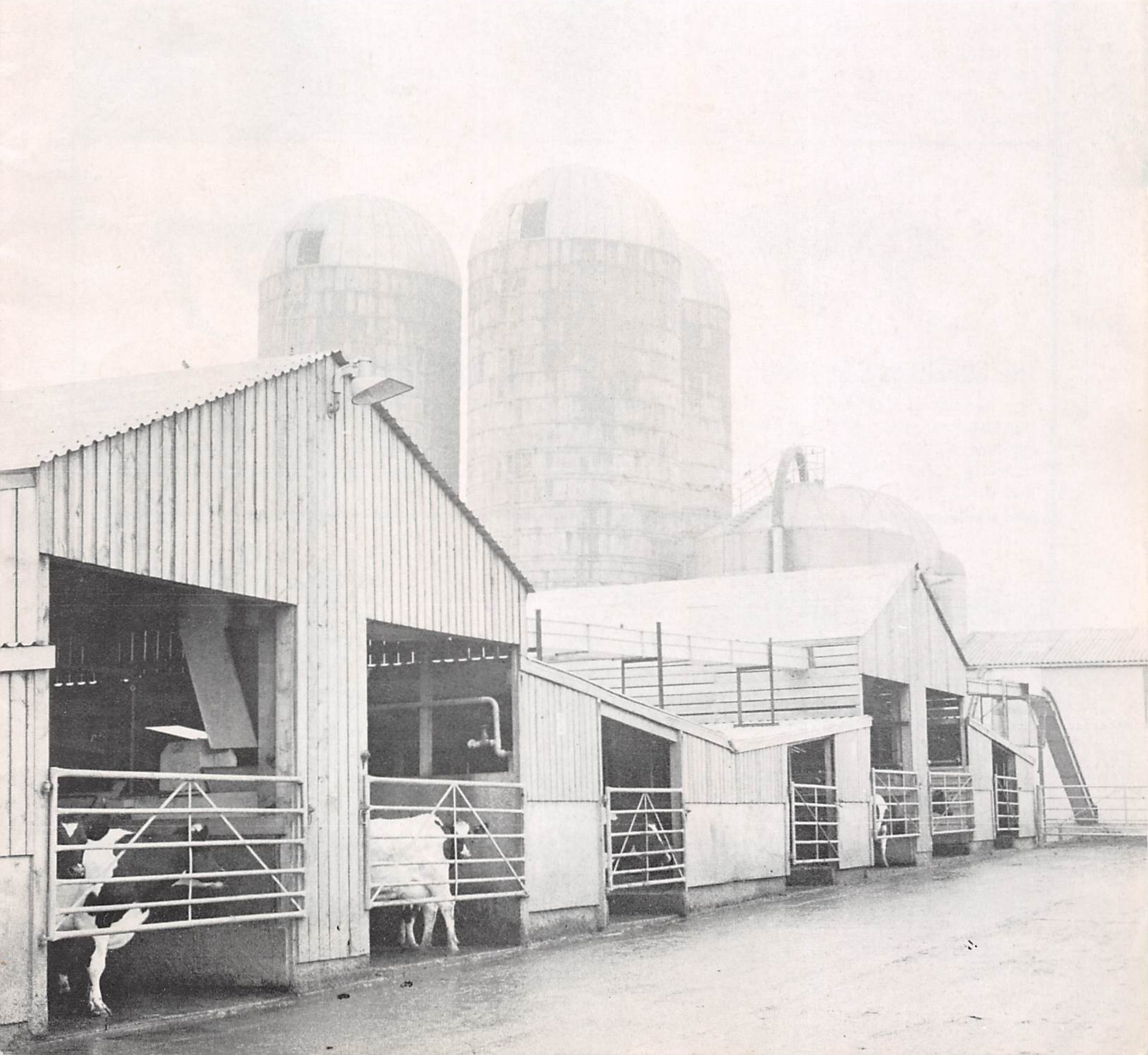
THE AGRICULTURAL ENGINEER

JOURNAL and Proceedings of the INSTITUTION of AGRICULTURAL ENGINEERS

Volume 29 Spring 1974 No 1



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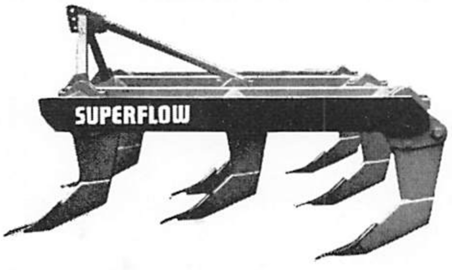

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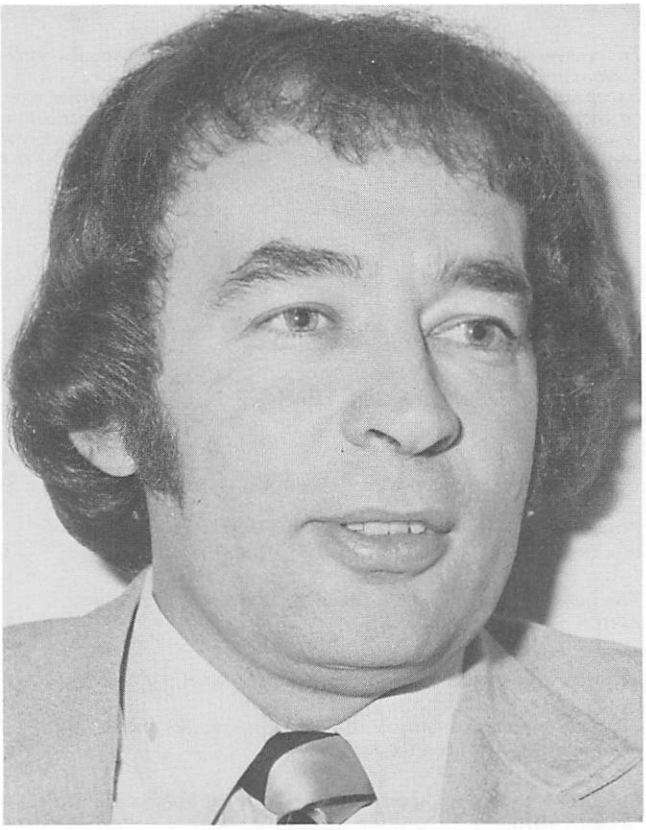
by L P Evans



MANY changes have taken place within and outside the Institution's portals since I was first appointed Chairman of the Membership Committee in 1971. Foremost amongst these have been the changes to the membership regulations to provide a more widely based structure whilst retaining the necessary links with the Engineers Registration Board, such that appropriate candidates may be sponsored for registration as Technician Engineer (T.Eng.(CEI)) or Technician (Tech.(CEI)).

The policy of the Council has been to fulfil the aims and objects of the Institution by creating a membership structure which recognises fully all persons engaged throughout the diverse agricultural engineering and farm mechanisation industry which it serves. With considerable confidence I can now claim that the Institution is able to offer an appropriate membership grade to all applicants whose aspirations range from a genuine interest in the subject of farm mechanisation to those who are, for example, deeply immersed in technical research work.

It is intended to publish a completely revised and full 'Guide to Membership' in a forthcoming issue of The AGRICULTURAL ENGINEER, presenting, in a much more simplified form than hitherto, the routes to membership in the present grades of Student, Graduate, General Associate, Technician Associate, Member, Companion and Fellow. This will enable existing and potential members to identify with the structure individually. I consider that there are many members who could benefit from the changes which have taken place in recent times, in particular the increased recognition of experience and proven ability as a satisfactory alternative to formal academic qualifications in determining eligibility for membership in the grades (Member and Technician Associate) accepted for registration with CEI.

You will know that the Institution was invited to become a founder member of the Engineers Registration Board and to be fully effective in this role it was necessary to impose the most stringent requirements in terms of registrable qualifications so as to start the registration process in an orderly way. At this early stage, however, it was fully recognised by the ERB and the Institution that this action would, temporarily, deny a considerable number of mature candidates the opportunity of registration.

The ERB began its registration operations effectively in 1973 and the Institution has already sponsored many registrants to the T.Eng(CEI) and Tech.(CEI) registers.

Following exhaustive negotiations, the Technician Engineer and Technician Sections of the ERB have now defined a Mature Candidate as 'a person with considerable experience and responsibility at the T.Eng. or Tech. level who, but for the absence of formal academic qualifications acceptable to the Engineers Registration Board, would be eligible for registration on the Composite Register'. Such persons will be at least 35 years of age at the date of application.

The ERB has determined outline procedures whereby appropriate candidates may become registered as Technician Engineers or Technicians. The Institution submitted its proposals for operation of these procedures immediately the announcement was made by ERB and will implement them as soon as the necessary approval is received.

In general terms it is expected that the Mature Candidate routes to membership of the Institution in the grades of Member and Technician Associate (qualifying for sponsorship to T.Eng.(CEI) and Tech.(CEI) respectively), will be as follows:

1. An interim procedure will enable certain existing members to transfer to the registrable grades with minimal further assessment — principally:
   (a) those who became members before 1 November 1973, and satisfy requirements as to their experience — normally 15 years total, with a minimum of 10 years continual employment at an appropriate level, or
   (b) those who became members before 17 June 1970, and who have remained ineligible for registration because they had not accumulated the necessary 10 years experience before that date, but did so before 31 December 1973.

Many Institution members will be able to benefit from this arrangement, but candidates must apply during 1974.

2. A full procedure will enable new applicants to be considered for admission to the registrable grades without formal academic qualifications provided that they meet appropriate experience requirements and are able to demonstrate their competence in agricultural engineering or mechanisation.

It is fully expected that ERB approval will be received in time to publish, in the next issue of The AGRICULTURAL ENGINEER, full details of these procedures incorporated into the aforementioned Guide to Membership.

At the last AGM held on 3 July 1973 changes to the membership structure of the Institution were adopted making the Companion a Corporate grade and widening its scope of application. This has enabled the Institution to reflect other modern changing patterns of agricultural engineering by recognising and accepting into membership candidates who are specialists in their own fields — architectural design, electronics, hydraulics, for example — applying their skills to agricultural engineering or mechanisation. Furthermore the Companion grade now bestows corporate status on those outstanding mature candidates of long experience and occupying positions of considerable responsibility in the manufacturing, distributive and allied sections of our industry.

The minimum age level for Member grade has been reduced to 23 years and certain changes to the academic qualification requirements for the Graduate and Member grades have been made to align more closely with those of ERB in order that the maximum possible number of members may be sponsored for registration. I strongly recommend that all eligible members seek and maintain registration because of its increasing importance in the international engineering context.

During the latter half of 1973 important changes were made to the administrative arrangements for considering applications for admission or transfer to the various grades of membership. By appointing me Chairman of the Membership Panel and delegating executive powers to its operation, the Council has enabled the majority of applications to be assessed much more quickly than hitherto, and has made it possible for the Panel to give much more attention to fundamental matters.

Production of controlled environments for crops in bulk and box stores

by B Montandon AMBIM MInstM AMIEx

Introduction

THE decision to adopt bulk or box storage for potatoes and vegetables is unlikely to be taken as a result of consideration of controlled environment conditions and is more likely to be taken after assessment of the cost of buildings, ducting, methods of handling, damage to the crop due to handling and other similar considerations.

The achievement of a set of environmental conditions within a building structure can be as readily achieved with a bulk store as with a box store. However, in order to realise these conditions some specialised building work might be necessary and equipment performance parameters may well be different, and these factors will therefore affect the costs of this equipment. An example of the main building difference will be that for bulk storage some form of low level ducting to distribute air through the mass of produce is necessary but with a box store this is unlikely to be a requirement (fig 5).

Once the environmental control parameters have been chosen[1] the method of achieving an environment is then under the control of the environmental equipment designer and the building architect. The effect of the building on the environment cannot be too highly stressed and the degree of environmental control is generally only as good as the building in which the environment is to be achieved.

Effect of building structure on the internal environment

The selection of building fabrics and building construction have been mentioned previously[2,3,4] but it is perhaps worth mentioning at this stage that the building should be essentially a sealed structure so that any air leakage to and from the building will take place under carefully controlled conditions rather than by accident.

Insulation material will be determined mainly by:

(a) The ambient temperature to which the building outer fabric is subjected.
(b) The temperature at which the inside of the building will operate.
(c) Duration of storage.
(d) Relative humidity at which the store will operate.

In general terms, the greater the differential between external and internal temperatures, the more effective must be the insulation. The selection of insulation is to some extent influenced by the duration of storage, but this is usually of secondary importance. The temperature at which the store will operate will radically affect the type and placing of insulation material. For stores operating at 5–10°C and sited in the United Kingdom the floor is unlikely to require insulation but if the store temperature is designed to be below 0°C insulation must be incorporated and also special precautions taken to prevent 'frost heave'.

During the long term storage of potatoes, leafy vegetables, carrots, beet and similar vegetables, water loss can be high and therefore a high humidity within the store is necessary to restrict this loss and Burton has already discussed the requirements for the ideal storage of these crops[4]. However in order to illustrate the possible effect of insulation on the relative humidity see the following example: A square building holding approx. 250 tonnes of potatoes in boxes erected in England. Holding temperature – 10°C. External temperatures of at least – 6°C. Total area of walls, roof and floor = 50.5 m^2. Insulation factor: U = 1.14 W/m^2 deg C. The total loss from the building through roof, walls and floor will be 38 000 kJ/h.

This loss, in order to maintain a temperature of 10°C, must be provided by respiration heat from the potato and additional artificial heating. In this particular example some 7 000 W of extra heat will be required which will inevitably have the effect of reducing the relative humidity of the air. Moisture will also condense on to the roof and other cold parts of the building and this moisture of course largely represents moisture removed from the potato and appears as a direct loss of weight from the potatoes in store. The moisture removed by condensation in this manner is replaced by additional moisture extracted from the potatoes by the warmed dry air being used to maintain the temperature of the stack which will naturally take up more moisture from the potatoes and which will in turn be condensed on the roof. This cycle will continue until either the outside temperature rises to a level where condensation will not take place or the internal relative humidity of the store falls to a low level.

If however an insulation factor of U = 0.28 is chosen instead of U = 1.14, the thermal loss through the insulation will become some 2 600 W and this is less than the heat output from the potatoes at that storage temperature. Additional heating therefore is not required and the relative humidity will stay high as cooling is always being applied. The temperature gradient across the insulation material will be much greater and the internal skin will more closely approach the temperature of the store. This therefore will have the effect of reducing the probability of condensation taking place. Perhaps rather briefly this example shows that a high degree of insulation is most desirable in order to reduce condensation as well as to reduce running costs. In practice however some compromise may be drawn between the two figures quoted in order to optimise cost of insulation, capital cost of environmental control machinery and weight loss from the potatoes, but in certain extreme circumstances the level of insulation will be even greater than the figure quoted.

Similar assessments can be made for other vegetable stores although in the case of onions, because the relative humidity of the store will be deliberately held at a lower figure than for potatoes and other highly respiring crops (in order to dry the onion), the insulation could perhaps be reduced as condensation under conditions of long term storage would not be so serious. Other factors however will influence this decision, such as the temperature at which the onions must be dried and as this is very high the internal temperature of the store has to be many degrees centigrade above the ambient temperature and therefore thermal loss through the insulation, and not condensation, will become of prime importance as this loss must be replaced by artificial heating. The cost of running artificial heating appliances might therefore influence the designer towards a better level of insulation.

Duration of storage and methods of cooling

The period of storage, duration of storage, temperature of storage, relative humidity within the store and the ambient temperature in which the store is built will all influence the method of cooling which will be chosen. To simplify the explanation of a typical store which might be installed in the United Kingdom and holding vegetables which require to be stored at a temperature of about 5°C during any part of the period May through to September will be considered. Fig 1 is a graph showing the percentage of time the ambient temperature is below a given temperature for a 12 month period and applies to East Anglia. As will be seen from this graph the ambient temperature does not fall below the desired temperature of 5°C and it will be impossible to use ambient air cooling for this period. Mechanical refrigeration must be used and in order to provide a commercially economic store a number of factors must be assessed and optimised. These factors include building construction

B. Montandon is a Director, BM Air Systems Limited.

Presented at the Spring National Meeting of the Institution of Agricultural Engineers at the Essex Institute of Agriculture, Writtle, Chelmsford, on 28 March 1972, when the subject was Building and Equipment for the Storage of Potatoes and other vegetable crops.

