systematic tractor range.

Therefore the method of classification is based on formulation of the relations among performance functions in ploughing and potential power curves of the tractors. The general definition of this method is worded as follows:

> Tractors of two neighbouring power classes are bound by a mutual performance function which for a tractor of the lower class represents the maximum possible rate of work by volume in ploughing whereas for a tractor of the higher class it represents a lower limit in this rate of work, characterised in that every increase of the working speed when the drawbar pull is kept constant will bring about a further increase in field performance.

A tractor range conceived to this rule will provide an uninterrupted range of field performance for ploughing, tillage in general, for other field operations, transport and material handling. The steps among neighbouring power classes are generally not uniform because every tangent velocity v_T depends on the concept of the tractor/plough combination and every velocity v_W depends on the type of plough body.

4.2 The classification quantity CQ of the power-range of tractors is the rated power of the engine. Now it will be explained how to compute the power ratings with reference to the given MC (fig 3).

4.2.1 The rated power P_{m2} of the tractor T1 for the working point 2 (or the point 4 and all the subsequent even numbers) at the speed v_T is computed with use of formulae (1, 2, 3):

$$P_{m2} = \frac{P_{f2}}{\alpha_{p2} \cdot \eta_{f2}} = \frac{W_{V2} \cdot \rho_{T2}}{\alpha_{p2} \cdot \eta_{f2}} = \frac{W_{V2}\,[\rho_0 + \epsilon\,(v_{T2} - v_0)^2]}{\alpha_{p2} \cdot \eta_{f2}} \qquad (21)$$

Alternatively the rate of work W_{V2} may be calculated from the formula (21) for given power P_{m2}.

4.2.2 The rated power P_{m4} of the tractor T2 refers to the points 3 and 4 is computed by use of the following procedure:

point 3

given values: W_{V2}; v_{W3}; ρ_{W3}; $\alpha_{p3} = 1$;

computed values: $P_{f3} = W_{V2} \cdot \rho_{W3}$;

$F_{x3} = P_{f3}/v_{W3}$;

point 4

given values: s_4; α_{p4};

computed values: μ_4; ρ_{f4}; η_{r4}; η_{f4}; v_{T4}; ρ_{T4};

Points 3 and 4

mutual value: $\rho_{p3} = \rho_{p4}$ . . . from the formula (18)

The engine power P_{m3} of the tractor T_2 is defined by the formula similar to (21):

$$P_{m3} = \frac{P_{f3}}{\alpha_{p3} \cdot \eta_{f3}} = \frac{P_{f3}}{\eta_{f3}} \qquad (22)$$

Both P_{m3} and η_{f3} are unknown; however they are coherent quantities. The shortest way now to proceed is to estimate the engine power by assigning it a certain value P'_{m3} and go through a trial and check procedure as follows:

from formula (16) : $G' = g \,.\, P'_{m3}/\rho_{p4}$

$\rho'_{f3} = F_{x3}/G'$

(14, 15) : $\mu'_3 = f(\rho'_{f3})$

(12) : $s'_3 = f(\mu'_3)$

(13) : $\eta'_{r3} = f_1(\rho'_{f3})$

(10) : $\eta_{f3} = \eta_t(1 - s'_3) \,.\, \eta'_{r3}$

The value of η'_{f3} is inserted into the formula (22) and P''_{m3} is computed. If P''_{m3} is different from P'_{m3}, next trial is necessary. Without a computer about three loops giving both $P''_{m3} < P'_{m3}$ and $P''_{m3} > P'_{m3}$ are sufficient to plot the function $P''_{m3} = f(P'_{m3})$ so that the solution $P''_{m3} = P'_{m3} = P_{m3}$ can be found graphically.

The engine power P_{m4} of the tractor T2 equals indeed P_{m3}:

$$P_{m4} = P_{m3}$$

so that the rate of work at the point 4 is:

$$W_{V4} = \frac{P_{m4} \cdot \alpha_{p4} \cdot \eta_{f4}}{P_{T4}} \tag{23}$$

and this enables the next step to be taken and the engine power P_{m6} computed and so on.

4.2.3 The graduation of the rated engine power in the neighbouring power-classes, represented for instance by tractors T1 and T2 (fig 3), is in agreement with formulae (21) and (23) as follows:

$$\frac{P_{m4}}{P_{m2}} = \frac{W_{V4}}{W_{V2}} \cdot \frac{p_{T4}}{p_{T2}} \cdot \frac{\alpha_{p2}}{\alpha_{p4}} \cdot \frac{\eta_{f2}}{\eta_{f4}} = q \tag{24}$$

This formula (24) is the mathematical model of the tractor power-range as it specifies both the CQ and the MC through the ratio q.

4.3 The structure of the tractor range will be demonstrated using the values from tables 2 and 3. For the sake of simplicity it will be presumed that the tractors and ploughs are rather similar in point of design and combination.

With this presumption and applying the formulae from the section 4.2, the ratios q have the following values:

type of transit (lower-higher power):	ratio q:
2WD – 2WD	1.46
4WD – 4WD	1.31
2WD – 4WD	1.35
4WD – 2WD	1.42

Taking the rated engine power P_m = 60 kW for basis, the sequence of the power classes in kW will be:

2WD: common ratio q = 1.46

19 – 28 – 41 – 60 – 88 – 128 – ...

4WD: common ratio q = 1.31

27 – 35 – 46 – 60 – 79 – 103 – 135 – 177 – 231 – ...

It is estimated that 2WD tractors will be produced as a standard model up to the engine power 90–100 kW as this is the upper limit where a tractor may be considered really general-purpose (ie besides other properties the possibility to change the wheel track, ability to work in some rowcrops, most power-driven machines consume power up to this limit etc). For this reason a systematic tractor range may be composed as shown in table 4.

Table 4 Structure of the tractor power-range (example)

Tractor	2 WD					4 WD			
P_m, kW	(19)	28	41	60	88	118	155	202	(265)
q	1.46				1.35		1.31		

5. Design aspects of tractor range

5.1 It is essential to have a clear notion about the concept and practical use of all the members of a tractor range. The tractors of a range should have common design features, should be produced with similar machine-tool equipment and procedures, comply with international and national standards or recommendations and indeed satisfy the necessary number of combinations with regard to certain interchangeability of equipment at least between two neighbouring power-classes.

In a direct relation with the power of the engine are, for example, these aspects.

Design and production unification of engines;

concept of a tractor with regard to power transmission;

attachment of implements and machines particularly concerning the hitches and the power take-off shafts;

size of associated transport equipment.

5.2 The unification of engines is effectively realised through similar, usually in-line arrangement of engines with the same stroke for the whole series. The bore and revolutions may be changed within certain limits. The consequent theoretical variations in power are summarised in table 5.