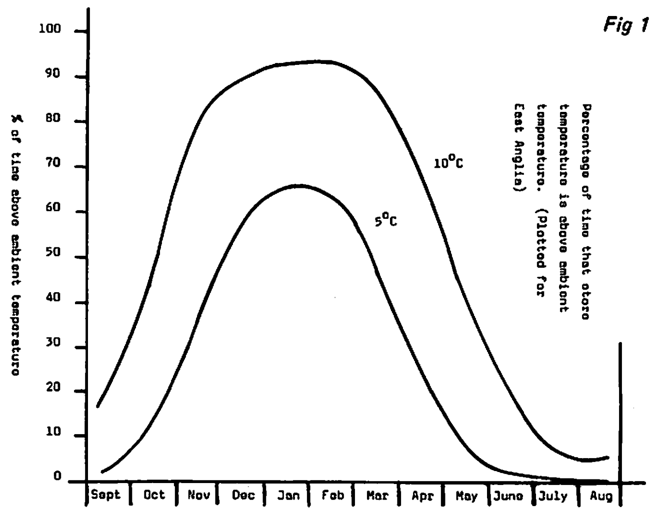


Fig 1

and insulation (as previously mentioned), the time of year (and therefore the ambient temperatures) at which the store must operate, the desired holding temperature and any other factors influencing the total maximum cooling load that the plant must handle.

Observation of fig 1 shows that the temperature difference between the inside and the outside of the store is going to be high and virtually any form of mechanical refrigeration system no matter how well designed is going to extract moisture from the store if the relative humidity of the store is to be maintained at a high level. Therefore the total heat load applied to the refrigeration plant must be minimized in order to minimize the size of this plant. The insulation of the building must therefore be at the highest practical level and air leakage into the building must be virtually eliminated. If fresh air is necessary to avoid build-up of unwanted gases this air should be deliberately introduced under controlled conditions so that the heat load appearing from this source can be predicted with reasonable accuracy. The other major heat load is provided by the vegetable and any other source of heat such as mechanical handling equipment. One other factor which must also be considered is the temperature at which the produce will enter the store and if this is higher than the final holding temperature, the rate at which the temperature must be reduced. This rate of pull-down of temperature is a most important aspect of equipment sizing and will greatly influence the rating for the machine. The loading regime applied to the store and methods of loading, ie how often the doors will be open, the rate of loading of the store, and the type of mechanical handling equipment which will be used will also influence the heat load and thus the size of the plant[5].

Determination of the heat extract requirement of mechanical refrigeration plant is only one of several aspects of this equipment design. Other major considerations are: the relative humidity at which the store will operate, the store loading and holding temperatures, air flow requirements, the resistance to air flow (back pressure), and the maximum ambient temperature (in order to design the condenser). The design of the cooling heat exchanger (or evaporator as it is often called if a direct expansion system of refrigeration is employed) is greatly affected by the relative humidity at which the store will operate and by the maximum permissible drop in air temperature across this exchanger. If the relative humidity is to be 90% and more, as in the case of potatoes, leafy vegetables, carrots and beet, the cooling heat exchanger must not extract an excessive quantity of moisture. This is achieved by operating the coolant at a temperature as close as possible to the temperature at which the store is to be held in order that the dew point of the air will not be reached when it is cooled by passing over the heat exchanger. In practice this is a costly and sometimes difficult condition to achieve in a commercial store but any relaxation of this requirement may cause an increase in vegetable weight loss which may be unacceptable. The generally accepted range of figures for very long term storage is 4–8°C below the designed holding temperature. The figure of 4°C is naturally to be preferred but duration of storage, assessment of increased weight loss as the coolant temperature is lowered, effective utilisation and availability of capital must all be jointly considered in order to arrive at the best compromise. The cost of refrigeration equipment does rise significantly as this differential is reduced. However the lower coolant temperature of 8°C below the holding temperature should not be exceeded as other factors such as excessive icing of the heat exchanger and therefore longer de-icing periods, together with lower delivery air temperature, begin to assume unacceptable proportions. The volume of air used for cooling must also be selected in order to provide an acceptably low differential between the air applied to and returned from the heat exchanger. Once the heat exchanger (or evaporator) has been sized, the condenser and compressor must be sized in order to provide the cooling capacity demanded from the evaporator. This is not as simple as might at first appear as at least the two extreme conditions of the heat exchanger (evaporator) operation must be considered. These are the heat to be extracted at the highest and lowest temperatures that the air will be applied to the heat exchanger.

The condenser must be rated, if it is an air cooled condenser, to give the maximum extraction requirement with the highest ambient air temperature it is likely to experience. The decision to utilise an air cooled condenser or a water cooled condenser will be governed by a number of things such as the ambient temperature, the size of the plant, the availability of cooling water etc. Sizing of the refrigeration plant is a fairly complex problem and it is extremely poor practice to cut corners in order to keep the price low if such corner cutting in any way causes a degradation of performance. The refrigeration plant is intended to hold the temperature of the produce at a certain level, particularly during conditions of high ambient temperature. If the plant is inadequately rated so that the temperature of the produce cannot be held at the designed value, the respiration heat (metabolic heat) from the vegetables will start to increase thus putting an additional load on the refrigeration plant. This additional load will not be handled because of the marginal rate of the equipment and therefore the temperature will rise further thus causing an additional increase of the heat output. The situation will therefore develop which might be described as 'thermal runaway' where the temperature of the produce escalates and the whole store goes out of control. This problem of thermal runaway cannot be too heavily emphasised as it is a very real problem which can well occur when the extremes of conditions coincide; obviously therefore it is false economy to purchase plant which is not capable of handling all the conditions likely to be experienced by the store. The foregoing comments refer to stores and refrigeration equipment installed in the United Kingdom during the summer. If overseas storage of vegetables is being undertaken the comments just listed must be even more firmly followed as in many parts of the world the ambient temperatures are extremely high with little reduction during the night.

Ambient air cooling

In the United Kingdom we are fortunate in that many of the vegetables which need to be stored are lifted at the end of the summer and are to be stored during the winter. The ambient temperatures between October and the end of April vary greatly but during much of this period whilst the daytime temperature can be high the night-time temperature is frequently low. A potato store therefore which is to be held at approximately 5°C and upwards may be satisfactorily held using ambient air cooling on a strictly controlled and selected basis. To determine the effective cooling capability of ambient air for a given location during the period of interest, detailed meteorological information must be analysed. This is an involved exercise but can be reduced to a simplified form by plotting the mean minimum temperature as a percentage of the time the ambient air temperature is below a given value, against time — where time is every month in a full twelve months. This graph will then clearly indicate the months in the year that ambient air is likely to be below the desired holding temperature (fig 1). This information is not sufficient in itself to determine the ability of ambient air to maintain a store at a given temperature and the cooling capability of varying rates of air flow must be assessed.

Fig 2 shows the cooling capability of varying rates of air flow plotted to illustrate the ability of a given air flow to maintain a pre-determined temperature of an insulated potato store for any given month. The basic information used to derive this graph was obtained from 15 years of meteorological information from the United Kingdom[6]. This graph clearly illustrates that the cooling benefit to be derived from increasing rates of airflows is not in any way proportional to this flow and for the majority of potato storage temperatures and periods of storage a flow of 67 m^3/tonnes/h is sufficient. Doubling the air flow only provides a small increase in the period of storage. This information has been deduced for stores utilising highly efficient fans where the power input to the fan for a given flow is very low. Fans which require a large amount of power

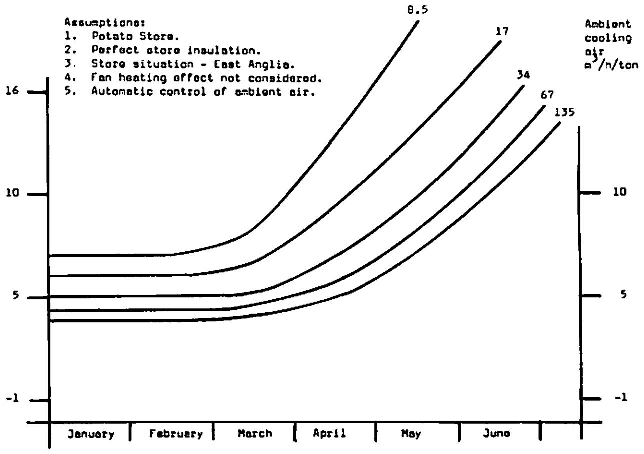


Fig 2 Estimated minimum achievable storage temperature using ambient air cooling under automatic control.

radically affect these figures by causing the period of storage to be significantly reduced. The information shown in fig 2 can be considered as idealised as the assumption has been made that fans will be operated as soon as the ambient temperature falls below the STORED VEGETABLE temperature and will be stopped when the ambient air exceeds this temperature. Automatic control of fans is therefore imperative in order to achieve this condition. The decision to install fans of very large capability might not therefore be taken solely on the basis of environmental control requirements but might be influenced by other considerations such as the drying of wet potatoes if for some reason potatoes are loaded into store in this condition. The loading into store of wet potatoes is in no way encouraged as severe damage can result to these potatoes whilst in store,[7] however, high air flow rates are considered beneficial in this instance to remove the excess moisture although it is unlikely that these potatoes would then be retained in the store for any length of time.

The above air flow and storage period conclusions can be applied to either box or bulk stores as the heat output from the potato is not dependent on the method of storage provided temperature and other similar considerations are the same. One factor which will have some bearing on the store performance is the power consumed by the fan and this aspect has been mentioned previously. Box storage of vegetables provides little restriction to the passage of cooling air and therefore the back pressure experienced by the cooling fan is small. The greatest restriction offered will be the air distribution ducts (if incorporated) and air exhaust passages. Cooling fan(s) having a capability of providing rated air flow into 12 mm water will be more than adequate for most applications. This rating is quite modest and allows the selection of efficient low horsepower fans. Bulk stores, in contrast, offer a significant restriction to air flow and the worst practical condition must be considered when selecting and sizing fans. The total resistance offered to air flow is the composite resistance of main air distribution ducts, lateral ducts and the stored vegetable resistance. In considering air duct losses due allowance must be made for bends, surface finishes, etc. With a clean crop of potatoes and a well designed duct system operating at a flow of 67 m^3/tonne/h, a resistance to air flow (back pressure) of less than 12 mm water can be expected. Current recommendations by the Ministry of Agriculture, Fisheries and Food are that for flows of 67 m^3/tonnes/h the fan should be capable of providing rated flow into a back pressure of 38 mm water. This figure may be considered high but does make allowances for the fact that dirt can be included with the potatoes when loading into store and can therefore be considered a good rule-of-thumb guide. If the store and air distribution ducts can be designed for minimum air flow resistance, and if the potatoes could always be loaded into store in a clean condition the fan rating could be reduced with a corresponding reduction both in capital and operating costs. In practice it is perhaps unlikely that this optimisation of ratings will be adopted as in view of the high capital cost of new controlled environment buildings the move is more likely to be towards the use of the store for more than one type of vegetable in order to achieve better building and equipment utilisation. This tendency should be encouraged as dramatic reductions in cost per ton can be achieved by spreading the store costs over more than one crop. The disadvantage of this technique is that some aspects of the building and air handling equipment may become more complicated and expensive but measured in terms of percentage increase in cost of complete store will not be very significant and amortized over several crops will show a tremendous saving.

Fans for ambient air cooling

The selection of the fan should be governed by the detailed application and conditions under which it will operate, as previously mentioned, in order to provide the most effective cooling. Providing electrical power is available at adequate levels electrically driven fans can be used thus providing easily controlled cooling. If electrical power is not available it would be imprudent to contemplate long or even medium term storage of potatoes or similar vegetables. The manual operation of internal combustion engine driven fans would be too imprecise to assure satisfactory storage. Short term storage might perhaps be contemplated with this method but the blow rate per tonne would almost certainly have to be increased compared with automatically operated electric fans and this would cause the consumed horsepower to be increased thus raising the temperature of the cooling air further.

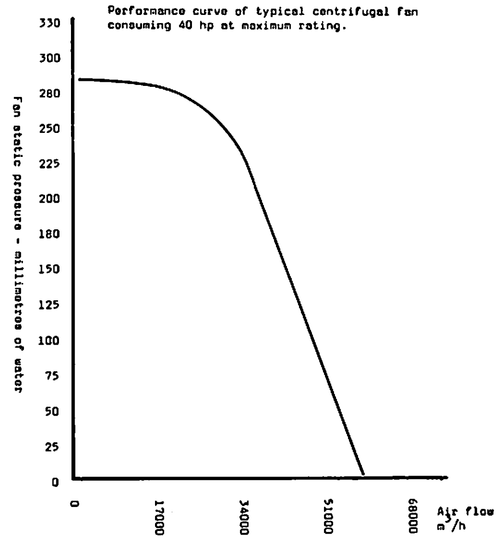


Fig 3

Electrically driven fans fall into two main categories—centrifugal and axial flow. Centrifugal fans have characteristics typified by the curve shown in fig 3 which is for a certain type of commercially available unit. The flow rate for this type of fan falls relatively slowly as the back pressure increases, and the maximum back pressure into which the fan will operate is very high. These characteristics are particularly useful if the fan is intended to operate into a high back pressure or if the range of back pressures to which the fan will be subjected in any particular application will be wide. The power for the fan quoted is 30 kW and the speed of rotation 1440 rev/min. Low speed axial flow fans have rather different characteristics as shown in fig 4. They cannot so readily feed into high back pressures except by multi-staging, high speed and other techniques, but can readily provide large flows into small back pressures. The example quoted is for a fan which provides an air flow into a back pressure of 25 mm water at the same volume as the centrifugal fan shown in fig 3 and yet the consumed power for this axial flow fan under these conditions is only 8.2 kw. The axial flow fan in this example would therefore be cheaper to run and have lower electrical installation costs than the centrifugal fan if a pressure of 25 mm water or even slightly higher was the design back pressure. (The particular example of fig 3 shows that a back pressure of 42 mm water (approx.) could be handled but at a reduced flow).

Both fans therefore have distinct differences one from the other and it is important to select the correct fan for the desired duty in order to derive the full benefits of a particular fan design and to ensure a satisfactory cool store.

Control of fans for ambient air cooling

The simplest form of fan control is the manual operation of the fan starter but for reasons previously mentioned this method cannot be endorsed and therefore only automatic systems will be discussed.

Fan operation can be controlled by thermostats which cause the fan to start if the ambient air temperature falls below a pre-set level

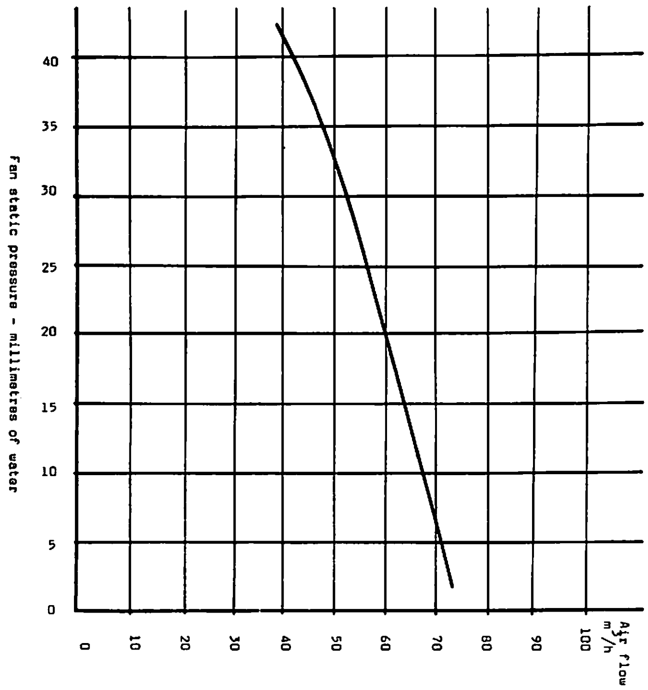


Fig 4 Performance curve of typical 1220 mm diameter axial flow fan operating at 720 rev/min and consuming 10.1 horsepower at maximum rating

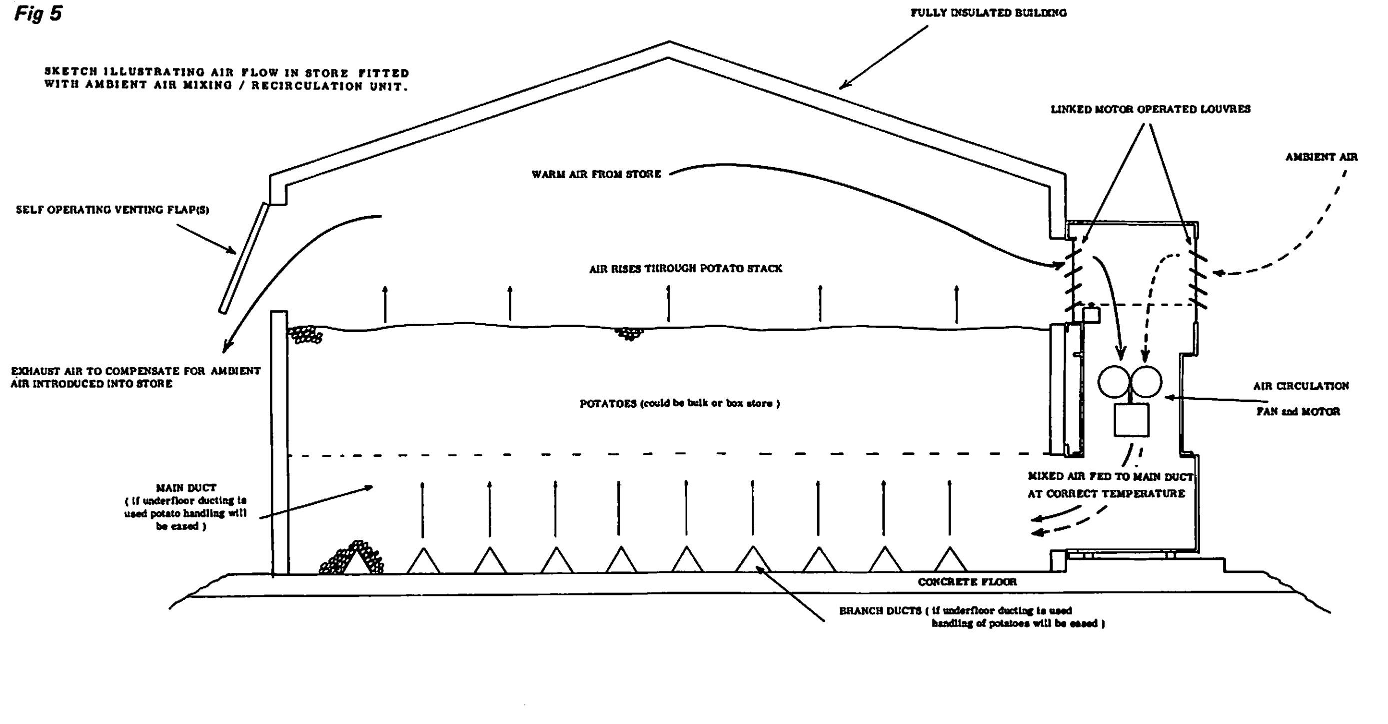
and a second thermostat will stop the fan if this air temperature falls below a lower pre-set temperature. This arrangement is simple and inexpensive but unfortunately does not take any account of the temperature of the stored vegetables. A better method therefore is one which senses the temperature of the stored produce and if this temperature is above the desired holding temperature causes the fan to start if the ambient air is below this temperature but above some other pre-set low temperature. With this arrangement the fan will continue to operate until the store is at the same temperature as the ambient air. The stored vegetable should be monitored at several points and the control of the fan effected by the average of these temperatures. Single point control presents the problem of sitting of the sensing probe as it is not always possible to determine the best position for one probe to ensure that it is not situated in a cold (or hot) pocket. The disadvantage of this method is that when the store is at the desired temperature, or when the ambient air temperature is above the store temperature or below the safe temperature, the fans cannot operate and therefore ventilation of the store will not take place. This is frequently undesirable as in bulk potato, beet, carrot, onion and similar vegetable stores, air should be circulated to remove the metabolic heat and therefore prevent severe temperature gradients which may develop between the bottom and the top of the vegetable stack. A second disadvantage of this method of cooling is that if the ambient air remains at a temperature below the minimum acceptable temperature for a long period the temperature of vegetables in an insulated store could well rise to unacceptably high levels.

Many vegetable stores must be kept to within a close tolerance of the nominal holding temperature. To achieve this situation the cooling air should only be applied to the store at a temperature as close to the holding temperature as possible, consistent with the differential necessary to extract the heat from the store. This can be achieved with ambient air cooling by incorporating some method of automatically mixing the ambient air with warm store air whenever the ambient air is at too low a temperature in order to achieve the desired cooling air temperature. In order to cope with the continually changing conditions of temperature, manually controlled mixing is unlikely to be a viable solution and some form of automatic control must be used. A typical method operates as follows:

The temperature of the stored vegetables is sensed at several positions and arranged to overcome the problems of single point measurement as previously mentioned. If this temperature is higher than the pre-set holding temperature the cooling fans will operate when the ambient air is below the STORED VEGETABLE temperature. The temperature of the cooling air is automatically and continuously monitored and if this deviates from a pre-set temperature a signal is passed to a servo motor which rotates and alters the position of two sets of louvres thus altering the proportion of mixing ambient and store air, until the cooling air temperature is the same as the pre-set temperature (fig 5). If the ambient air is at a temperature in excess of the pre-set cooling air temperature but below the store temperature the louvres will cycle to a position which provides all ambient air and no mixing of store air. When the store temperature falls to the pre-set holding temperature, or the ambient air rises above the stored vegetable temperature, the fan will stop. The fan could be in an inoperative state due to the combination of temperatures for many hours and to ensure that air is passed over the vegetables this system will incorporate 'timed recirculation'. Timed recirculation can be readily applied to this system as a time switch can be incorporated which will cause the fan to operate for a number of minutes in each hour irrespective of ambient temperature. To avoid introduction of ambient air in this period the servo motor is given a signal which causes it to shut the ambient air louvres and open the store louvres, thus the fan will recirculate the store air through the vegetables. In practice a period of some 6 minutes in each 60 minutes has proved to be satisfactory.

Free moisture in a potato store is to be avoided as this leads to massive damage due to rotting and other diseases (see Burton[7]). The technique of ambient air selection and ambient/store air mixing described above has been shown to be particularly successful in

Fig 5



avoiding condensation in potato stores. Conventional ambient air ventilation with conventional gable ventilation can frequently cause condensation to appear on the building structure, on the inside skin of the insulation and also above the potatoes. The reason for this condensation is believed to be as follows:

With a low ventilation rate the cooling air is applied to the bottom of the stack and in rising through the stack takes up heat and moisture from the potatoes. With potatoes stored several metres high and with a ventilation rate of less than 15 m^3/h per tonne the air passing over the potatoes could rise in temperature by several degrees C. Older stores traditionally have gable vents which are usually open to the weather. Wind can therefore blow through the store removing the warm air from above the potatoes and replacing with cold ambient air. This cold air will cool the inside skin of the insulation and also the building structure. As soon as cooling air is applied to the stack at the low ventilation rate this air, having been raised in temperature by passage through the potatoes, will encounter the colder air barrier above the potatoes. Due to the high moisture content of the air coming off the potatoes, when cooled by contact with the cold air, moisture will frequently condense out and fall on to the potatoes. This warmed air will also impinge on the inside skin of the store and any of the building structure which may well be at a lower temperature and again cause condensation. In the past, the top of the potatoes have been covered by several feet of straw in order to absorb moisture which would otherwise appear on the potatoes. The modern approach of providing a sealed building with no free ventilation of the space above the potatoes will prevent the warm air being removed by cold ambient air. Larger ventilation rates of at least 30 m^3/h per tonne will reduce the temperature gradient the air will experience in traversing the potato stack and will maintain the space above the potatoes and the inside of the building at substantially this temperature. The air introduced from outside for this cooling purpose must of course be exhausted in order to avoid an excessive pressure build-up within the store and this is best accomplished by pressure operated flaps above the potato stack. The flaps will therefore only open and exhaust air as a result of a positive pressure within the store. Because therefore the whole of the store is maintained at substantially the same temperature as the potatoes the likelihood of condensation appearing, even though the relative humidity at which the store is operating will be very high, is considerably reduced. Three stores using this technique and which have been monitored this season have been shown to be virtually free from condensation at all times and the need for straw on the potatoes has therefore been eliminated. Two of the stores monitored were bulk stores and neither of these stores had straw on the surface of the potatoes. The insulation factor for these stores was approximately $U = 0.68$ $W/m^2/°C$.

A store designed to hold potatoes without a covering of straw must of course be completely light-proof. This will usually be achieved by satisfying the earlier requirement of a sealed building but the exhaust air vents will require particular attention. Cowls can be fitted to the inside and outside of these vents and providing they are deep enough to prevent a direct passage of light this method will be satisfactory. These cowls should be painted internally with a matt black paint to prevent light being reflected into the building.

Vegetable store heating

To determine the required heating load for a vegetable store, all losses must be considered eg air change, respiration load, loss through the insulation, air leakage and the rate of produce temperature increase that is desired. Once the heat load has been determined the heating medium which will be used will be governed by the economics of the fuel available.

Electric heating applied to air circulation systems is probably the easiest system to control as contractors can be readily operated by temperature control devices and give very rapid response. Electric air heating may not however be selected if the cost of providing a large incoming supply to the store is such that the project becomes uneconomic, and an alternative method of heating might be selected. Typically therefore oil or gas fired heating might be employed. If gas or oil heating is used the products of combustion must not come in contact with the potatoes or other vegetables as often these products of combustion will contain harmful gases and wastes which may well deposit on the crop and cause deterioration. Another disadvantage which is equally important is that due to the large amount of water produced by combustion of these fuels the moisture laden air on coming in contact with the cooler vegetable may well deposit water on the vegetable which might encourage deterioration of the vegetable due to rotting[7], therefore either electric air heating should be used as this does not increase the water content of the air or indirect heating should be employed if oil or gas heating is utilised. A combination of electric heating and oil or gas heating can prove advantageous as the more easily controlled electric heating could be used to provide a fine control over temperature and other fuels could be used to provide the major heat input when this is required. Typical applications of course for this dual system would be the drying of vegetables eg onions etc and would not normally be associated with holding of a vegetable crop as vegetables are usually held at relatively low temperatures and even potatoes for process purposes are generally held at approximately 10°C. Providing however the building insulation is good, little or even no heating would be required.

Air flow in ducts

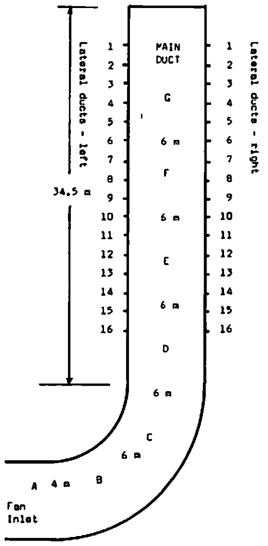
Main and lateral ducts for bulk stored vegetables should be designed specifically to provide the correct air distribution characteristics required for each store. These ducts should offer only a small resistance to air flow so that the fan is not called upon to do an unnecessary amount of avoidable work with a corresponding increase in consumed horsepower. The cross-section area of the main duct must therefore be as large as possible in order to maintain a low air velocity. There are practical considerations which limit the size of this duct and not the least of which is capital cost. This factor however must not be the sole criterion by which the duct is sized as an excessively small duct will require a much larger fan, fan motor, starters, cables and electricity supply – all of which are capital expenditure items offsetting the reduced cost of the smaller duct. In addition much higher operating costs are incurred which are an annual and recurring levy on the store, together with the distinct possibility that the store will be less effective. A good compromise must therefore be drawn. The main duct is usually the means of distributing air to a number of smaller lateral ducts which are at 90° to this main duct. These lateral ducts feed the air through the stored vegetable to provide the desired rate of ventilation and cooling. The following comments relate to this particular configuration and not to a main air feed duct which is used solely to transmit a given volume of air from one point to another point many metres away, as other standards may well be adopted for this simpler duct.

Correct matching of a fan to any form of ducting is important as a mis-match will cause a very significant back pressure. The type of matching will depend upon the fan used and the geometry of the duct into which it will feed. It is not usually sufficient to simply bolt a fan directly to a duct inlet, but instead an outlet cone would normally be required, the size and shape of which would be governed by the duct and fan. Rapid changes of direction of air flow should be avoided, but if necessary then deflectors should be used. If the change of direction is necessary in the main duct and deflectors cannot be used for reasons of accessibility, the bend must be gradual. The main duct should have a cross-section area which is large enough to ensure a substantially constant pressure throughout its length. Main ducts which have a small cross-section area will operate at a very high velocity and may well have a much greater pressure at the closed end furthest from the fan. This situation will result in the lateral ducts feeding from the end near the fan being 'starved' and the ducts at the furthest end of the main duct passing an excessive volume of air. It should perhaps be mentioned that if this situation results due to factors beyond the designer's control then devices can be employed to remedy the situation, such as deflectors and adjustable shutters on each lateral duct opening. These devices, if necessary to balance the flow, do severely complicate store management and are therefore to be avoided.

Fig 6 shows the tabulation of results taken from a store with underfloor main and lateral ducts with velocity measurements taken in the main duct on the floor and 1.5 m above the floor at two rates of flow.

Fig 7 shows the velocity in each of the lateral ducts at the two rates of air flow.

These results were taken from an insulated potato seed store measuring 34.5 m by 10 m by 2.6 m high storage. The store was two thirds filled with seed potatoes in bags and is furnished with automatically operated ambient air cooling equipment coupled to refrigeration machinery and has a maximum flow capability of 100 m^3/h per tonne stored. The store was holding mini-sprout seed potatoes and has a maximum bulk store capacity of 500 tonnes. Some of the results were taken with one third of the lateral ducts closed as this was the way the store was being operated, and one set



Position in duct	Air flow 25,000 m^3/h Duct velocity (m/min) Height 0 m	Height 1.5 m	Air flow 60,000 m^3/h Duct velocity (m/min) Height 0 m	Height 1.5 m
A	400	70	700	0
B	333	200	700	570
C	170	330		
D	150	220	430	600
E	100	100		
F	50	50	300	333
G	0	25		

The back pressure measured at the fan outlet during these tests was:-

Air flow at 25,000 m^3/h - 4.5 mm water

Air flow at 60,000 m^3/h - 12.5 mm water

Sketch of main duct showing position of laterals and table of results of air flow velocities measured at selected positions and heights in this duct

Fig 6

of results were taken with all the lateral ducts open to the main duct. This is not a representative situation as one third of the lateral ducts were not covered by potatoes and therefore would be operating at a different impedance from the other two thirds of the ducts. Despite this imbalance the results show that a good balance of flow has been achieved with this system at both rates of air flow without resorting to any form of flow adjustment. It is also significant that the velocity down Numbers 16L and 16R ducts is very similar to the velocity in Numbers 1L and 1R.

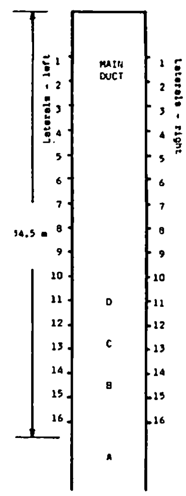
Fig 7

Velocity of air entering lateral ducts (m/min)

Flow into main duct:	25,000 m^3/h	60,000 m^3/h	
Left laterals	*Velocity m/min*	*Velocity m/min*	
1	closed	closed	700
2	closed	closed	700
3	closed	closed	700
4	closed	closed	600
5	closed	closed	700
6	closed	closed	530
7	closed	closed	500
8	closed	closed	700
9	closed	closed	700
10	closed	closed	700
11	433	700+	700
12	333	700+	500
13	400	700+	700
14	433	700+	700
15	370	500	700
16	333	700	630
Right laterals	*Ducts L1–10 closed*	*Ducts L1–10 closed*	*Ducts L1–10 opened*
1	370	700+	700
2	333	700+	600
3	400	700+	700+
4	333	700+	600
5	333	700+	630
6	350	700+	600
7	270	500	430
8	370	700+	700
9	320	600	500
10	333	700+	630
11	433	700+	700
12	420	700+	600
13	400	700+	600
14	333	700+	600
15	433	700+	700
16	370	600	600

Fig 7 Table of velocities measured in lateral ducts fed by main duct in Figure 6.

The results in fig 6 show that the velocity on the floor of the duct near the fan outlet is considerably higher than the velocity 1.5 m above that point. This is because the fan is discharging vertically downwards and the duct has been designed to deflect this flow into a horizontal direction within a short distance and no additional deflectors have been fitted. With a main duct having the dimensions shown, with a bend before the commencement of the lateral ducts and with the injection point for the lateral ducts at roof level, this arrangement was considered to be suitable in order to provide a balanced flow into the lateral ducts. The results would appear to confirm that this was a satisfactory approach and the small differences in flow between the lateral ducts is believed to be a combination of slightly differing opening sizes due to the difficulty of constructing ducts of this nature, and the different impedances offered by the bagged potatoes.