Table 5 Possible variations in power of a series of engines with equal stroke

Change in engine design	*Ratio of power increase*	*Symbol of the variant*	*Remark*
Increase in the number of cylinders:			
2–3	1.50		Equal bore and revolutions
3–4	1.33		
4–6	1.50		
6–8	1.33		
8–10	1.25		
8–12	1.50		
Increase of revolutions	1.10	N	Realistic Values
Increase of bore	1.10	D	
Combined increase of revolutions and bore	1.21	ND	
Turbocharging	1.33	T	From 4 cylinders up

Table 6 Some alternative engine series for tractor power-range (example)

		No. of alternative						
		1	*2*		*3*		*4*	
	P_m,	*Number of cylinders in engine series with equal stroke and bore per series*						
q	*kW*	*Ia*	*Ia*	*IIa*	*Ib*	*IIb*	*Ib*	*IIc*
1.46	19	(1)	(1)		2		2	
1.46	28	2	2		3		3	
1.46	41	3	3		4N		(4N)	3
1.46	60	4N	4N		(6N)	4		4N
1.35	88	6N	6N			6		6N
1.31	118	6TN		6		8(6T)		6TN
1.31	155	8TN		6T		8T		8TN
	202	12T		8T		10TN(12ND)*		12T(10TND)*

*Exception

Some alternative engine series which could be installed in models of the tractor range from table 4 are listed in table 6. The alternatives 2, 3, 4 consist of 'light' series I and 'heavy' series II. In the alternative 2, the 2WD tractors have the engines of the series I, the 4WD tractors those of the series II. The alternative 3 has both the engine series well balanced. With the alternative 4, the series I is well suited for countries with small-scale agricultural production whereas the series II is more suited for countries with large-scale production. In all the alternatives discussed the engines with power 155 kW may have a V-type arrangement and the engines with 202 kW must have such an arrangement. Specifically the complete series denoted IIa could be designed as V-type.

5.3 The concept of a tractor depends first of all on the purpose of the tractor. Three basic categories of agricultural tractors are well known: row-crop RC, general purpose GP and heavy duty HD.

All the RC tractors and most of the GP tractors must have adjustable wheel track which mostly excludes the use of four wheel drive with front steering wheels (there are indeed exceptions).

The limiting factor to the engine power transmitted as drawbar power are the tyres, and notably their load capacity Q. The width of tyres must suit well the purpose of a tractor category so that each category has a characteristic engine power depending on the maximum size of adequate tyres (table 7).

The concept of the tractor range discussed, including some information about the attachment facilities and about the capacity of trailers, is summarised in table 8.

6. Conclusion

This paper was an attempt to derive the essential theory of the systematic power-range of tractors. The structure of a tractor range computed as an example was discussed with respect to tractor design.

A system of tractors must be realistic and have a well-defined relation to their operational features. A system must also be exact;

Table 7 Concept of tractors regarding their purpose and drive

Category	Concept of drive of tractor model: basic	Concept of drive of tractor model: adapted	Tyre width	P_m/Q, W/N	Max. P_m, kW, concerning traction
RC row-crop	2WD	–	from 9.5/9(4) or 12.4/11	3.71	43
GP general purpose	2WD	4WDa(1)	up to 18.4/15(5)	3.57	97
HD heavy duty	4WDb(2)	–	as above(5)	4.35	118
	4WDc(3)	–	as above(5)	5.24	142
			unlimited		unlimited

Comments: *(1) improved traction, restricted use*
(2) front wheels smaller than rear wheels, more than 40 per cent of static loading on front wheels
(3) all the wheels have the same size
(4) for operation in sugar beet and potatoes depending on the row spacing
(5) ploughing is possible with wheels in the furrow for plough bodies at least 14 in wide

Table 8 The concept of the systematic tractor range (example)

P_m, kW	Tractor category	Type of drive	Attachment of machines: three-point(2) hitch	Attachment of machines: power take-off(3)	Load capacity of trailers, t(4): single axle	Load capacity of trailers, t(4): double axle
19	RC	2WD	category 1	type 1 540 rev/min	2.5–3.0	
28					4	
41			(category 2)		5	4
60	GP	2WD (4WDa)	category 2)	type 2 1000 rev/min	8–9	6
88					10	8
118	HD	4WDb(1) 4WDc	category 3	type 3 1000 rev/min	12–16	
1 115		4WDc	(category 3)	?		
202			?			

Comments: *(1) in-the-furrow ploughing is possible*
(2) ISO R730
(3) ISO R500
(4) Czechoslovak regulations for trailers with brakes . . . max. mass ratio (loaded trailer:tractor) should be 2.5:1 for two axle trailers and 3.0:1 for single axle trailers.

that means to give unambiguous and replicable magnitudes of members of the range. The important primary factors of the power-system, notably the thrust conditions for tractors and the velocity dependent draught of plough bodies, may be given individual and perhaps variable values when applied by a certain manufacturer of tractors or they may be convened in a standardised form to enable a wider application of the system.

Theoretically the power-classes would have precise power ratings but practically it could be recommended to allow for a certain tolerance, for instance 10% from the nominal power rating. This tolerance could be realised by deviations either ± 5% or + 10%. The firm structure of the power range indicates that a change in power of a single or several members of the range out of the permitted deviation would call for corresponding changes in power for all the other members of the tractor range to conserve its harmony.

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List of symbols

(SI units; other symbols are in fig 2)

F_x	N	force of (drawbar) pull
G	N	force of gravity of a tractor
H	N	thrust force
P_e	W	engine power, effective
P_f	W	drawbar (tractive) power
P_m	W	engine power, rated
P_p	W	potential power, full load
P'_p	W	potential power, part load
Q	N	tyre load capacity
S	m^2	furrow cross section
W_S	m^2/s	rate of work by area
W_V	m^3/s	rate of work by volume
b_p	m	width of cut
c	N/m^2	soil cohesion
d_f	m	depth of furrow
g	m/s^2	acceleration of gravity
i_k	m	characteristic soil displacement
l	m	length of tyre contact area
m	kg	mass of a tractor
p	N/m^2	specific draught
q	–	ratio of the tractor power-range
s	–	slip (travel ratio)
t, u	–	coefficient (composite expression)
v	m/s	working (travel) speed
α_p	–	engine load ratio, $P_e/P_m = P'_p/P_p$
ϵ	kg/m^3	velocity coefficient (draught of a plough)
η_f	–	tractive efficiency (ratio)
η_r	–	force ratio, F_x/H
η_s	–	travel reduction, 1 – s
η_t	–	transmission efficiency (ratio)
λ_x	–	ratio of a dimension x to the wheelbase w (see fig 2)
μ	–	coefficient of thrust
ρ_f	–	gross traction ratio, F_x/G
ρ_p	W/kg	specific engine power, P_m/m
ϕ	°	angle of internal soil friction
ψ	–	coefficient of rolling resistance

DEVELOPMENT IN TRACTOR DESIGN AND APPLICATION

Edited summaries of discussion

Mr P. G. Finn-Kelcey (consultant) asked Dr Dwyer whether the use of vibrating tools might lead to an improvement in efficiency of cultivations. Dr Dwyer replied that research has shown that vibrating the tool can lead to a reduction of draught but that the total power requirement is increased. However, the draught reduction in itself is a significant potential advantage because tractor weight, and hence cost, could be reduced. Rotating soil engaging implements are probably a more promising line of development.