Air flow (approx.) 55,000 m^3/h

Position in duct	Duct Velocity (m/min) Height 0 m	Height 1.5 m
A	700+	130
B	700+	600
C	600	530
D	200	300

The back pressure measured at the fan outlet during these tests was 12.5 mm water

These velocity measurements were made in a main duct furnished with 32 lateral ducts. Lateral ducts, numbered - Left 9 - 1 and Right 8 - 1 were closed The flow of 55,000 m^3/h in this situation therefore corresponds to an equivalent flow of over 78 m^3/ton. Measurement of velocity of air entering ducts showed that all were working at more than 700 m/min as a result of the number of ducts which were closed However, not one duct was operating below 700 m/min thus demonstrating the effectiveness of the main duct system.

Sketch of main duct showing position of laterals and table of results of air flow velocities measured at selected positions and heights in this duct.

Fig 8

Fig 8 shows velocity measurements made in a main duct measuring 1.1 m by 2 m by 34.5 m long, with 32 lateral ducts entering at roof level. The fan was discharging vertically downwards and the duct was contoured to provide good deflection and matching into the main duct. The store is a bulk filled potato store having a total capacity of some 1500 tonnes and measures 34.5 m by 23 m by 4 m high storage and at the time of making the measurements filled with some 600 tonnes. For the reason under half of the lateral ducts were in operation and therefore the air flow provided to the main duct was half the maximum total flow available (which was designed at 65 m^3/h per tonne of potatoes stored).

The results show that the velocity gradient between the floor and roof of the duct is virtually eliminated within a distance of 4 m. The flow down each of the open lateral ducts could not be measured accurately owing to limitation of the measuring instrument although the results showed that not one of the ducts was operating below 700 m/min (and in every instance more than this figure), which compares favourably with the theoretical performance under these conditions of approximately 800 m/min.

The behavour of lateral ducts is not always easy to determine or predict and the author felt that tests carried out on one particular arrangement might be of interest. For this investigation the duct chosen was an underfloor duct of the previously mentioned 1500 tonne potato store. Owing to the difficulties of monitoring air flow from a duct covered by potatoes a duct which was not covered was used, although it is recognized that the results may not be truly representative of a covered duct.

The duct was formed in the concrete floor and covered with timber blocks measuring 153 mm wide. The effective clear cross-section area was 230 mm deep by 380 mm wide ie 0.087 m^2. The length of the duct was approximately 9 m and there were controlled gaps between each 153 mm timber of 19 mm and totalling 49 gaps. The effective width of each gap was 0.31 m thus giving a total effective discharge area of 0.29 m^2. The results shown in fig 9 were obtained with the duct air inlet velocity considerably more than 700 m/min, and the wide range of outlet velocities over the first 3 m are the result of the interference of the air stream by the slight irregularities of the timber blocks causing some 'gaps' to pass more air than others. As the pressure builds up towards the end of the duct the air velocity falls thus providing better and more uniform flow from the outlet 'gaps'. These results indicate that more analysis should be made including detailed pressure measurements, with potatoes over the ducts.

Measurement of velocity of air leaving under-floor lateral duct measured at 0.3 m increments from the point of entry to the main duct. The velocity at the point of entrance to this lateral was in excess of 700 m/min. This chart clearly shows the effect of the pressure increase at the stopped end of the duct resulting in a larger volume of air leaving at this point.

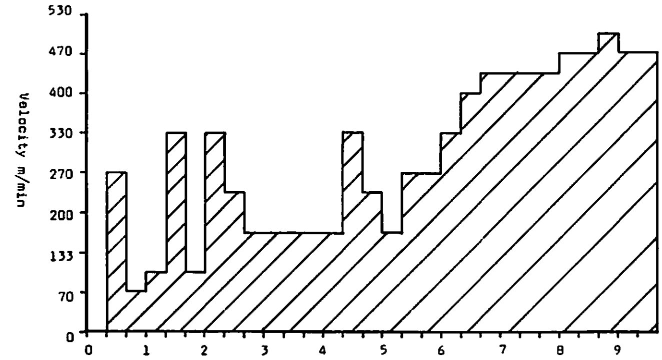


Fig 9

Control of relative humidity in stores

The foregoing has dealt with cooling and heating of vegetable cool stores and comment has been made about the effects of cooling equipment on maintenance of high relative humidity within the store. Despite the efforts taken to maintain high relative humidity levels in stores additional artificially induced humidification could be incorporated in order to raise this relative humidity even further, as Burton has shown[7] that this could reduce moisture loss from potato and green vegetables. The decision to incorporate additional humidification equipment should not be taken lightly and should be made after due assessment of the operating parameters of the store and the improvements to be gained, balanced against the dangers. If the decision is still to incorporate artificial humidification, two methods are available:

(1) The injection of steam.
(2) The injection of water mist.

The injection of steam is a method which is to be favoured as water is injected as true water vapour and can be readily taken up by the drier air. In order to convert 1 g of water into vapour nearly 2512 joules of heat must be imparted to the water. Steam of course is water into which this heat has already been transferred and if it is injected into the air stream in the correct quantity the relative humidity of the air can be increased to the desired level. One major hazard of injection of water vapour is the distinct possibility of saturation of the air so that as the air passes over the potatoes etc water could be deposited out of the air on to the potatoes. If the method of injecting the water vapour is not carefully controlled there is a possibility of free moisture being carried in the air stream in the form of fine water droplets and again this water could be deposited on the potatoes as the velocity of the air fell during the dispersal of the air through the potato stack. Steam injection is a method which is least likely to cause this situation but even so the problem must be carefully considered, particularly in relation to the control of the amount of steam which is injected into the air stream.

The second method of increasing the moisture in the air is the direct injection of water into the air in the form of a 'mist'. One method which has been used[9] is the forcing of water under pressure through a series of fine nozzles positioned in the main air stream, usually immediately after the fan outlet. In order to convert this water into water vapour heat must be imparted to the water from the air stream, and this of course will cause a lowering of the air temperature. The amount by which the temperature of the air will naturally depend on the amount of water introduced and the initial vapour pressure of the air. This reduction of air temperature could be beneficial in assisting the cooling of the potato or vegetable stack but the probability of free moisture being carried through the potatoes is naturally greater as factors such as droplet size, velocity of air, initial humidity of the air and final desired humidity will all govern whether excess moisture is carried over.

Whichever method is selected for the introduction of water vapour, a method of control must be provided which will control the amount of water vapour injected without causing free moisture to be deposited on the potatoes. It is unlikely that satisfactory humidification can be achieved using continuous monitoring of the air stream with continuous injection of water vapour. The method which is to be preferred at this point in time is that which measures the air stream relative humidity and if the relative humidity is below the desired level injects a certain amount of vapour for a predetermined period. At the end a further delay as the relative humidity of the air is again measured and vapour is added if required. This has to be a continuous sampling process using automatic techniques.

The measurement and control of relative humidity is not an easy parameter to monitor and a number of methods are available but the cost will vary greatly and will depend on the method employed and the quality of the instrumentation. Many systems require frequent calibration and/or cleaning of the sensing transducer in order to ensure accuracy. The method favoured by the author for vegetable store applications and one which appears to suffer least from these problems is the well established method of wet and dry bulb measurement. These days it is relatively simple and inexpensive to measure electronically temperatures to acceptable accuracies. Providing therefore that one of the temperature measuring transducers is maintained in a moist environment by the use of a wet wick or similar method, it is possible to measure relative humidity easily in this manner. The particular advantage of this method for agricultural applications is that the accuracy of the temperature measuring system can be readily checked using an independent means of temperature measurement. This method of relative humidity determination allows the control function to be accomplished with ease. The information from the wet and dry transducers can be electronically compared against a reference voltage — the value of which can be altered. Any deviation from this reference voltage will indicate that more or less vapour must be added and therefore a control signal can be passed to the device which is controlling the flow of vapour into the air thus modifying this flow and controlling the relative humidity of the air stream.

The type of temperature measuring transducer used will depend upon the accuracies which are required, the range of temperatures etc. For vegetable stores the thermistor has much to recommend it as the rate of change of resistance against temperature is large. Although this is not a linear relationship over a wide range of temperatures this is not normally a problem with vegetable stores as the range of operating temperatures is low and any non-linearity over this range can be electrically compensated.

Air flows through bulk and box stores

The determination of air flow patterns within stores is a tedious exercise and whilst it can be readily accomplished in box stores, bulk stores provide difficulties which are so far only soluble by resorting to highly sophisticated techniques and expensive equipment. The problem is simply that of the measurement of air velocities in a mass of produce where the gap between adjacent vegetables is extremely small and therefore the introduction of a transducer into this gap will radically affect the air flow pattern. There is naturally the additional problem of being able physically to introduce velocity measurement transducers into a mass of produce stored up to 4 m. For this reason therefore little is known about the true air flow pattern throughout a bulk store although a fair amount of information has been gathered concerning the distribution of air from a main feed duct into lateral ducts which provide injection of the air to the produce. A method of assessing the acceptability or otherwise of the air flow throughout a bulk store can however generally be achieved by the measurement of temperatures at many different points within the store. If the basic requirement is to maintain the temperature at a given level one might argue, with justification, that the determination of air flows is a secondary problem and that providing the temperatures are satisfactory then by definition the air flow is of an acceptable standard; this is possibly an acceptable approach for existing installations but the problem of designing new installations, especially for different conditions of storage eg greater depth of storage than currently accepted as standard, leave the designer in the situation that he must over-design in order to ensure that the store is likely to work to an acceptable standard. Air flow distribution throughout box stores is often easier to measure as the gap between boxes is much greater and the interference of the measurement transducer has little affect on the dynamic characteristics of the air stream. The problem of accessibility is also usually overcome as there is sufficient space for human access between the boxes. Much more is therefore known about air flow in such stores.

Conclusion

The production of a controlled environment in a vegetable store can be readily achieved to virtually any standard providing the building, equipment, produce, loading rates etc are considered collectively and not in isolation. The building will greatly influence the size and type of equipment chosen and therefore in order to obtain the best cost/performance compromise for a store the architect, equipment designer and the store owner/operative must collaborate closely. Specifications must be tightly drawn by the owner of the store as a broad specification with unnecessarily tight control and temperature reduction requirements may well be achievable but at a disturbingly high cost. Therefore the main parameters should be accurately stated without the incorporation of unrealistic safety margins. The decision to increase the design capacity by 50% on a 'just in case I need it' basis may well convert an otherwise highly profitable concept into an uneconomic unit. Unfortunately the converse can also be true that a store designed for a given capacity should not be overloaded without considering the FULL implications and effects of this action. A refrigerated store for example could go out of control.

Long term storage of vegetables has great significance today in view of the avowed intention of the British Government to increase United Kingdom production and reduce imports. The establishment of a correctly designed controlled environment store will not in itself guarantee high quality produce being available many months after harvesting, as crop management plays a major role. However, it is fair comment that good quality vegetables cannot be stored for long periods to the standards required by the consumer WITHOUT a controlled environment store.

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INSTITUTION OF AGRICULTURAL ENGINEERS

West End Road Silsoe Bedford

APPOINTMENTS REGISTER

This service is available to members who wish to learn of vacancies in specific branches of agricultural engineering and the related services; it is also designed to assist organisations and employers to bring any such vacancies to the attention of persons who have a direct interest. It will operate in the following way:

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Broad areas of interest have been categorised and identified by a letter as shown below:

A. Design/Manufacture
B. Administration
C. Technical representation for manufacturer
D. Technical representation for distributor
E. Service for manufacturer
F. Service for distributor
G. Farmbuilding
H. Field Engineering
I. Education
J. Advisory

OTHERS

New categories will be included as and when it proves necessary.

NB: Members may wish to include details of qualifications and any other information which, it is felt, could help in ensuring that suitable information is forwarded; but this is optional. Any information will be treated as confidential.

Members wishing to use the scheme should write to:

J. Turner, Ryecotewood College, Thame, Oxon (Tel. 2501) indicating the types of vacancy on which they would like information and enclosing some stamped addressed envelopes up to ten in number, suitable for A4 or foolscap size papers.

As vacancies are notified, Mr Turner will arrange for photocopies of particulars to be forwarded to members who have expressed interest in the particular type of post involved.

This service will continue and the penultimate stamped addressed envelope, returned to the member, will contain a reminder that the supply of s.a.e's is almost exhausted. If the member wishes to continue the service, more s.a.e's should be sent. Particulars of vacancies will continue to be sent until either the supply of s.a.e's is exhausted or the member writes asking that the service be discontinued.

ORGANISATIONS/EMPLOYERS

Details of vacancies should be sent to:

J. Turner, Rycotewood College, Thame, Oxon (Tel. 2501) in a form suitable for copying by the thermal photocopying process. Copies of information will be sent to members who have expressed an interest in the type of work in question.

There will be no charge to either party for the service.

The building fabric

by D J Allott BSc (Estate management) ARICS

THE vegetable storage building is a container in which a management system takes place. Experience shows that the most successful schemes are those where a requirement for storage and handling are defined first and a building is finally proposed as an outer wrapping. The design brief should contain the user's requests for doorways, working spaces (eg riddling), artificial light, power points and overall appearance.

Doorways must be wide enough for easy manoeuvering of the largest vehicles foreseeable during the life of the store. Traditionally, 3 m by 3 m doors have been recommended, increased recently to at least 3.7 m X 3.7 m. Hanging is safer and simpler by overhead track and guide rollers at the bottom are preferred rather than channels. Doorways in gable ends are preferred at one side of the gable.

Working spaces will be determined by the handling, grading and packing arrangements that are proposed, or may be envisaged in a few years.

Artificial lighting will be essential and although a single waterproof bulkhead fitting may do to light the doorway, internal lighting is better done with one or two quartz-iodine or similar lamps.

Power points are usually only needed at one end where handling or packing machinery are used and where radiant heat may be provided for the operators. It would be folly to contemplate anything other than the best waterproof outlets.

Overall appearance. The two essential ingredients for success are an awareness that the big storage buildings have a visual impact over several kilometres, and a determination to present the onlooker with three or four areas of contrasted harmony, one of which may be quite bold. Suggested colour schemes are now readily available.

Dimensions influence three factors: the surface area through which heat is lost or gained; the area of expensive retaining wall, and the relative simplicity or otherwise for the builder.

The span should be selected from the nearest convenient size offered by the chosen builder. However, since the cost differences between the materials, including concrete, are mostly less than 10% and tenders for the same material often vary by 25%, there is no substitute for obtaining competitive quotes.

The bay width during the 1960's has mostly been 4.6 m, with an intermediate support at 2.3 m to suit the retaining wall. Six metre bays are sometimes used, and will be especially suited to high box stores.

Building height offers the most marked opportunity to economise on building costs. A 20% increase in a building's height would add about 5% to the insulated shell and 4% to total cost. A 50% increase would add about 15% and 11% respectively.

Plan dimensions. The narrowest spans are cheapest for frame building. The square building is most economical in walling use. These opposing forces are balanced in practice to give preference to spans of 9 m for building up to 500 tonnes, 13.7 m up to 1500 tonnes and 18.3 m for all larger capacities.

Roof pitch is not very significant except in external appearance and the need to seal the roof laps if a pitch of less than 15° is used.

Materials. The traditional brickwork with piers and an insulating or straw bale lining is being replaced by portal frame structures and infill panelling. The choice of materials will usually be determined by local price and by preference for a particular appearance.

Insulation. It is not difficult to decide on the likely temperature differences between inside and outside of the building and to calculate the resistance to heat flow needed to maintain equilibrium with the rate of heat production. In the high humidity atmosphere insulation materials must be protected from moisture and if necessary, their thickness increased to allow for it. As a general rule, it is recommended that a continuous vapour barrier is used such as polythene sheet between the insulation and the high humidity. In all cases, the quality of workmanship will be very important. Some vapour migration should be allowed for. The most vapour resistant materials should be near the inside so that any leaking vapour will find it progressively easier to migrate to the exterior. A small amount of ventilation just inside the exterior corrugated cladding will help. Scandinavian and European practice, in conditions more severe than in the UK, is to use polythene on the inside and breather paper on the outside of the insulation. Vapour barriers may be omitted if an insulation material is used that is very resistant to moisture vapour.

Insulation thickness is basically determined by relating its K value to the U value required of the structure. The insulation is in an adverse environment, more critical than in the laboratory test from which the published K value is derived. The theoretical minimum thickness of insulation should be increased by a factor to allow for moisture content. It is probably sensible to install the insulation in the next thickness up from that calculated. As an example of the cost differences, the change from 19–25.4 mm rigid plastic foam insulation would cost less than £60 for a 500 tonne store, but would increase the U value by about 20–25%.

D. V. Allott is Technical Officer, Farm Buildings Centre.

A summary of the paper presented at the Spring National Meeting of the Institution of Agricultural Engineers at the Essex Institute of Agriculture, Writtle, Chelmsford, on 28 March 1972, when the subject was Building and Equipment for the Storage of Potatoes and other vegetable crops.