Mr L. P. Evans (Massey Ferguson) asked whether the viability of transportation systems proposed by Dr Dwyer might be influenced by EEC and national regulations. Dr Dwyer stated that maximum road speeds would need to be limited to avoid an involvement with certain road vehicle acts. He went on to say that further and more stringent regulations are to be expected in future. These may relate to braking, lighting and direction indicators for example and could perhaps be best met by incorporation in the more expensive and sophisticated single purpose vehicle.

Mr D. R. F. Tapp (County Tractors) said that his organisation had six years' manufacturing experience of forward control tractors and had found that there were legal restrictions on the road carriage of loads, eg lime, in an open body or container. This was an example of particular legislation limiting development. Had this kind of problem arisen with Intrac tractors? Dr Gego replied that this particular problem had not been encountered but pointed out that the Intrac vehicles were not to be regarded as the solution to all farm transport problems.

Mr H. C. G. Henniker-Wright (Ford Tractor Plant) asked Dr Gego for more information on the Intrac-system 2000 hydraulic lift control. He also wondered what noise levels had been experienced by operators and enquired whether any problems had been met with cabin air filtration when spraying insecticides for example, using a front mounted boom.

Dr Gego replied that the hydraulic lift was operated by a pressure control system which provides the opportunity of achieving even weight distribution on front and rear axles in work. Noise levels in the order of 90 dBA had been measured in the cabin although efforts were being made to reduce this level to 85 dBA. There had been no experience of air filtration problems so far in field work.

Mr D. Bottoms (NIAE) questioned the capacity of an operator to control both front and rear mounted implements simultaneously. Dr Gego said that successful operation depended on the operational stability of the implements. Unless the implement had a stable mode of operation even one implement was too much for the operator to control effectively. Unless the operator was sure of the implement another operator or automation must take over the monitoring function. He foresaw that automation of various functions would be developed within a few years, for example semi-automatic tractor guidance.

Mr J. M. Chambers (retired) noted that the Intrac-System 2000 had a three point linkage at both front and rear. He imagined that the rear linkage was of conventional design and the front linkage was fixed. This was confirmed by Dr Gego. Mr Chambers went on to enquire whether a flexible front linkage had been tried which, if the attachment points at the implement were narrower than those at the tractor, would produce a virtual hitch point in advance of the implement, thus leading to a stable flexible linkage which might not be the case if the link converged to a point behind the implement.

Dr Gego replied that he did not think a flexible front linkage was necessary since no problems had been experienced in the field with the existing arrangement.

Mr R. H. F. Jeffes noted that Dr Dwyer had been talking about the three-point implement linkage. He had been living with three-point linkage for a number of years and was concerned that standardisation had not been effective from the farmers' point of view; manufacturers of new implements often paid scant regard to standardisation recommendations. A number of good automatic coupling systems were available but none had achieved acceptance.

Mr Manby (NIAE) mentioned that the NIAE had tried to promote standardisation of automatic couplers but without success.

Mr Tapp drew attention to the fact that the effect of plough speed on smear had not been considered by the authors so far and invited comment on the relative importance of timeliness.

Mr Matthews stated that Mr Zoz considered cost to be the most important factor but suggested that a bonus of up to £9/acre might be available for some autumn sown crops compared with spring sowing. He went on to say that four-wheel drive tractors were relevant to timeliness since they could normally work under a wider range of soil conditions than two wheel drive models. He did not feel qualified to give detailed comments on the smear problem but suggested that a lower total plough weight would be required for high operational speeds. The lower weight per body combined with less wheel slip would perhaps lead to less smear.

Prof P. C. J. Payne (NCAE) agreed with Mr Matthews remarks regarding soil smear.

Mr C. H. Hull (David Brown Tractors) congratulated the authors of the papers on providing so much food for thought. One matter which had caught his attention was that while Dr Dwyer had indicated that there was a limit of about 60 kW to 80 kW in tractor power other speakers had indicated that much larger tractors were sensible. Was there a natural limit to tractor power?

Dr Dwyer said that he had looked in his paper at the limits for a conventional two-wheel drive machine. Other speakers had indicated that for greater power other concepts were required, such as increased operational speed or four-wheel drive.

Mr C. Culpin (retired) asked whether twin rear wheels were another possibility.

Dr Dyer replied that so long as it was possible to operate the tractor out of the furrow twin rear wheels could give a performance approaching that of four-wheel drive and could enable a tractor of up to 120 kW to be used effectively on heavy land.

Mr H. G. Pryor (farmer) suggested it was better to use single wheels since twin wheels rapidly filled up with mud.

Mr Henniker-Wright expressed interest in Dr Grečenko's recommendations concerning the optimisation of a tractor size range which he accepted as probably correct in theory but was not reflected in practice. He believed that tractors up to 80 hp were a compromise not restricted to tillage operations. Several tractor manufacturers produced models below 80 hp which reflected the need to take account of other farm operations.

Dr Grečenko recognised that three principal categories of power unit existed ie rowcrop, general purpose and high draught machines. He thought that the large number of models currently available were too many. He believed that this number would decrease in future in favour of self propelled machines which in a number of cases he considered to be a more appropriate solution than trailed machines.

Mr T. C. D. Manby (NIAE) outlined a concept put forward by Zweegers in Holland of increasing the engine power of a motive agricultural unit without weight increase. The engine power of the unit was about 110 kW (DIN) but the capacity of the hydrostatic ground drive transmission was deliberately limited to 45 kW, thus ensuring that considerable power was available at the two front and two rear pto outlets. The hydrostatic drive in conjunction with three-range final drive gears provided speeds from zero up to 25 km/h. The high pto power was available for such equipment as forage harvesters and rotary cultivators. Mr Manby asked Dr Gego whether this represented an alternative concept.