The Institution secretariat–Resignation of Mr H N Weavers

MEMBERS will be sorry to learn that on 14 December Mr Harold New Weavers handed to me a letter tendering his resignation from the post of Institution Secretary which he had held since April 1972. He had previously been a Senior Administrative Assistant, and then held the post of Acting Secretary from October 1971 to March 1972.

Following a brief but alarming illness in April 1973, it had been agreed to lighten Mr Weavers' work load. This was done partly by transferring administrative responsibilities in connection with publications directly to the Editorial Panel, under Mr Brian May, and the Production Manager, Mr Norman Stuckey, and by accepting an offer from Mr Ray Fryett to undertake responsibility for financial matters from 1 October 1973, on a part-time basis. Mr Fryett was an elected member of Council, in the Associate grade, but relinquished this position on becoming an employee of the Institution.

It was intended that Mr Weavers should continue to work for the Institution, on a part-time basis and at a reduced level of remuneration, until his retirement at the age of 60 in June 1974. However, in the light of a number of difficulties during the past few months and having consulted as many of the senior members of Council as was practicable, I agreed with Mr Weavers that his resignation should be accepted, technically from 31 March 1974 but in effect from 31 December 1973.

On behalf of the Institution I have expressed to Mr Weavers our gratitude for his endeavours on our behalf during a particularly difficult period, and in the face of great personal problems, and offered our best wishes to him and his family in the future.

Quite apart from Mr Weavers' resignation major changes have been taking place in the secretariat, especially in connection with the move from Rickmansworth to Silsoe. Ray Fryett is co-ordinating these activities, including the appointment of new office staff. The three girls employed at Rickmansworth – Mrs C. Franzen (formerly Miss Hicks), Miss G. Miles and Mrs P. Anderson – have all obtained other jobs during the last few weeks, and have now left our employment with appropriate parting gifts.

Mr John Fox, President-Elect, is the Chairman of the Appointments Committee whose main task is to select a new Institution Secretary, and is working actively to this end. In the meantime, Ray Fryett will be designated Acting Secretary and will play a most important role in maintaining the Institution's headquarters operations.

J. A. C. Gibb

Lubrication requirements of future farm tractors

by P B Bostock CEng MIMechE MIAgrE

Introduction

BEFORE considering future requirements it is necessary to understand in some detail how lubricants are classified, tested and formulated for various applications. The majority of lubricants used on the farm fall into one of two categories, either lubricants for engines or lubricants for transmissions and hydraulic systems.

Lubricating oil requirements of a diesel engine fitted to an agricultural tractor are similar to those of a diesel engine fitted to a commercial vehicle. It is therefore usual to find that a good quality lubricating oil suitable for a high speed diesel engine is equally suitable for an agricultural tractor engine. Many small and medium size petrol engines are also used in agriculture, and it is therefore essential for an oil company to ensure that any multi-functional lubricant available to the farmer is suitable for industrial petrol engines as well as diesel.

The design of the agricultural tractor transmission differs considerably from that of the automotive and commercial vehicle. Many tractors have a common oil reservoir serving the gear box, final drive and hydraulic system, a practice not often adopted by vehicle designers. Because of the differences in design automotive transmission oils will not necessarily give satisfactory performance in a tractor. This has led to the introduction of lubricants developed specifically for use in tractor transmissions, a trend likely to continue.

Present situation

Engine lubricants

It is normal practice for the engine manufacturer to specify lubricating oil viscosity requirements and quality levels.

(a) Viscosity

The need for reliable classification of automotive engine (and transmission oil) viscosities was recognised in 1926 when, to replace previous vague terms such as 'light', 'medium' and 'heavy', the American Society of Automotive Engineers (SAE) adopted an arbitrary scale of numbers corresponding to viscosity ranges. The SAE viscosity numbers constitute a classification in terms of viscosity only. Other factors of oil character or quality are not considered.

The SAE viscosity classifications for lubricants have been accepted by manufacturers world wide. From this classification a manufacturer will select an oil of low enough viscosity to ensure that cranking resistance in cold weather is not so high that difficulty is experienced in starting. In contrast the oil must have sufficient viscosity at high temperature to provide an adequate oil film for the lubrication of bearings and at the same time control flow past the piston rings to an acceptable level. In Sweden an oil of SAE 10W viscosity may be specified whilst in South Africa the same machine would require an oil of say SAE 30 viscosity. The quality of the oil would, however, remain unchanged.

For crankcase oils there are seven viscosity grade numberings; these are SAE 5W, 10W, 20W, 20, 30, 40 and 50 (table 1). Each grade defines a viscosity range at a particular temperature. The least viscous (or lightest) oil is the SAE 5W, the most viscous (or thickest) is the SAE 50.

The suffix 'W' denotes that the viscosity of the oil is controlled within limits at 0°F (−18°C). These oils are of low viscosity intended for winter use when engine starting could be difficult with a thicker oil. Grades without the 'W' suffix have their viscosity controlled at 210°F (99°C) which represents a typical operating bulk oil temperature.

This feature is based on a paper presented at South East Midlands Branch meeting, on 6 March 1972.

P. B. Bostock is a lubrication engineer with the Technical Services Branch of BP Trading Ltd.

Table 1 SAE viscosity classification for crankcase oils

SAE viscosity No. (Note 1)	*Centipoises* 0°F *Min*	*Centipoises* 0°F *Max*	*Centistokes* 210°F *Min*	*Centistokes* 210°F *Max*
5W	–	1200	–	–
10 W (*Note 2*)	1200	2400	–	–
20 W (*Note 3*)	2400	9600	–	–
20	–	–	5.7	9.6
30	–	–	9.6	12.9
40	–	–	12.9	16.8
50	–	–	16.8	22.7

Note 1. *Viscosity of all oils included in the classification shall not be less than 3.9 cSt @ 210°F.*

Note 2. *The minimum viscosity at 0°F of SAE 10W may be waived, provided the viscosity at 210°F is not below 4.2 cSt.*

Note 3. *The minimum viscosity at 0°F of SAE 20W may be waived, provided the viscosity at 210°F is not below 5.7 cSt.*

A multi-viscosity or multigrade oil has a viscosity which falls within a particular SAE viscosity range at 210°F (99°C) and at the same time falls within a particular SAE 'W' viscosity range at 0°F (−18°C). This is illustrated in fig. 1.

(b) Quality

In contrast to this one classification system for oil viscosity there are very many classifications for lubricating oil quality.

Performance levels and standard test procedures are established by engine manufacturers, military authorities, oil industry

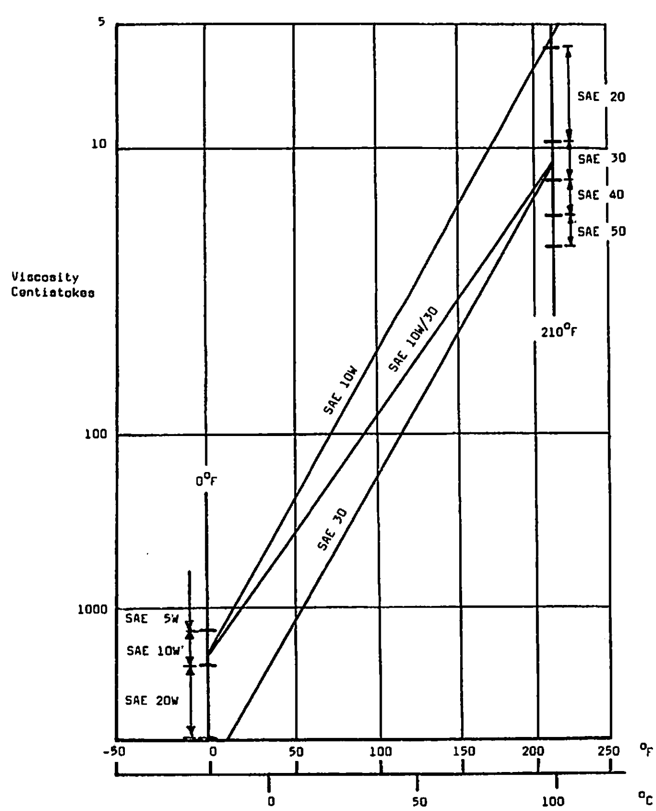

Fig 1 Example of multi-grade oil viscosity characteristics

laboratories or independent bodies such as the SAE. The quality of oil required by an engine will depend upon its design and application. Factors such as piston temperature, camshaft loadings, bearing material, engine operating cycle etc must be taken into consideration.

When selecting a lubricant a manufacturer will ensure that the oil passes test procedures that are appropriate to the engine under consideration. If no standard tests are already in existence a manufacturer may feel it is necessary to develop his own. Obviously oil companies cannot market a separate lubricant to meet each individual manufacturers requirement and it is normal practice for a range of oils to be available that meet varying sets of performance targets that increase in severity.

A valuable scheme for defining oil quality and performance is the API (American Petroleum Institute) engine service classification system (table 2). Widely used by American manufacturers it is hoped that it will be adopted by European manufacturers in the future.

Table 2 API lubricant service designations (Gasoline engine oils)

SAE letter designation	*API engine service description*	*Engine oil description*
SA	*Utility gasoline and diesel engine service* Service typical of engines operated under such mild conditions that the protection afforded by compound oils is not required. This classification has no performance requirements.	Oil without additive except that it may contain pour and/or foam depressants.
SB	*Minimum duty gasoline engine service* Service typical of engines operated under such mild conditions that only minimum protection afforded by compounding is desired. Oils designed for this service have been used since the 1930s and provide only antiscuff capability, and resistance to oil oxidation and bearing corrosion.	Provides some antioxidant and antiscuff capabilities.
SC	*1964 gasoline engine warranty service* Service typical of gasoline engines in 1964–67 models of passenger cars and trucks operating under engine manufacturers' warranties in effect during those model years. Oils designed for this service provide control of high and low temperature deposits, wear rust, and corrosion in gasoline engines.	Oil meeting the 1964–67 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides low temperature antisludge and antirust performance. Ford Motor Co.'s M2C101A is a related specification.
SD	*1968 gasoline engine warranty service* Service typical of gasoline engines in passenger cars and trucks beginning with 1968 models and operating under engine manufacturers' warranties. Oils designed for this service provide more protection from high and low temperature engine deposits, wear, rust, and corrosion in gasoline engines than oils for API Service Classification SC and may be used when oils for API Service Classification SC are recommended.	Oil meeting the requirements of the automobile manufacturers since 1968. Intended primarily for use in passenger cars. Provides low temperature antisludge and antirust performance. Ford M2C101–B and GM 6041 prior to July 1970 are related specifications.
SE	*1972 gasoline engine warranty maintenance service* Service typical of gasoline engines in passenger cars and some trucks beginning with 1972 and certain 1971 models operating under engine manufacturers' warranties. Oils designed for this service provide more protection against oil oxidation, high temperature engine deposits, rust and corrosion in gasoline engines than oils which are satisfactory for API Gasoline Engine Warranty Maintenance Classifications SD or SC and may be used when either of these classifications are recommended.	Oil meeting the requirements of the automobile manufacturers since 1972. Intended primarily for use in passenger cars. Provides low temperature antisludge and antirust performance. Ford M2C101–C and GM 6041 M (July 1970) are related specifications.

(Diesel engine oils)

SAE letter designation	*API engine service description*	*Engine oil description*
CA	*Light duty diesel engine service* Service typical of diesel engines operated in mild to moderate duty with high quality fuels. Occasionally has included gasoline engines in mild service. Oils designed for this service were widely used in the late 1940s and 1950s. These oils provide protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.	Oil meeting the requirements of MIL–L–2104A. For use in gasoline and naturally aspirated diesel engines operated on low sulphur fuel. The MIL–L–2104A Specification was issued in 1954.
CB	*Moderate duty diesel engine service* Service typical of diesel engines operated in mild to moderate duty, but with lower quality fuels which necessitate more protection from wear and deposits. Occasionally has included gasoline engines in mild service. Oils designed for this service were introduced in 1949. Such oils provide necessary protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines with high sulphur fuels.	Oil for use in gasoline and naturally aspirated diesel engines. Includes MIL–L–2104A oils where the diesel engine test was run using high sulphur fuel.

	Moderate duty diesel and gasoline engine service	
CC	Service typical of lightly super-charged diesel engines operated in moderate to severe duty and has included certain heavy duty, gasoline engines. Oils designed for this service were introduced in 1961 and used in many trucks and in industrial and construct-ion equipment and farm tractors. These oils provide protection from high temper-ature deposits in lightly super-charged diesels and also from rust, corrosion, and low temp-erature deposits in gasoline engines.	Oil meeting require-ments of MIL–L–2104B (now super-seded), or the more recent MIL–L–46152. Provides low temperature anti-sludge, anti-rust, and lightly supercharged diesel engine perform-ance. The MIL–L–2104B specification was issued in 1964, but was superseded in November 1970.
	Severe duty diesel engine service	
CD	Service typical of super-charged diesel engines in high speed, high output duty requir-ing highly effective control of wear and deposits. Oils designed for this service were introduced in 1955, and pro-vide protection from bearing corrosion and from high temp-erature deposits in super-charged diesel engines when using fuels of a wide quality range.	Oil meeting Cater-pillar Tractor Co. certification require-ments for Superior Lubricants (Series 3) for Caterpillar diesel engines. Provides moderately super-charged diesel engine performance. The certification of Series 3 oil was established by Caterpillar Tractor Co. in 1955. The related MIL–L–45199 45199 specification was issued in 1958, but was superseded in November 1970 by MIL–L–2104C.

Transmission oils

For a tractor transmission a manufacturer may specify an oil that falls into one of the following categories:

1. Straight or EP gear oil.
2. Hydraulic fluid.
3. Special purpose transmission fluid.

1. Straight gear oils and EP gear oils

The SAE viscosity classification for gear oils is accepted in a similar manner to that of engine lubricants. For gear oils there are at the present moment only five viscosity grade numberings, SAE 75, 80, 90, 140 and 250. The viscosities of SAE 75 and 80 grades are controlled at 0°F (–18°C) and are intended to meet the requirements of gear lubrication under low temperature conditions. The viscosities of SAE 90, 140 and 250 grades are controlled at 210°F (99°C) for high temperature operation (table 3).

During 1972 and 1973 modifications to this recommended practice have been under consideration. Following discussions with the oil industry and manufacturers changes to the gear oil classifications will be introduced during 1974. The changes to the viscosity characteristics are only slight and are not likely to be noticed by the user. Other changes include the use of the suffix 'W' to the three SAE viscosity numbers having both a low temperature and 210°F viscosity requirement. An additional grade SAE 85W has been added. This grade could find use in certain climates but its availability will depend upon adoption by manufacturers. Details of the new classifications are given in table 4.

SAE numbers for gear oils bear no direct relation to SAE numbers for engine oils. However, to give an indication of relationship, an SAE 40 engine oil is of approximately the same viscosity as an SAE 90 transmission oil.

Straight gear oils contain no additives and they are generally

Table 3 SAE viscosity classification for transmission and axle oils

SAE viscosity No.	Centistokes			
	0°F		210°F	
	min	*max*	*min*	*max*
75	–	3250	–	–
80	3,250	21700	–	–
90	–	–	14.2	25.0
140	–	–	25.0	43.0
150	–	–	43.0	–

1. No viscosity in this (transmission) classification shall be less than 4.2 cSt @ 210°F.
2. The minimum viscosity of SAE 80 @ 0°F may be waived if viscosity is not less than 6.7 cSt @ 210°F.
3. Lubricants with viscosities above 162 900 at the starting temperature may cause undesirable resistance during start-up and warm-up.

Table 4 Axle and manual transmission lubricant viscosity classification J306 SAE recommended practice

SAE viscosity No.	*Maximum temperature for viscosity of 105000 cP*	*Viscosity at 210°F (99°C) minimum*	*maximum*
75W	–40°F (–40°C)	4.2 cSt (40)[1]	
80W	–15°F (–26°C)	7.0 cSt (49)	
85W	+10°F (–12°C)	11.0 cSt (64)	
90	–	14.0 cSt (74)	25 cSt (120)
140	–	25.0 cSt (120)	43 cSt (200)
250	–	43.0 cSt (200)	

[1] *Numbers in parentheses are approximate SUS values corresponding to the centistokes shown.*

specified for gearboxes where gear tooth loadings are low and where the use of an EP (extreme pressure) type gear oil may adversely affect the performance and life of a syncromesh mechanism. Extreme pressure gear oils were originally introduced for use with hypoid gears where sliding speeds between mating gear teeth are high and it is not possible to maintain a hydrodynamic oil film. The use of EP gear oils has extended during recent years to heavily loaded spiral level gears and straight spur final reduction gears where the EP properties of the oil can be of advantage particularly during running-in.