Dr Gego replied that although the Zweeger machine posed a number of questions, he did not regard it as providing a confrontation with the Intrac machines. He classified it as a self-propelled pto machine and the Intrac system was intended to provide a third possibility between the general class of self propelled machines and conventional tractors operating as pull machines. Over the years, the number of self propelled machines was likely to rise steadily and the number of Intrac machines might rise very markedly, while the number of pull machines would remain about the same. In ten to fifteen years time each class of machine might hold about an equal share of the market. This would reflect the current trend for an increasing proportion of the total machine power to be provided via the pto at the expense of draught power. Sales of Intrac machines were at the stage of rapid increase.

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The Institution secretariat— appointment of Ray Fryett as Institution-secretary

THE work of the Appointment Committee, set up by Council in the autumn of 1973, culminated in a series of interviews of candidates, at Silsoe, on 10 April 1974.

The Committee received seventeen applications, of which seven were short-listed. The interviewing board was impressed by the exceptional calibre of several of the candidates, and it was against this background that the board decided unanimously that the post should be offered to Mr Ray J. Fryett.

Members will be aware of the very great contribution which Ray had already made to the Institution in his capacity as Special Assistant during the autumn of 1973, and as Acting Secretary since 1 January 1974. Nevertheless, the Appointment Committee felt it to be right and in the Institution's best interests to explore the possibilities offered by outside applicants. The confidence which he had already inspired was further reinforced as a result of the comparison which the interviewing board was able to make with other very able candidates.

It gives me great pleasure, both as Chairman of the Appointment Committee and as President, to extend to Ray Fryett the congratulations of the Committee and the cordial greetings and good wishes of the Institution at the start of his tenure of office as Institution Secretary.

Ray is the first Secretary to be also an Institution member in his own right: he was admitted as an Associate in 1968. Appointed to the Council in 1972 and selected for membership of the Finance and General Purposes Committee, he took an active part in the proceedings of both Council and Committee. He is currently an elected Member of Council and a member of the South East Midlands Branch Committee.

He joined the agricultural industry direct from college, when he entered into the administration side of flour milling; after three years he moved into the practical side of the agricultural corn and seed trade.

During the Second World War his duties covered staff administration at Command and Unit level. He was mentioned in despatches in 1942.

On demobilisation he spent a number of years gaining an appreciation of, and taking an active part in — at junior management level — road transport for agriculture, fruit and arable farming, and agricultural engineering.

Joining the BP Group in 1952 he again identified himself with the agricultural sector — being the instigator of the wider application of gas-fired schwank type (low cost) radiant heating used for livestock rearing under intensive and environmentally controlled conditions.

In more recent years he was deputy project leader for an investigation by BP Trading into the viability of a nationwide increase in grass conservation, and project leader of a multi-organisational

investigation into conservation of tropical crops for human consumption using petroleum fueled direct fired drying units

He is an Associate of the Institution of Gas Engineers, Fellow of the Institute of Petroleum, an Associate of the British Association of Green Crop Driers, and an Associate member of the Intermediate Technology Development Group.

He has served two spells abroad, four years in the Middle East and four years in Nigeria.

Most of his spare time is devoted to hockey at divisional level. An ex-international umpire, he is now a vice-president and a selector of the East Anglian Hockey Umpires' Association.

The Silsoe Secretariat currently has a permanent staff of two: Ray and Mrs E. A. Atkinson, ably supported by part-time assistance. The appointment of a third member to complete the staff is envisaged in the near future.

Discussions with the College authorities and other interested parties concerning the provision of permanent accommodation are continuing, and an announcement will be made as soon as it has been possible to resolve the many complex factors which have to be considered.

J. V. Fox

Reprint Service

CHANGES have recently been introduced in the reprint service offered to members of the Institution. The Editorial Panel has now made arrangements with University Microfilms Limited, St John's Road, Tylers Green, High Wycombe, Bucks., for THE AGRICULTURAL ENGINEER to be placed on microfilm from which enlarged copies of articles or papers can be obtained. Those members wishing to obtain copies of articles should now address their requests direct to University Microfilms Limited who will make a charge for this service at the rate of $3 each for articles and 8c. per page for complete issues. Charges will of course be made in sterling, the equivalent being obtained by conversion at the rate current at the time of placing order.

At the present time only Volume 28 is available under this service but it is planned to place earlier volumes of the Journal on microfilm in the future.

A few back numbers of the Journal are still in stock at Institution Headquarters and will be made available to members upon application. Once Institution Journal and paper supplies have been used up it will no longer be possible to offer members up to six items a year free of charge and post-free through University Microfilms Limited.

BRANCH PROGRAMMES

East Anglian Branch

Hon. Secretary J. B. Mott MIAgrE
County Hall, Norwich (tel: Norwich 22288 ext 5076).

September 27 — Agricultural Engineering Education, by M. G. Clough, The Scole Inn, Diss, Norfolk, 2015 h. This talk follows a committee meeting.

November 20 — Conference on Farm Logistics – Problems of Materials Movement, Norfolk School of Agriculture 1015–1630 h. Speakers: D. A. Bull (ADAS), J. Macpherson (New Holland), P. A. M. Murray (Big Bale Designer), K. D. Brandon (Fisons) P. Simpson (Chafers), G. F. Shattack (FYM Consultant).

1975
February 28 — Dinner Dance, King's Head, Diss, Norfolk, 1915 for 1945 h.

April 4 — Annual General Meeting, Scole Inn, Diss, Norfolk, 1930 h. Followed by Further Problems of Mechanisation by R. A. den Engeles (East Anglian Real Property Co. Ltd).

East Midlands Branch

Hon. Secretary E. F. Beadle
Lincolnshire College of Agriculture, Riseholme, Lincoln.

October 8 — Visit to cold store of Christian Salvesen Ltd, Easton, nr Grantham, Lincs., 1430 h.

31 — Mechanical damage and its effect on marketability of Potatoes, by G. S. Grantham (Chairman PMB) Notts. College of Agriculture, Brackenhurst, 1930 h.

November 20 — Conference on Energy Conservation, Leicester College of Agriculture, Brooksby, 1000 h. Speakers: B. Wilton, a member of the Institute of Petroleum, and a member of the Severn-Trent Water Authority.

1975
January 21 — Vegetable Harvesting, Lincs. College of Agriculture, Caythorpe, nr Grantham, 1930 h.

February 20 — Ergonomics and Noise, Haycock Hotel, Wansford, 1930 h.

March 4 — Developments in Planting and Harvesting Maize, Lincs. College of Agriculture, Riseholme, Lincoln, 1930 h.

Northern Branch

Hon. Secretary K. A. Pollock MSc(AgrEng) MIAgrE
Dept of Agricultural Engineering, The University, Newcastle upon Tyne NE1 7RU (tel: Newcastle upon Tyne 28511).

October 8 — The Energy Crisis and Agriculture, by Prof. J. R. O'Callaghan (Newcastle University), Northumberland College of Agriculture, Kirkley Hall, Ponteland, 1930 h.

November 12 — The NIAE Mower-Conditioner, by W. Klinner (NIAE Forage Conservation Dept), Northumberland College of Agriculture, 1930 h.

December 10 — Farmers Lung, by Dr I. W. B. Grant (Respiratory Unit, Edinburgh Northern General Hospital) and Minimising risks by Good Engineering, by D. J. Greig (Newcastle University), School of Agriculture Newcastle University, 1930 h.

1975
January 14 — Agricultural Engineering in Kenya, by D. J. B. Calverley (Tropical Products Institute, ODA), Northumberland College of Agriculture, 1930 h.

February 11 — Recent Developments in Potato Harvesting and Handling, by D. C. McRae (NIAE Scottish Station), School of Agriculture Newcastle University, 1930 h.

March 11 — Fish – the Food of the Future, by G. C. Trout (MAFF Fisheries Laboratory, Lowestoft), Northumberland College of Agriculture, 1930 h.

North Western Branch

Hon. Secretary R. B. Kitching
4 Northall, Much Hoole, Preston PR4 4QN.

September 19 — Visit to Tile Works, Skelmersdale.

October 24 — Turbo charging, speaker to be announced, Leigh Library, 1930 h.

November 14 — Electronic Circuits, by John Tyblewski (senior lecturer, Northampton College of Agriculture), Lancashire College of Agriculture, Myerscough Hall, Bilsborrow, Preston, 1930 h.

1975
February 27 — Discussion panel – Grain storage, speakers on dry and moist grain storage and Propcorn to be announced, Warrington (exact venue to be decided).

March 15 — Dinner Dance, Harden Park Hotel, Alderley Edge, Cheshire.

20 — Annual General Meeting, The Royal Oak, Chorley, 1930 h.

Scottish Branch

Hon. Secretary J. A. Pascall NDA MIAgrE
'Donmaree', Springhill Road, Peebles (tel: Peebles 20161).

September — Visit to drainage site and/or peat extraction site, followed by evening talk. Date, venue and speaker to be finalised.

October 22 — Sources of Energy, by Dr M. Slesser, Minto Hotel, Edinburgh 9, 1930 h.

November 19 — Panel Discussion – Mechanisation Problems. Speakers: R. Graham (MF), R. Hart (G & H), B. Houstoun (Bowens), G. Scott-Watson (Farmer), and J. Palmer (NIAESS), Ednam House Hotel, Kelso, 1930 h.

1975
January 15 — Dairy Feeding and Rotary Milking Parlours, by M. Turner (NIAE) and H. Shepherd (NOSCA), Recreational Centre, Cumnock Academy, Cumnock, 1930 h. In association with Cumnock Discussion Society.

16 — Repeat of talk on 15 January, Gordon Arms Hotel, Inverurie, Aberdeenshire, 1930 h.

February 26 — Annual Conference – Profit from Straw. Speakers: C. Brutey, J. Macfarlane and Dr D. Slight, 1000 h, Dunblane Hotel Hydro. Annual general meeting, 1700 h, followed by buffet supper, 1900 h.

South East Midlands Branch

Hon. Secretary G. Spoor BSc(Agric) MSc(AgrEng) MIAgrE
National College of Agricultural Engineering, Silsoe, Bedford MK45 4DT (tel: Silsoe 60428).

October 14 — Machinery requirements of the Continental European Farmer during the next five years, by Comte Louis de Lauriston (Farming and Executive Director of Federation of Land-owning Farmers, France), NCAE, Silsoe, 1930 h.

November 1 — Social evening, Farmers' Club, Cambridge,

11 — Design and Construction of Farm Buildings in the USA, by Professor R. A. Aldrich (Pennsylvania State University, USA), NCAE, Silsoe, 1930 h.

December 9 — Energy and Food Production. Speaker to be arranged, NCAE, Silsoe, 1930 h.

1975
January 20 — The definition of the Biological Target for Aerial Spraying, by R. J. V. Joyce (CIBA-Geigy Research Unit, Cranfield, Beds.), Shuttleworth College (to be confirmed), 1930 h.

March 3 — Annual General Meeting, 1900 h. Followed by Developments in Farming and their Implications for the Agricultural Engineer, by J. M. Botting (Thurlow, nr Haverhill), NCAE, Silsoe, 1930 h.

South Eastern Branch

Hon. Secretary — K. A. McLean NDA CDA CDAE NDAgrE MIAgrE Government Offices, Beeches Road, Chelmsford, Essex (tel: Chelmsford 532011).
Details of the Branch programme will appear in The Winter 1974 issue of The AGRICULTURAL ENGINEER.

South Western Branch

Hon. Secretary — J. Pritchard AIAgrE Hillside, South Brentor, Tavistock, Devon (tel: Mary Tavy 216).

October 10 — Pipeline Pig Feeding, by R. J. Nicholson (Mechanisation Officer, ADAS), Lord Elliot Hotel, Liskeard.

November 14 — Engineering for the Environmental Control of Pigs, by B. H. Boyce and E. E. Hosken (ADAS), Exeter College.

1975

January 16 — Direct Tilling Techniques, speaker to be confirmed, Seale Hayne Agricultural College.

February 13 — The Economical Use of Tractor Power, speaker to be confirmed, SWEB Training Centre, Taunton.

March 13 — Eastern European Approach to Pig Management, by R. Stokes, Bicton College of Agriculture.

Western Branch

Hon. Secretary — H. Catling NDAgrE MIAgrE Royal Agricultural College, Cirencester, Glos (tel: Cirencester 25311).

October 16 — Mechanical Handling on the Farm, by D. Butcher (Sanderson [Forklifts] Ltd), Bath Arms, Market Place, Warminster, Wilts., 1930 h.

November 13 — Rotary Milking Parlours, by F. E. Goldsmith (Alfa-Laval Co. Ltd), Bath Arms, Market Place, Warminster, Wilts., 1930 h.

1975

February 12 — Annual General Meeting, 1830 h, to be followed at 1945 h by The Big Baler, by P. A. M. Murray, Bath Arms, Market Place, Warminster, Wilts.

March 12 — Visit to P. J. Parmiter & Sons Ltd, Tisbury, Wilts., 1400 h. Pneumatic Conveyors, by M. J. Ling (Henry Woods [Agricultural] Ltd), Bath Arms, Market Place, Warminster, Wilts., 1930 h.

West Midlands Branch

Hon. Secretary — M. J. Bowyer CEng MIMechE MIAgrE 9 Lyng Close, Mount Nod, Coventry CV5 7JZ (tel: Coventry 73331).