Two quality levels of EP gear oil are currently available – the first meets the requirements of the now obsolete American military specification MIL–L–2105 and the second meets the more stringent and higher performance requirements of the current MIL–L–2105B. Manufacturers will specify either quality, selection depending upon the design and loading of the gears being lubricated.

The API having a lubricant service classification system (table 5), comparable with the engine scheme referred to earlier. This defines six types of service ranging from API GL–1, which is light duty, non-critical gear sets, to API GL–6 which is the heaviest type of duty coupled with the most critical high offset hypoid gears. Although not widely adopted by European manufacturers the API system is used by the oil industry for describing gear lubricant performance.

2. Hydraulic fluids

These are not now widely specified by manufacturers of agricultural machinery. Generally they have nothing to offer in terms of performance over a good quality engine oil, and are not so readily available. The performance and viscosity of hydraulic oils from different oil companies can vary considerably and it could be dangerous to use a particular oil without knowing exactly its performance and characteristics.

3. Special purpose transmission fluids

These have been widely specified by North American tractor manufacturers for many years and their use by European manufacturers is increasing as transmissions become more complex.

Table 5 API lubricant service designations (Transmission oils)

API–GL–1 Automotive spiral-bevel and worm gear axles and some manually operated transmissions operating under such mild conditions of low unit pressures and sliding velocities, that straight mineral oil can be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be utilised to improve the characteristics of lubricants for this service. Frictional modifiers and extreme pressure agents shall not be utilised.

API–GL–2 Automotive type worm-gear axles operating under such conditions of load, temperature, and sliding velocities, that lubricants satisfactory for API–GL–1 service will not suffice.

API–GL–3 Manual transmissions and spiral-bevel axles operating under moderately severe conditions of speed and load. These service conditions require a lubricant having load carrying capacities greater than those which will satisfy API–GL–1 service, but below the requirements of lubricants satisfying API–GL–4 service.

API–GL–4 Gears, particularly hypoid in passenger cars and other automotive type equipment operated under high-speed, low-torque, and low-speed, high torque conditions.

API–GL–5 Gears, particularly hypoid in passenger cars and other automotive equipment operated under high-speed, shock-load; high speed; low-torque; and low-speed, high-torque conditions.

API–GL–6 Gears, specifically high offset hypoid gears (above 2.0 inches offset and approaching 25% of ring gear diameter) in passenger cars and other automotive equipment operated under high-speed, high performance conditions.

Unfortunately no standard test procedures or performance levels have been agreed and manufacturers have developed tests using their own transmissions and components. This has resulted in each major manufacturer having his own lubricant specification. Because of the high cost involved in developing this type of oil, the smaller manufacturer is forced to select a grade that is already available even though it may not suit his requirements exactly.

Lubricating oil additives

Plain mineral oils, however well refined, are not able to perform all the duties required of them and it is necessary to use additives to improve their physical and chemical properties. Modern engines and transmission systems rely heavily on the additives contained in the oil for correct functioning.

The following list summarises the most important types of additive currently in use in engine and transmission lubricants.

Anti-oxidants	– to resist the oxidation of the lubricating oil itself.
Detergents	– to prevent or reduce deposits formed at high temperature.
Dispersants	– to disperse or reduce the formation of sludge and hold in suspension products of combustion.
Corrosion and rust inhibitors	– to resist chemical attack from acid materials and water.
Viscosity index improvers	– to reduce the extent to which viscosity is affected by temperature.
Pour point depressants	– to improve low temperature flow characteristics.
Anti-foam agents	– to reduce foaming which can occur when oils are agitated in the presence of air.
Load carrying additives	– required when pressures or relative speeds between rubbing surfaces are high. There are two distinct types (a) anti wear (b) EP – extreme pressure.
Friction modifying agents	– to control the friction between brake and clutch components to ensure satisfactory operation.

A number of these additives are multifunctional in that they affect the performance of the oil in more than one way. It is not proposed to discuss the subject of additives in detail other than to say that it is a relatively new science and many of the chemical actions that occur are not fully understood. It is, however, true to say that many of the advances in power units and transmissions would not have been possible without the continuous development of new and improved additives.

Lubricants for future tractors

It is always difficult to predict the future. Lubricating oil qualities will depend largely upon the requirements of tractors still on the drawing board or in the mind of the designer. Obviously this sort of information is not readily available and often the subject of lubrication is unfortunately not considered until the first prototype machines are being assembled.

There are, however, some changes that can be forseen without the above mentioned information and it is this type of change that is mentioned in the following section.

Power units

The diesel engine will remain the prime mover for agricultural machinery for the foreseeable future. Gas turbines are currently finding new application in commercial vehicles and large off-highway machines. Their application to agricultural machinery will, however, require extensive proving and we are unlikely to see them used for this purpose for many years if at all. Alternative power units such as steam engines, external combustion engines, fuel cells etc have not yet been developed to such a stage where they can be considered within the present discussion.

Changes in the design of the conventional diesel (and petrol engine) over the next few years will be associated with the need:

(a) To meet exhaust and noise legislation.
(b) To obtain more power from a given size of engine.
(c) To extend maintenance periods.
(d) To reduce fuel consumption.

These changes will undoubtedly place greater demands on lubricating oils. It will be necessary for them to withstand higher sump temperatures for longer periods of time. An improvement in the shear stability of viscosity index improvers used in multi-grade oils will be required whilst increases in temperature in the piston ring belt area will demand an increase in detergency and oxidation performance.

To meet these increased demands improved base oils produced by new refinery processes will become available. To fortify these improved base oils new additives will be developed as current types prove inadequate. In general these changes will not be seen by the user other than as improved quality lubricating oils meeting the demands of new tractor engines.

Synthetic lubricants are sometimes mentioned with respect to future engine oils. At the present moment there is only one advantage to be gained from using a synthetic material and that is improved fluidity at extremely low temperatures. Lubricants containing synthetic components are currently being evaluated under arctic conditions when lubricants produced from conventional hydrocarbons become solid and refuse to flow. In all other respects the conventional mineral lubricant can be expected to meet the requirements of future engine lubricating oils at a price lower than that of an equivalent synthetic fluid.

Transmissions and hydraulic systems

With the wider adoption of powershift gearboxes, power steering systems, oil immersed clutches and brakes and sophisticated hydraulic systems the use of high viscosity gear oils and EP gear oils will diminish in favour of special purpose transmission fluids.

This change has already taken place in North America where each major tractor manufacturer has developed his own test methods and produced his own lubricant specification. This has led to the availability of a range of special purpose fluids on the agricultural market all very similar but none the less slightly different in performance. Whilst this may not be a problem to the individual manufacturer it certainly presents a problem to the oil industry, and the farmer. Also manufacturers of implements powered by the tractor hydraulic system may be affected particularly if there is an increase in the use of external hydraulics. Mixing of fluids could occur if one implement is used on several tractors. Similarly an implement developed to operate on one fluid may not necessarily reach its optimum performance on another.

This problem has been appreciated in the USA where the SAE set up a working group comprising manufacturers and oil industry representatives to consider the possibility of developing a common fluid specification. After ten years of discussion and a considerable amount of test work very little progress has been made towards the original objective. From this it could be deduced that the problem is not serious, nevertheless it is still very real and it can only be in the

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National Institute of Agricultural Engineering Subject Day Oct 1973

The object of Subject Days at NIAE is to provide an opportunity for designers, advisers, farmers and research workers to be brought up-to-date on a particular subject. Short papers are presented reviewing work done, and in progress, at the Institute and elsewhere on various projects relevant to the main theme, exhibits and demoı discussion of the problems stimulated.

Professor C. J. Moss, Director of NIAE, has agreed to the publication of reports on each of t during October 1973. The reports on Greenhouse Engineering, Tractor Ergonomics and Livestock l been written by the Subject Convenors, Messrs Winspear, Matthews and Stansfield respectively. Tl day will be published in full in the NIAE Report series.

Greenhouse engineering

THE Subject Day on Greenhouse Engineering was attended by over 100 invited representatives of the glasshouse industry, including growers, glasshouse manufacturers and equipment suppliers, together with members of the research, advisory and education services and the trade press. It was organised not only to present the latest information on selected engineering research topics but also to stimulate discussion to help ensure that research is relevant to the present and future needs of the industry.

Eight papers were presented, under the chairmanship of Mr S. B. Spencer, (glasshouse grower of Hawkwell, Essex) covering three main topics: Structures, environment and mechanisation. Two of the papers were read by members of the staff of the *Instituut voor Tuinbouwtechniek Wageningen* (Dutch Institute for Horticultural Engineering), the remainder by NIAE staff.

The titles of the eight papers, which will be available with full text and illustrations in a single report are:

1. Engineering research for the glasshouse industry – K. W. Winspear.
2. Wind loading of glasshouse structures – D. A. Wells; R. P. Hoxey.
3. Inflated roof greenhouses – G. E. Bowman.
4. The design of ducted-air heatin Dawson.
5. Fan ventilation of glasshouses
6. Delta X – a new control systerr
7. Travelling gantries for glassł Holt; J. S. Aspinwall.
8. Mechanisation of transport in (

The introductory paper by Winspe by the glasshouse industry in adoptir anisation over the past decade. Engiı part in this process, and many of t research had the double benefit of i the technique as well as releasing work worthwhile tasks. Nearly half the glas: Wales now consisted of modern struc re-building spread quite uniformly ov The larger nurseries, however, had inv modern automatic systems such as ver than the smaller holding. Automatic practically unknown in 1965 had by half the nurseries over one hectare iı also. The ways in which past and pre objective of improving the efficiency discussed, and an attempt was made influence the glasshouse industry in th

Wells, in the next paper, gave de mine the wind loads on glasshouses. the design of the structure but insu accurate predictions of such loads t full-scale glasshouses under natural v relationships (pressure coefficients) velocity and wind loads. These, whe tions of maximum wind speed would mined. Three glasshouses were being wide single-span and multi-span typ During periods of high winds recor stream wind velocity at a height of 10 48 points on each glasshouse. The sy allow the effects of gusts down to 0.4

A greenhouse incorporating a d described by Bowman who showed t of worthwhile fuel saving, minimum members and easy access, for a reasc Against these advantages had to be set the structural members, loss of light r film and the difficulty of handling la construction or subsequent recladdir the forces in curved films and in the st to weather and crop loads. Experir greenhouse were described; in compar house, a fuel saving of some 20% was

Bailey, on the design of ducted ai tion to the important requirement fo the region of the crop. To achieve required the perforated ducts to have length. Part of the heat transfer fron and convection from the duct wall but most was by the discharge of warm air from the perforations. Uniform heat output along the duct could only be produced if the perforations were correctly spaced.

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interest of everyone to have a common specification for a tractor transmission lubricant.

The introduction of oil immersed disc brakes in the rear axle has probably been the greatest single factor affecting tractor transmission oil quality in recent years. To obtain satisfactory brake performance it is necessary to include in the oil a friction modifying additive. This controls the coefficient of friction between the brake components ensuring noise free operation and safe braking distances with acceptable pedal effort.

Currently used friction modifiers are derived from sperm oil which is gradually becoming unavailable as a result of the conservation order on Sperm Whales. Alternative materials are currently being evaluated but development is proving more difficult than originally anticipated.

Hydrostatic transmissions are not expected to present a lubrication problem. We must, however, ensure that there is not a demand for yet another type of lubricant specifically for this type of transmission. A good quality engine oil, or special purpose transmission fluid, should be satisfactory providing the viscosity characteristics do not result in excessive pumping losses at low temperature or high internal leakage at high temperature.

Tractor hydraulics in the future should not be demanding with respect to oil quality providing systems are designed correctly and effort is made to ensure that the oil is not contaminated by water or external dirt. At the present moment when the hydraulic oil reservoir is common with the final drive lubricant it is necessary to compromise on oil viscosity. For optimum lubrication of spiral bevel gears a high viscosity oil is preferred whilst a low viscosity oil is generally required for the hydraulic system. For the future it is hoped that new load carrying additives will become available that will enable low viscosity hydraulic fluids to satisfactorily lubricate the most heavily loaded spiral bevel gears. However, developments of this nature will continue to be hampered as long as manufacturers cannot agree on a common fluid specification.

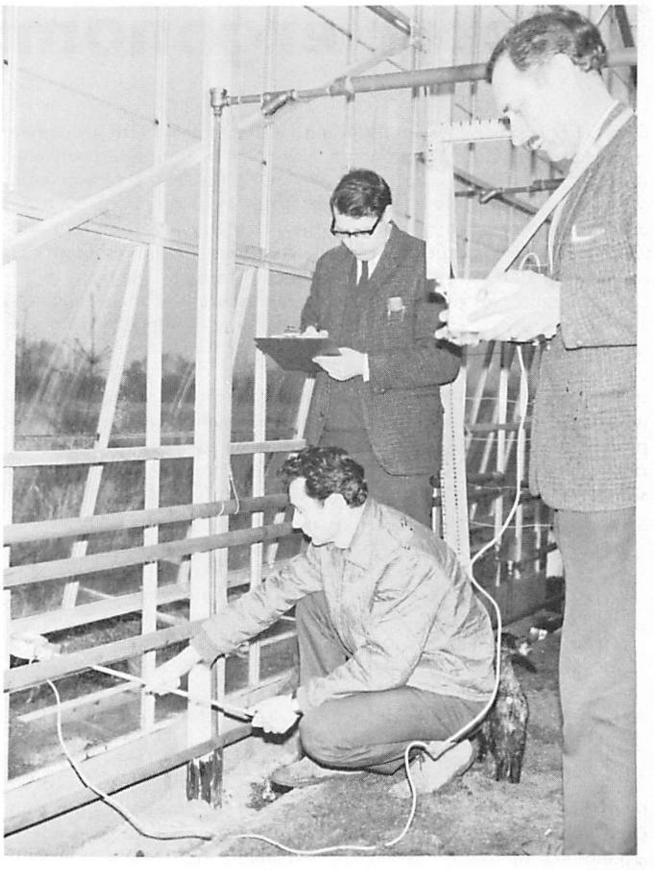
The spacing depended on the temperature and pressure of the air within the duct, which changed from one perforation to the next. The design thus required repetitive calculations which were done with the aid of a computer. Test ducts 56 m long were installed in a 60 X 9.1 m single-span glasshouse. Measurements of the glasshouse air temperature showed the standard deviation of the temperature variation along the length of the house to be 0.25°C. The design method would be simplified to allow of use by growers.

The paper by Wolfe dealt with air flow and temperature in fan ventilated glasshouses, describing how the solar heat passing through the glass was transferred to the air partly by evaporation of water from the plants and partly by raising their temperature and hence that of the air. When excess heat was removed by fan ventilation, the uniformity of temperature in the house depended on the pattern of air flow. A uniform stream of air, as assumed in theoretical studies, results in a gradient of temperature. Such a simple flow pattern might occur in houses with a large air inlet with evaporative cooling pads; with other types of inlet the flow pattern was shown to be more complex and influenced by the inlet configuration, and in some cases the roof configuration. The flow was also modified by the crop. Temperature rise, and variation along the direct air path and vertically, had been investigated to validate factors used in calculating ventilation system capacity.

Ir B. J. Heijna of Holland spoke of the many types of controller for greenhouse climate marketed in his country. One type, offered by three firms, controlled the plant environment on the basis of air moisture vapour deficit (Delta X). Plant transpiration depended upon moisture deficit and absorbed solar radiation; the Δx control system operated so as to avoid excessively high or low transpiration rates. A light-dependent controller was associated with the mixing valve of the heating system and a moisture vapour deficit-dependent controller was connected to the ventilators. Δx control systems have been used commercially for tomatoes, cucumbers, roses, freesias and carnations. Although such systems cost over £1000, growers claim that the saving of labour and worry worth this expense.