September 30 — Irrigation Equipment, by J. Ingram (Luddington Experimental Horticultural Station, Warwickshire), Massey-Ferguson Training School, Stareton, 1930 h.

October 28 — Forum — Straw: Its Problems and Potential. Panel: K. A. McLean (ADAS, Chelmsford), B. Wilton (University of Nottingham), R. G. Wiltshire (Stramit Ltd, Suffolk), Warwickshire College of Agriculture Moreton Morell, 1930 h.

November 25 — Agriculture in Japan, by a representative of the Japanese Embassy, Farm-Electric Centre, NAC, Stoneleigh, 1930 h.

1975

January 6 — Soil and Water Management, by a representative of SAWMA, ADAS Liaison Unit, NAC, Stoneleigh, 1930 h.

February 3 — Producing Protein Crops for Manufacture, by M. E. H. Fiddian (NIAB, Cambridge) and D. M. Walker (John Deere Ltd, Langar), Massey-Ferguson Training School, Stareton, 1930 h.

March 3 — Annual General Meeting, 1830 h. Followed by Steam on the Land, by J. E. Durrant (Mid-Warwickshire College of Further Education), Mid-Warwickshire College of Further Education, Leamington Spa, 1930 h.

Wrekin Branch

Hon. Secretary — J. Sarsfield MIAgrE Staffordshire College of Agriculture, Rodbaston, Penkridge, Stafford (tel: Penkridge 2209).

October 7 — Oil Exploration, speaker to be confirmed, Staffordshire College of Agriculture, 1930 h.

November 4 — Equipment for Hill Land Improvement, by G. B. H. Spear (ADAS) and M. Roberts (Director, Pwllpeiran Experimental Husbandry Farm), Welsh College of Horticulture, 1930 h.

18 — Visit to ATV studios, Birmingham, 1930 h.

December 9 — Power Measurement, speaker to be confirmed, Harper Adams College, 1930 h.

1975

January 13 — Towards faster Trains, speaker to be confirmed, Staffordshire College of Agriculture, 1930 h.

February 10 — Sound Attenuation, by J. Salt (Birmingham Polytechnic) and G. F. Chapman (RoSPA), Shrewsbury Technical College, 1930 h.

March 10 — Annual General Meeting, 1900 h. Followed by The Logistics of a large Demonstration, by O. J. H. Statham (PMB), Harper Adams College, 2000 h.

21 — Annual Dinner, Tillington Hall Hotel, Stafford, 2000 for 2030 h.

Yorkshire Branch

Hon. Secretary — R. Ashley-Smith MSc(AgricEng) 57 Acre Lane, Meltham, Huddersfield HD7 3DH (tel: Meltham 850361).

September 12 — The Big Bale System, by M. Williams (Howard Rotavator), Holmfield House, Wakefield, 1930 h.

October 10 — Visit to David Brown Tractors. Assemble at Product Training Centre, Meltham Hall.

17 — Provisional meeting. Details and venue to be announced. Special meeting in Malton area for members in east of county).

November 14 — Mechanisation of the Sugar Beet Crop, by Messrs Maughan, Webster and Turner (BSC), Buccles Inn, on A64 near Askham Richard, 1930 h.

December 10 — Visit to the Packhouse of East Riding Farm Produce, Melbourne, York.

1975

January 9 — Land Drainage, by B. Miers (MAFF, Lincoln), Holmfield House, Wakefield, 1930 h.

February 13 — Legislation effects on Total Tractor Design, by L. Evans (Massey-Ferguson), Holmfield House, Wakefield, 1930 h.

March 13 — Annual General Meeting. Followed by Design Thinking on Flail Mowers, by W. Lupton (Lupat), Holmfield House, Wakefield, 1930 h.

April 8 — Noise, by J. Harris (J. I. Case, Racine), Dept of Mechanical Engineering, University of Leeds, 1930 h. Joint meeting with NE Centre, Automobile Div. IMechE.

Correction in Volume 29 No. 2

THE Editor regrets that the title of H. W. Whitton's paper on page 44 of Volume 29 No. 2 was incorrect. It should have read:

'A System of Mechanised Feeding of Grass Silage from Horizontal Silos'.

Institution of Agricultural Engineers

ADMISSIONS, TRANSFERS & RESIGNATIONS

The undermentioned have been admitted to the Institution, transferred from one grade to another, or have resigned.

ADMISSIONS

Member

Sarker R. I.	Bedfordshire	5.4.74
Jones K. G.	Bristol	1.1.74
Belford B. C.	Warwickshire	5.2.74
Thiagarajah V.	Malaysia	19.2.74
Firth G.	Bedfordshire	5.2.74

Technician Associate

Busari L. O.	Nigeria	5.2.74
Castle D. A.	Kent	29.1.74

General Associate

Bromley J. V. C.	Indonesia	1.3.74
Swift J. L.	Wiltshire	5.2.74

Student

Manoharajah N. P.	London	4.1.74
McCullagh S. B. P.	Ayrshire	4.1.74
James R. W.	Monmouthshire	4.2.74
Von-Kalfmann M.	Wiltshire	7.1.74
Sanker B. G.	Bedfordshire	18.2.74
Carey R. H. W.	Oxfordshire	4.2.74
Cottam M. J.	Ayrshire	4.1.74
Ramalan A. A.	Bedfordshire	5.2.74
Wood S. H.	Warwickshire	4.1.74

TRANSFERS

Member

Samarasinghe D. K.	Hertfordshire	5.2.74
Elwes E. H.	Gloucestershire	1.3.74
Foster B. C.	Worcestershire	23.1.74
Rothery C. C.	Lincolnshire	19.2.74
Smith J.	N. Ireland	31.10.73

Companion

Moll D. A.	Norfolk	19.2.74

The late L. S. Cordy was inadvertently included in the last issue as a resigned member (12.73) when he should have been included under obituary.

AROUND THE BRANCHES

West Midlands Branch

A FORUM on the implications of the larger tractor was held by the West Midlands Branch last October at which I. Rutherford (ADAS Liaison Unit, NIAE), DRF. Tapp (County Commerce Cars Limited, Fleet) and S. D. Bond (Velcourt Ltd., Ledbury) each presented their views in a lively and informative manner. The evening concluded with a full discussion on the points of view expressed by the speakers. The West Midlands Branch have produced a typed report of the main contributions and discussion which no doubt could be made available to individual members if required.

A PARTY of between 50 and 60 West Midlands Branch members and their families and friends braved a torrential downpour and took a step back into the 18th century when they visited the Ironbridge Gorge Museum, Shropshire, for the 1974 WMB Spring Outing.

The visit started with an excellent two hour guided tour of the 42-acre Blists Hill Open Air Museum where the industries and crafts that once brought prosperity to East Shropshire, which was the cradle of the Industrial Revolution, are being re-created. The party saw giant steam blowing engines which had been removed from threatened sites; pit heads and drift mines which had been re-erected and re-opened; iron blast furnaces and rolling mills which were in the course of being excavated and re-built; examples of charcoal burning and the Thomas Telford method of road building; and the site of the Hay inclined plane where canal boats were raised-and lowered through a vertical height of 207 feet between the Shropshire Canal and the River Severn.

Also during the tour the party were able to see a horizontal steam winding engine working at one of the Blists Hill mine shafts and a demonstration of the art of wheel-thrown pottery which is a traditional craft once carried out in the Severn Gorge.

The party then proceeded to the tar tunnel which was driven 1000 yards by William Reynolds, the most inventive of the Shropshire iron masters, from the banks of the Severn under Blists Hill.

The more resolute members of the party continued on to see the unique cast iron bridge spanning the River Severn and the indoor Coalbrookdale Museum where many fine examples of cast iron work and relics of local history were displayed.

BRANCH VIEWS

Speakers at branch meetings

IT is always a difficult task for a branch committee, in Yorkshire at least, to decide on subjects and possible speakers for its following season's programme of meetings. One source of ideas is The AGRICULTURAL ENGINEER with its reports of meetings held by other branches.

We have, however, found ourselves led astray occasionally, in that a speaker, implicitly recommended by the publication of a brief report of his previous presentation of a paper, has turned out when he visits Yorkshire not to be up to the standard expected. We must believe that far from this being any reflection on this branch's geniality or expectations, rather the speaker in question was equally unsatisfactory on the earlier occasion he presented his paper.

My personal view is that it would be preferable for The AGRICULTURAL ENGINEER to publish reports of branch meetings, only when the speaker, and his paper, can be recommended to other branches. If however my view is not acceptable, then perhaps this letter may nevertheless serve as a caution.

J. R. ASHLEY-SMITH
Hon. Secretary Yorkshire Branch, 57 Acre Lane, Meltham, Huddersfield, HD7 3DH.

COUNCILS & COMMITTEES

THIS new section will in future include reports of selected aspects of the work of Council and Institution Committees. Membership of Council and Committees for 1974/75 are given below.

Members of council 1974/75

President	Mr J. V. Fox
President-Elect	Mr T. C. D. Manby
Past Presidents on Council	Mr J. A. C. Gibb — Immediate Past President
	Mr T. Sherwen
Vice-Presidents	Mr J. H. Nicholls
	Mr L. P. Evans
	Mr B. A. May
Hon. Treasurer	Mr J. C. Turner
Hon. Editor	Mr B. A May
Chairman of Membership Panel	Mr L. P. Evans
Chairman of Exam. Board	Mr J. A. C. Gibb
Fellows	Mr R. H. Miers
	Mr G. L. Reynolds
	Mr J. L. Carpenter
Members	Mr G. Spoor
	Mr D. H. Rowe
	Mr G. P. Shipway
Companions	Mr F. Dean Swift
	Mr U. G. Spratt
Associates	Mr C. V. Brutey
	Mr R. Stokes
	Mr R. J. Fryett
	Mr R. F. Farr
Graduate	Dr P. R. Philips
Special Scottish Representative	Dr B. D. Witney
Branch Representatives	
East Anglian	Mr M. G. Clough
East Midlands	Mr B. Wilton
Northern	Mr R. Cowen
Scotland	Mr J. S. Armstrong
South East Midlands	Mr G. Shepperson
South Western	Mr C. R. Clarke
Western	Mr P. G. Finn-Kelcey
West Midlands	Mr S. D. Burley
Wrekin	Mr J. Sarsfield
Yorkshire	Mr G. A. S. Frank
North Western	Mr A. Stoddart
South Eastern	Mr E Barker
CIGR Representative	Mr D. P. Evans

Members of the executive committee 1974/75

President	Mr J. V. Fox
President-Elect	Mr T. C. D. Manby
Immediate Past President	Mr J. A. C. Gibb
Past President	Mr T. Sherwen
Vice-President	Mr J. H. Nicholls
Hon. Treasurer	Mr J. C. Turner
Deputy Hon. Treasurer	Mr O. J. H. Statham
Hon. Editor	Mr B. A. May
Deputy Hon. Editor	Mr G. Spoor
Chairman, Membership Panel	Mr L. P. Evans
Deputy Chairman, Membership Panel	Mr J. C. Turner
Fellow	Mr R. H. Miers
Member	Mr G. P. Shipway
Companion	Mr U. G. Spratt
Associate	Mr R. Stokes

Co-opted

Representative on "B.P. Landwork '74" Committee	Mr J. C. Alcock
ERB Representative (Technician Engineer Board)	Mr J. Kilgour

It is essential that all members of the Institution of Agricultural Engineers keep the Secretary informed at all times of any change in their address.

Members of the membership panel for 1974/75

Chairman	Mr L. P. Evans
Vice-Chairman	Mr J. C. Turner
Fellow	Mr P. G. Finn-Kelcey
Fellow	Mr B. D. Witney
Member	Mr G. A. S. Frank
Member	Mr E. Barker
Companion	Mr U. G. Spratt
Associate	Mr C. V. Brutey
Associate	Mr R. Stokes

Co-opted

Graduate	Mr P. R. Philips
Fellow	Mr M. G. Clough
Member	Mr A. Stoddart
Member	Mr G. P. Shipway
Member (representative ERB — Technician Engineer Board)	Mr J. Kilgour

Members of the editorial panel for 1974/75

Chairman and Hon. Editor	Mr B. A. May
Vice-Chairman	Mr G. Spoor
Fellow	Mr J. C. Hawkins
Fellow	Mr N. W. Hudson
Fellow	Mr F. M. Inns

Other appointments

Appointment Officer	Mr J. C. Turner
Careers Adviser	Mr J. C. Turner
Education Adviser	Mr J. C. Turner
Professional Institutions Council for Conservation (PICC) Representative	Mr M. A. Keech (NCAE)

CIGR representative and correspondents

Representative	Mr D. P. Evans
Correspondents:	
Section 1	Mr N. W. Hudson
Section 2	Mr S. Baxter
Section 3	Mr J. H. Neville
Section 4	(to be named)
SecSection 5	Mr R. R. Menneer

Birthday Honours

IN the Queen's Birthday Honours, immediate Past President of the Institution, Mr J. A. C. Gibb, was awarded the OBE for his work as a member of Council of Management of the Council for Small Industries in Rural Areas; and Mr A. de Engeles also received an OBE for services to land drainage in Suffolk and Norfolk.