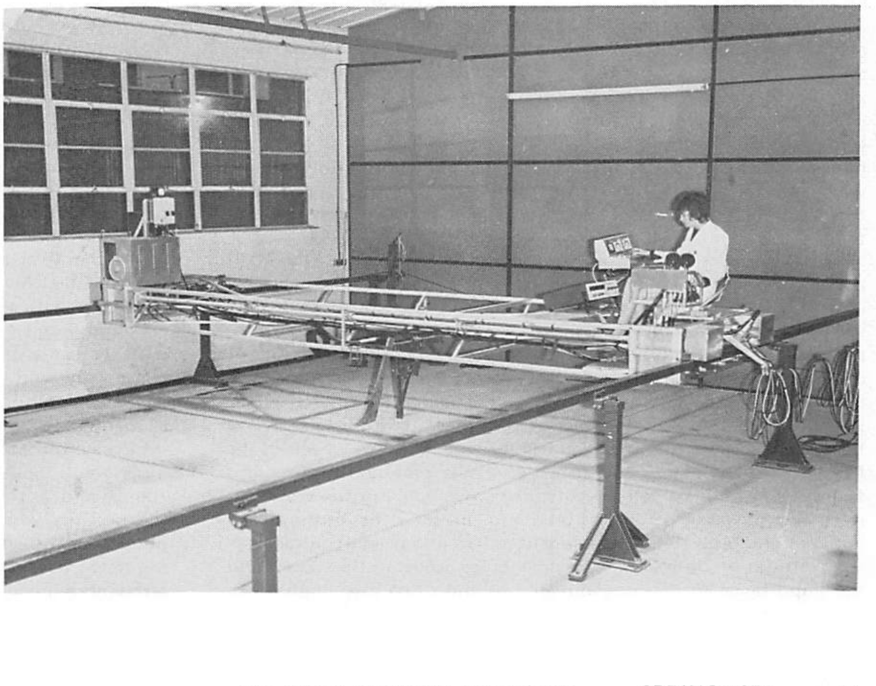
Greenhouse mechanisation work based on gantries which travelled on rails and spanned the crop growing area was described by Holt. Various crop production methods might call for a range of gantries some of which could carry implements, materials, workers and machines such as planters and harvesters. The benefits which the gantry span system was expected to offer in the production of many crops were listed and the specification of possible gantry systems outlined. Bed widths, without pathways, of between 3 and 10 m were envisaged and both powered and non-powered gantries discussed. For the lighter unpowered gantries heating pipes might be used for rails, but for the heavy duty machines special rails would be installed. Experimental 6 m span powered and unpowered gantries were shown in the laboratory; the engineering problems of propulsion, guidance and control were being studied. A rotary cultivator, tines and tray lifting equipment had been operated on the powered gantry and the problems of remote control were being examined to see if the equipment could operate with only occasional supervision.

The paper by Ir J. C. J. Kuiken of the Institute of Horticultural Engineering Wageningen described why it has become increasingly necessary to mechanise the operations in glasshouses. Among the factors listed as affecting the choice of a transport system were the ways the crop may be grown and the seasonal distribution of the labour requirement. After describing with the aid of illustrations the more advanced aids to be seen on commercial holdings, the ITT project on Industrial plant production systems, was covered. This embraced sowing, transplanting, spacing, harvesting and similar operations as well as transport to and from the growing area. The author claimed that the system of moving plants to a work zone would be suitable for all crops which can be grown in soil blocks, pots or containers but not those which require strong supports.



Measurement of airflow in a fan ventilated glasshouse.

The papers were supported by static information displays and demonstrations of measurement techniques and instrumentation, and by a working experimental gantry rig for glasshouse mechanisation. Useful discussions and exchanges of information took place after the paper presentations and during viewing of the exhibits.



Experimental gantry for glasshouse crop mechanisation.

Tractor ergonomics

EARLIER subject days in 1964 and 1970 had dealt with protective cabs, noise and ride vibration and with noise reduction respectively. As with the previous occasions the 1973 Subject Day was well attended and approximately 170 delegates included about 30 from overseas. These were generally either concerned with safety and welfare regulations in their own countries or represented the engineering staff of overseas tractor manufacturers. The majority of the UK tractor manufacturers were represented by their engineers and the audience was completed by a large contingent from the MAFF Safety Inspectorate and by research workers.

The Subject Day Chairman was Mr J. C. Weeks, Chief Safety Inspector, MAFF and papers were divided into three sessions dealing with general ergonomics and workplace design, ride vibration and protective cabs including cab heating and air conditioning. The full programme of papers which were supplemented by session discussions and by a longer closing discussion was as follows:

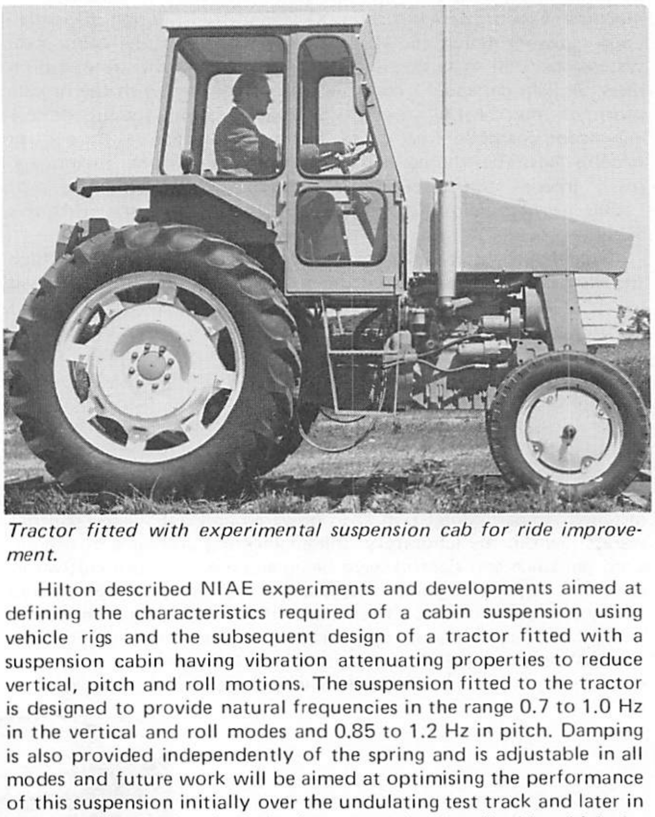
Paper 1 Review of tractor ergonomics — J. Matthews.
Paper 2 Task analysis of the tractor driver — Prof. W. T. Singleton, D. Whitfield, R. Stammers.
Paper 3 Tractor workplace design — D. J. Bottoms.
Paper 4 Ride vibration and human response — R. M. Stayner.
Paper 5 Suspended cabs for tractors — D. J. Hilton.
Paper 6 An analysis of overturning accidents with safety cabs — J. R. Whitaker.
Paper 7 Design and test criteria for safety cabs — C. J. Chisholm.
Paper 8 Climatic requirements in tractor cabs — H. A. Eriksson.

In the opening paper J. Matthews, Head of Tractor and Cultivation Division at NIAE reviewed progress made in the application of ergonomics to tractor design and explained the framework within which the individual specialised papers were offered to the Subject Day. He also dealt briefly with other matters on which demonstrations were available but which were not covered in the specific papers. Matthews emphasised the importance to date of environmental aspects of tractor ergonomics indicating that the noise problem was largely solved but that he considered ride vibration to be of critical importance over the next decade. He also explained the likely need for improved facilities for the driver to monitor and control the functioning of his implement particularly as the enclosure by cabs and possible reduction of other cues through noise and vibration improvements would lead to greater difficulty in the operator obtaining feedback information. He suggested that in the future instrument monitors might be more commonly employed to demonstrate implement functioning and that more sophisticated control arrangements might be necessary including automation of implement or some tractor functions as machinery became more common.

The paper by Professor W. T. Singleton, D. Whitfield and R. Stammers of the Department of Applied Psychology, University of Aston in Birmingham introduced the concept of a scientific task analysis and explained how such a technique might be used to study the task of the tractor driver and possibly lead to conclusions in relation to the layout of his workplace, the provision of arrangements for controlling or monitoring the components and improved training for safe and efficient operation of the tractor. Some preliminary observations on tractor design and tractor driver training were made from a limited study and the paper suggested how further employment of the technique might produce more substantial data.

D. J. Bottoms of Tractor Department, NIAE discussed the available ergonomics information relating to workplace design including access to the workplace, seating, posture and controls, instruments and displays. He emphasised the importance of population anthropometric data variability and the influence on workplace design of clothing. In relation to seating and driver posture, particularly in turning to view functioning of implements behind the tractor, NIAE investigations of a swivelling seat were outlined. Work on a sideways tilting seat to counteract the vehicle running with two wheels in the furrow was also mentioned although it was pointed out that this facility appeared less valuable than the swivelling. Further work was necessary, however, before the optimum characteristics of the swivelling seat could be stated. Investigations had also been undertaken at the Institute on optimum arrangements for access to the tractor and the importance of doorway dimensions and siting was emphasised. Bottoms described recent developments in the international standards field in relation to symbols for control and instrument identification and also standards work on the location of the main tractor controls.

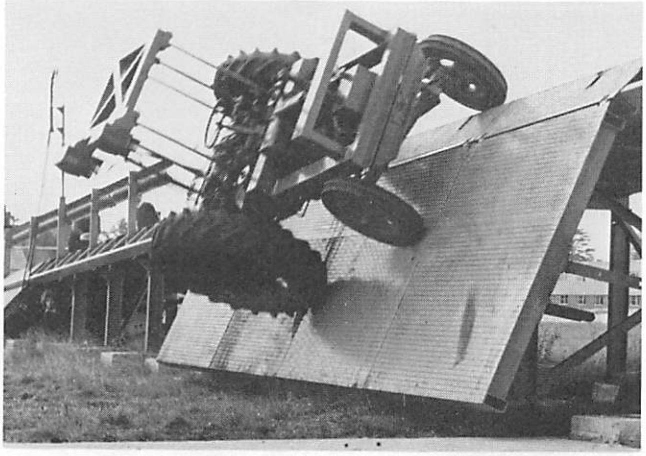
The second session of the Subject Day dealt with ride vibration on tractors and included papers by R. M. Stayner of Tractor Department, and D. J. Hilton, Head of Engineering Research Department, NIAE on human tolerance to vibration and general aspects of ride vibration improvement and on cab suspension studies respectively. Stayner described the soon-to-be-published international standard 'A guide to human tolerance to whole body vibration' and from field measurements undertaken drew the conclusion that there was a need for a reduction of vertical vibration by a further 40% from that which appears on tractors fitted with typically good suspension seats whereas in the horizontal directions vibration needs to be reduced by 60—65%. It is concluded that these reductions are really possible only by the use of a suspended cab or by a suspension fitted to the wheels or axles of the tractor. The former appears to be the less expensive but may give inadequate reduction of the horizontal vibration components.



Tractor fitted with experimental suspension cab for ride improvement.

Hilton described NIAE experiments and developments aimed at defining the characteristics required of a cabin suspension using vehicle rigs and the subsequent design of a tractor fitted with a suspension cabin having vibration attenuating properties to reduce vertical, pitch and roll motions. The suspension fitted to the tractor is designed to provide natural frequencies in the range 0.7 to 1.0 Hz in the vertical and roll modes and 0.85 to 1.2 Hz in pitch. Damping is also provided independently of the spring and is adjustable in all modes and future work will be aimed at optimising the performance of this suspension initially over the undulating test track and later in field studies. Further investigations were also described in which the application of a cabin suspension to less conventional arrangements of tractor is being studied particularly in relation to siting of the cabin near to the centre of gravity of the vehicle and the provision of some attenuation for horizontal linear components of vibration as well as those in the pitch and roll modes.

In the final session dealing with tractor cabs J. R. Whitaker, Deputy Chief Safety Inspector, MAFF analysed the performance of protective cabs in actual overturning incidents, more than 150 of which have been reported to MAFF and analysed in detail. He dealt with the cause of the overturning incident, the injuries to drivers in overturning and the damage sustained by the protective structures. He concluded that the reasons for overturning incidents were almost as many as the incidents themselves and that specific criteria for the avoidance of hazardous situations were almost impossible to define. More could, however, be done to advise on the basic precautions to follow and as many cases would be covered by misjudgement or inexperience which led the operator to take the tractor into a situation from which he was unable to extricate himself, further training might be beneficial. Injuries were in the majority of cases minor although experience has shown that it is necessary to improve on



Tractor overturning on simulated bank for studies of the dynamics of overturning and protective cab impact.

the original standard of padding and to avoid injury hazards within the cab if seriousness of injuries is to be further reduced. From the analysis of cab damage it is concluded that the information so far available suggests that the test procedures are satisfactory for normal operational hazards.

C. J. Chisholm of Tractor Department, NIAE after describing the development of strength test procedures for protective cabs, outlined the research in progress at the Institute on the determination of impacting energies under a large range of possible overturning situations including tractors with and without attached implements and vehicles travelling at different speeds. He described the development of a mathematical model for overturning and subsequent impact and the experiments in progress to validate this model through the overturning of tractors fitted with experimental frameworks on which impacting forces and energies together with vehicle motion parameters could be measured.

Finally, H. A. Eriksson of the Swedish Institute for Agricultural Engineering Research presented a paper on research into the climatic requirements of operators within tractor cabs, relating both to the heating of cabs during the winter and air conditioning during hotter summer periods. Eriksson's work included field measurements from which the significance of radiant heat from external sources, air movements and heat generated by the tractor could be assessed. This was completed by experiments in a temperature controlled chamber in which the comfort of an operator could be related accurately to the environmental conditions within the cab and the external influences such as radiant heat. It is intended that this research should lead to test and acceptance criteria for heating and air conditioning systems. Mr Eriksson pointed out that this topic is of considerable significance at present in view of the development work on international test standards for cab environmental control equipment.

The papers were supplemented by displays and demonstrations mounted by NIAE and the Swedish Institute and covering the following research topics:

- Field measurement of driver stress and fatigue.
- Tractor access and workplace anthropometry.
- Heating and ventilation of tractor cabs.
- Tractor cab noise.
- Survey of noise exposure.
- Noise test chamber.
- Cab acoustic studies.
- Ride vibration survey.
- Suspension seats.
- Suspended cab.
- Human response to vibration.
- Ride meter.
- Protective structure testing.
- Protective cab overturning.
- Bout width control for spraying.
- Aid for out of furrow ploughing.

In addition ten commercial companies exhibited instrumentation or components relevant to ergonomics aspects of tractor design and ergonomics research.

In the discussion periods which concluded each of the three sessions and the general discussion at the end of the day a number of very interesting issues were raised. It was clear that the large majority of the topics dealt with were of particular concern both to the manufacturing industry and to those responsible for safety and welfare regulations. Pleas were made for these regulations to be based on scientifically determined analyses of possible hazards and for a maximum exchange of research information between countries prior to attempts to standardise test procedures or acceptance criteria within international bodies. Concern was expressed that the

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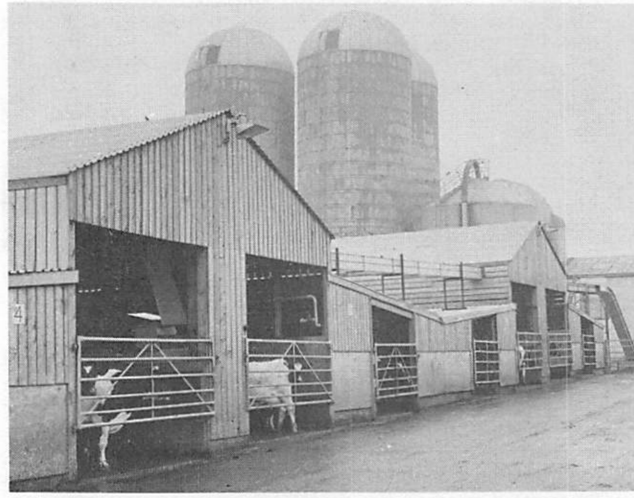
Livestock feeding and weighing

THE Livestock Feeding and Weighing Subject Day was devoted to reviews of the present state of mechanisation in livestock farming, consideration of trends and possible future requirements and to descriptions of certain research and development projects being undertaken at the NIAE and elsewhere. Professor J. C. Bowman of Reading University took the chair for three sessions during which papers were presented on cattle feeding, pig feeding and animal weighing. There were discussion periods during the day and demonstrations and films of experimental weighing and feeding equipment.

The proceedings opened with a review of the requirements for mechanised feeding and weighing on beef, dairy and pig farms. The justification for highly developed mechanisation and automatic control was partly economic, it being advantageous to spend up to £12,500 to save the services of one man, and partly social, the farm worker of today being in a position to demand equipment which would improve his working conditions. On the 'family' sized dairy herd, for instance, automatically controlled feeding systems using conveyors and belt feeders were likely to become more common. At the same time, the need was foreseen for further developments in special purpose feeder wagons for the delivery with the minimum of labour of mixed rations in controlled quantities to groups of animals on large farms. The feeding of maize silage for beef production could also become more important especially in view of the present very high price of barley, and this would lead to further demands for mechanisation.