MISCELLANIA

Proposal for an EEC directive on equipment and machinery used on building sites

IT has been decided within the Commission of the European Communities (CEC) to prepare a Directive on the elimination of technical barriers to trade in the field of equipment and machinery used on building sites. The subject is being considered under three headings — Noise, Site Safety and Road Traffic Requirements.

Three ad-hoc working groups have been set up to draft respective sections of the directive and the Institution has been invited to send a representative to the Noise Working Group. The first meeting of this group was held in April 1974 at which a wide cross-section of interests were represented, including manufacturers, trade and industrial committees, environmentalists, the Civil Service, professional bodies and local authorities. The work of the group concerned with noise includes the consideration of possible certification procedures and a general method of measurement for the majority of machines. Work has now commenced on the general method of measurement and three problem areas have been identified.

(a) The amount of noise emitted (at a distance) by a machine as a moving vehicle.
(b) Noise emitted by a machine when stationary.
(c) Noise emitted by a machine at the operator's position.

Book Review

'Motor Vehicle Technical Regulations' — This book is an explanatory guide to the Motor Vehicle (Consideration and Use) Regulations and the Road Vehicle's lighting Regulations. The book is aimed at providing a better understanding of the Regulations and to give some guidance to their meaning. The essential meaning of each regulation is stated together with the classes of vehicle to which each Regulation applies. There is also a section dealing with Type Approval, Approval Marks, EEC Directives and ECE Regulations which are having an increasing impact on regulations generally.

The book is sub-divided into 13 sections:
Classification of vehicles
General construction requirements
Body items and ancilliary equipment
Engine and fuel systems
Noise
Tyres and roadwheels
Seat belts
Brakes
Laden weights
Light equipment
Manufacturers and ministry plates
Maintenance and use
type approval and approval marks

Motor Vehicle Technical Regulations by C. C. Toyne.
Publishers — Liffon Engineering Services, 102 Fourth Avenue, Luton, Beds. Price: £2.35p.

concluded from page 86

Mr R. Sadler (NCAE) asked whether it was right that future thinking in design and development should be constrained by the statutory regulations previously referred to. Authors reluctantly agreed that it was right but in some respects unfortunate.

Mr Matthews added that there were examples where research and development had overcome regulations. He quoted the safety cabin for which testing was originally based on conventional tractors but as tractors became less conventional it was necessary for regulations to change. In long term development programmes it was possible to modify regulations.

Mr H. G. Pryor considered that the Intrac arrangement had two possible major advantages — forward control and improved transport ability. However, forward control would only be acceptable if the operator could effectively control the operation of ploughing, perhaps by having seating and controls at each end of the tractor.

Dr Gego replied that in ploughing, as in every operation, the priority function was guidance which involved looking forward. He suggested that ploughing was in any case likely to yield to an increase in pto work and the main justification for Intrac was pto work and work involving combination machinery such as forage and beet harvesters.

Mr D. H. Noble (NCAE) in a written contribution said a concerted effort was being made in agricultural engineering research to establish 'mechanisation' as a science. Agricultural operations were being examined critically with a view to establishing best least cost ways of performing them, taking into account physiochemical constraints of crop material, the influence of weather and soil on the performance of machines etc

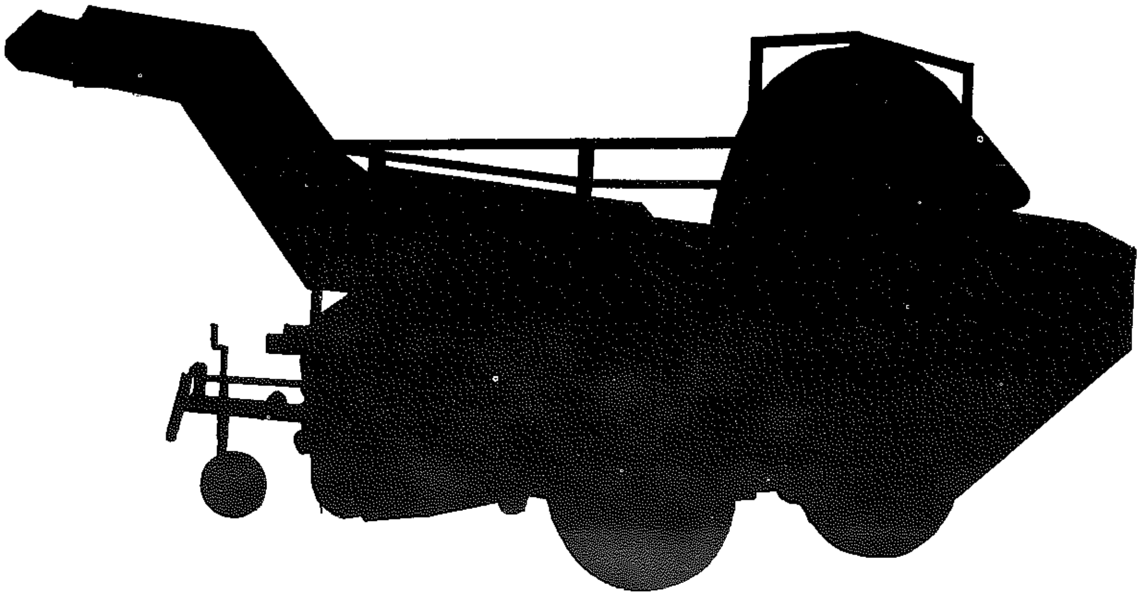
In Mr Zoz's paper an attempt was made to examine primary cultivations in this way. His fig 5 presented the outputs from his model in a graphical form. From this it was clear that there was a considerable range of tractor operating speeds and implement widths over which the cost per acre did not vary by more than 5% from his theoretical minimum. This was somewhat comforting, not only to the farmer who would have to act on this information but also to the analyst who was more aware of the limitations of his data and the assumptions made in forming his model.

Designer, adviser and farmer alike could derive further useful information from fig 6 which indicated the effect of varying each of several important factors (eg cost of fuel, cost of labour, plough resistance, acres ploughed annually etc) on the optimal solution — particularly relevant at a time when costs were increasing markedly. Fig 6 was also useful to the analyst insomuch as it indicated which areas would reward more detailed analysis and determination of more accurate data. In addition fig 7, 8 and 9 illustrated the interaction of pairs of variables on the optimal solution.

Another important factor whose variation would affect the optimal solution was weather. Perhaps this analysis could be extended in the future to examine what effect the 'one bad year in ten' would have on the solution?

THE POTATO MARKETING BOARD'S EUROPEAN POTATO HARVESTING AND HANDLING DEMONSTRATION

PILLATION HALL FARM
PENKRIDGE, STAFFORDSHIRE



Ist and 2nd October 1974