Conveyor feeding equipment for cattle, some commercially available and some still under development, was described, and a film was shown of an installation at Bridget's Experimental Husbandry Farm. Tower silos with top unloaders deliver silage to a static forage box mounted on load cells. When the correct quantity for a particular group of animals had been unloaded, it was discharged to a chain and flight conveyor, a weighed amount of rolled barley was augered on and protein pellets were added by means of a vibratory feeder. The mixed ration was conveyed to a forage box or direct to mangers by means of belt or cascade feeders to each group of animals. The whole sequence of operations was programmed in advance. In an automatic system of this type the inclusion of devices to monitor the flow of materials and the movement of conveyors was essential if continual supervision during feeding was to be avoided. Also, detailed attention had to be paid to reliability, duplicating equipment in appropriate circumstances. For example, if there were two tower silos and unloaders, it was most unlikely that both would fail at the same time. Even when all reasonable precautions had been taken, emergency arrangements should be available for use when required.

Developments in the use of continuous weighers were described, and a machine was demonstrated consisting of a short conveyor in which a belt slid over a weighing platform pivoted at one end and supported on a load cell at the other. The electrical output indicated the rate of flow of silage, and by using an integrating circuit a measure was obtained of the total flow. The use of a continuous weigher in a conveyor feeding system had several advantages. The feed could be dispensed in one operation from the silo, over the weigher and into a manger or mobile forage box, the additional operation of first transferring to a weigh box was then unnecessary, and the time required for feeding was correspondingly reduced. Furthermore, the rate of flow signal could be used to control the speed of an auger in relation to the flow of silage and so barley or other materials could be added in any chosen proportion. The integrated signal could stop the feed when the required total weight had been delivered. A laboratory rig was demonstrated which will be the basis of an experimental farm installation.



A view of Bridgets EHF showing the cow houses and overhead conveyors carrying mixed rations to groups of animals. The weighing and automatic control equipment is in the building in the background.

One paper, supported by films, was devoted to experience in the USA. In reviewing wagons for feeding, reference was made to the part-time use of combination feeding and forage harvesting wagons, in some cases using whole shelled corn, or in conjunction with a portable grinder mixer wagon. There were also special purpose mixer feeder wagons which could be used to dispense complete mixed rations in controlled quantities to groups of animals, and a self powered driverless version had been developed and used experimentally. There was a very rapidly growing interest in 'giant' balers producing rolled bales of up to 454 or 681 kg and in stack wagons which pick up loose dry hay in the windrow, blow it into the wagon and compress successive layers to form a stack. Stack movers were also available with machinery for slicing and dispersing the stack for feeding.

The session of cattle feeding terminated with a short film and description of experimental work on the extraction of edible protein from alfalfa. The possible economic advantages of removing some protein and using the residue for feeding ruminants were discussed.

Developments in the mechanisation and automatic control of pig feeding were described by three speakers. Equipment for dry feeding made use of either feed hoppers which were moved along a feeding passage dispensing food to each pen, or conveyors carrying the food to a separate dispenser for each pen. A fully-automatic pneumatic method of conveying to dispensers had been developed at the NIAE in which pellets were carried along two inch plastic pipes by air from a low-pressure blower. Dispensing is by weight, the dispenser consisting of a hopper suspended on springs into which pellets were deflected from the pipeline by a comb-like deflector. The springs extended under load until a pre-set weight was reached, when an adjustable trip mechanism moved the deflector out of the air stream and allowed the pellets to pass on to the next dispenser. In practice, there would be one dispenser for each pen, which would be filled during feeding, and its contents discharged later at a pre-set time. By operating in this way, any fault is apparent well in advance of feeding time, and animal stress while the dispensers are being filled is avoided. An experimental rig was used

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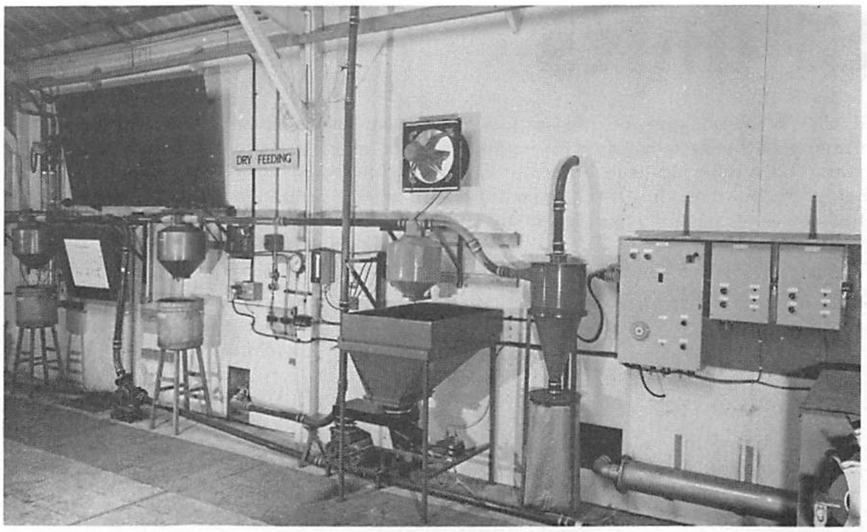
additions to the tractor to provide improved welfare, safety or efficiency could be expensive and might not be acceptable to the farming communities. It was, however, generally accepted that such improvements and increases in sophistication of the vehicle were almost certain ultimately and that it was important to progress with the evolution of the vehicle at a correct rate. A particular plea was made that we should not remove from the tractor driver so much of his activity and responsibility on the tractor that he became bored and consequently lost motivation and efficiency.

In summing up the discussion the Chairman commented that it had been particularly beneficial to have had so many contributions in the discussion from the overseas delegates. He was sure that the opinions expressed in the discussion would be taken into account by NIAE and its Study Group on Tractor Ergonomics and that as far as possible the priorities apparent at the Subject Day would be reflected in the NIAE programme of research.

An experimental rig for dry feeding of pigs by pneumatic conveying of pellets. From left to right are seen two weighing dispensers, the feed hopper and rotary seal injector, dust collector and switch gear.



to demonstrate the equipment, which was designed to feed up to 5000 pigs.

The NIAE work relating to wet feeding of pigs was at an early stage and was stimulated by the lack of knowledge of the flow properties of meal and water mixes. Data were being accumulated on the pressure/flow characteristics of mixes of various stiffnesses through pipes of diameters from 28 mm to 53 mm. It had been found that the soaking time affected the flow rate for a given pressure, and that the flow properties of any particular mix were not sufficiently consistent to permit accurate feed control by timing methods. The use of mixes as stiff as 2:1, water/meal was possible after soaking. The work was aimed at providing design data, from which improved wet feeding installations could be developed.

An automatically controlled feed hopper developed at the Institute for Agricultural Engineering and Rationalisation in Wageningen, Holland, was described and its operation illustrated in a film. The hopper moved on rails along a feeding passage, at each pen meal was dispensed by a vibratory feeder, and a jet of water directed into the trough gave an 'instant' wet mix of suitable consistency. Specially constructed cams mounted over each trough controlled the feed quantity in relation to the age of the pigs in each pen. The number of pig rations per pen was determined by inserting an equivalent number of pegs along the track. Animal stress was reduced by filling the troughs immediately after the previous feed, and giving all the pigs access simultaneously by the movement of swing panels above the troughs.

A final paper on livestock weighing underlined the important features of various equipment which had been demonstrated during the day, and gave the background to the developments which were taking place. A pig weigher designed to reduce the physical and mental strain on the operators, and to reduce the number required,

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SI units

SI UNITS provide the most refined of many metric systems of measurement, ie systems based on the metre as one of the primary units. The system has been officially adopted by the majority of European countries; the UK Government intends that Great Britain should have substantially 'metricated' by 1975.

Primary units

All SI units are derived from six primary units:

	unit	*symbol*
length	metre	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
temperature	degree Kelvin	°K
luminous intensity	candela	cd

Derived units

Derived units include:

	unit	*definition*	*symbol*
force	newton	kg m/s²	N
work, energy	joule	Nm	J
power	watt	Nm/s	W
pressure	pascal	N/m²	Pa or N/m²

Multiples and fractions

When the basic SI unit is of an inconvenient size for a particular measurement the measurement may be specified in terms of multiples or fractions of the basic unit:

multiplying factor	*prefix*	*symbol*
1 000 000 000	giga	G
1 000 000	mega	M
1 000	kilo	k
0.01	centi	c
0.001	milli	m
0.000 001	micro	μ
0.000 000 001	nano	n
0.000 000 000 001	pico	p

In general, measurements should be specified in terms of units such that the 'whole number' part of the measurement is between 1 and 10 000 thus

300 mm, not 0.300 m
90 kN/m², not 90 000 N/m²

Conversion charts

The charts shown are designed to give a visual appreciation of the numerical magnitude of measurements in SI units relative to imperial units. They may be used for conversion when great accuracy is not required. If necessary both bottom and top of the chart may be multiplied by a factor, eg 12 lb = 5.4 kg may be read as 120 lb = 54 kg or 1.2 lb f 0.54 kg.

Conversion factors must be used if greater accuracy is necessary.

Conversion factors

For more accurate conversion use may be made of the following factors, where imperial units x k_1 = SI units and SI units x k_2 = imperial units:

imperial	k_1	SI	k_2	imperial
length				
in	25.40	mm	0.0394	in
ft	0.3048	m	3.281	ft
yd	0.9144	m	1094	yd
mile	1.609	km	0.6214	mile
area				
in²	645.2	mm²	0.00155	in²
ft²	0.0929	m²	10.76	ft²
yd²	0.8361	m²	1.196	yd²
mile²	2.590	km²	0.3861	mile²
acre	0.4047	ha	2.471	acre
volume				
fl oz	28.41	cm³	0.0352	fl oz
pt	0.568	litre	1.760	pt
gal	4.546	litre	0.220	gal
U S gal	3.785	litre	0.264	U S gal
bushel	36.40	litre	0.0275	bushel
mass				
oz	28.35	g	0.0353	oz
lb	0.454	kg	2.204	lb
stone	6.350	kg	0.157	stone
cwt	50.80	kg	0.0197	cwt
ton	1.016	tonne	0.984	ton
velocity				
ft/s	0.3048	m/s	3.281	ft/s
ft/min	0.0051	m/s	196.9	ft/min
mile/h	1.609	km/h	0.6214	mile/h
acceleration				
ft/s²	0.3048	m/s²	3.281	ft/s²
volume rate of flow				
ft³/s	0.02832	m³/s	35.32	ft³/s
ft³/s	28.32	l/s	0.03532	ft³/s
gal/min	0.0758	l/s	13.2	gal/min
mass rate of flow				
lb/s	0.4536	kg/s	2.205	lb/s
density				
lb/in³	27.68	g/cm³	0.0361	lb/in³
lb/ft³	16.02	kg/m³	0.0624	lb/ft³
force				
lbf	4.448	N	0.2248	lbf
tonf	9.964	kN	0.1036	tonf
pressure				
lbf/in²	6.895	kN/m² (kPa)	0.1450	lbf/in²
in water	249.1	N/m²	0.004014	in water
in mercury	3.386	kN/m²	0.2953	in mercury
torque				
lbf ft	1.356	Nm	0.7376	lbt ft
work				
ft lbf	1.356	J	0.7376	ft lbf
Btu	1.055	kJ	0.9479	Btu
power				
ft lbf/s	1.356	W	0.7376	ft lbf/s
hp	0.7457	kW	1.341	hp
Btu/h	0.293	W	3.412	Btu/h
illumination				
lm/ft²	10.76	lm/m² (lx)	0.0929	lm/ft²
luminous intensity				
cd/ft²	10.76	cd/m²	0.0929	cd/ft²

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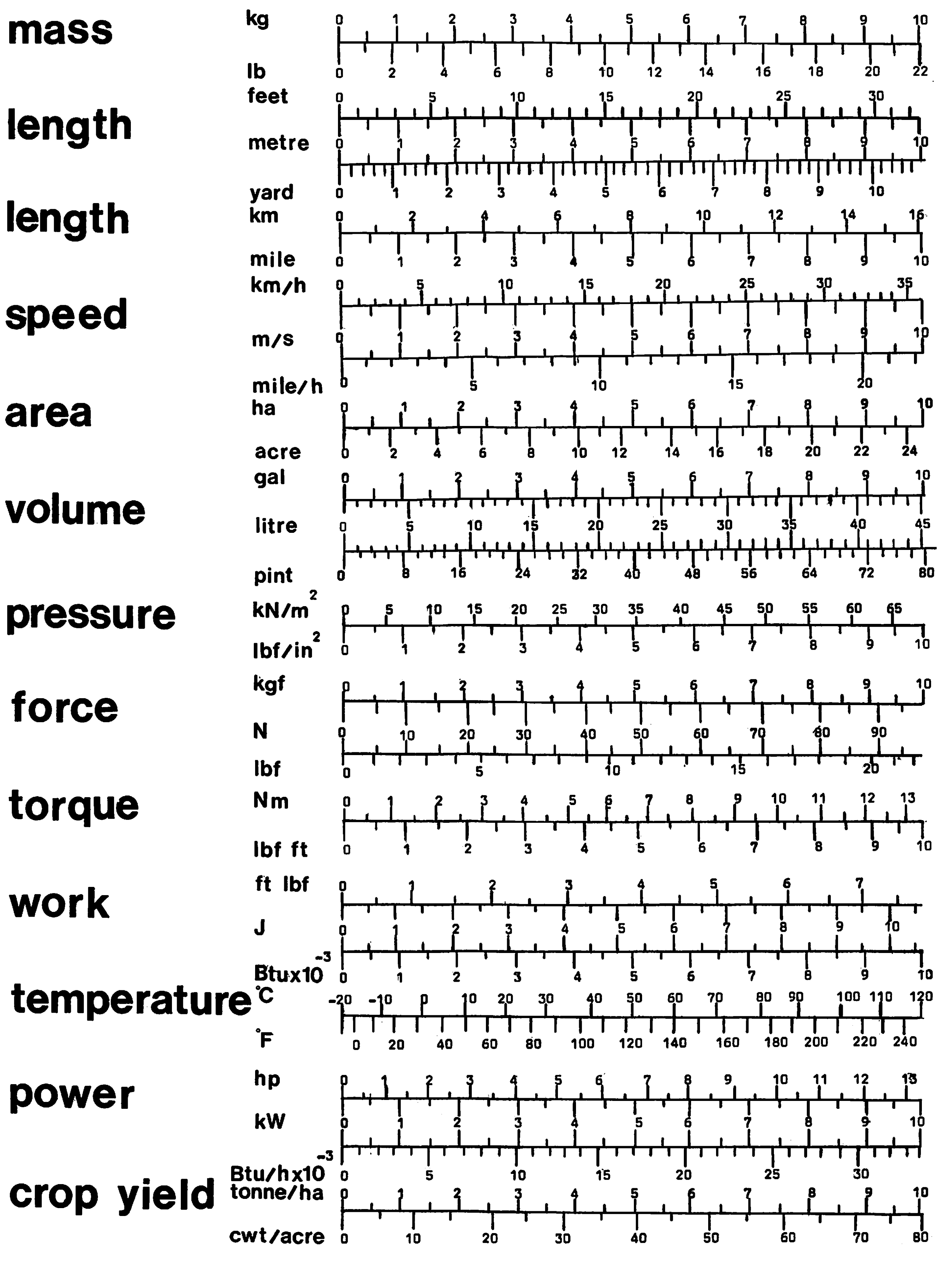
made use of pneumatically controlled gates and pushers to take the animals through a weigh crate. An electrical transducer and integrating circuit gave a steady reading in digital form for the weight of each pig and eliminated fluctuations due to animal movement which make it difficult to read a pointer on a spring balance scale. For weighing cattle, a hand controlled, pneumatically powered gating system was under trial as an operator aid. Consideration was also being given to the possibility of a gateless 'walk-through' weigher and experiments were in progress to determine the type of platform and suspension which would be needed. Such a weigher used regularly would be of value as a health monitor in situations where the animals were already separated, for example as they came from a rotary milking parlour.

CONVERSION CHARTS



Research and development work at University College Dublin

A FULL undergraduate 4-year degree programme in agricultural engineering was established in the School of Engineering, University College, Dublin, in 1961. Since then an active research programme has been in progress at both undergraduate and postgraduate level.

Undergraduate research and development

In the third year, students are given an individual or group machine design project. Last year four students worked as a group in designing an improved pilot plant for extracting protein-rich juice from grass. Procedures for scale-up to a commercial plant operation were established. In the current year, the following design projects are being conducted in collaboration with industry:

(a) Design of a one-man steerage hoe.
(b) Redesign of the lifting mechanism of a sugar beet harvester to suit southern European conditions.

In the final year, students undertake an individual experimental project and an individual food production and processing enterprise design project. Current experimental projects are as follows:

(a) Freeze drying studies using a fruit product.
(b) A study of an environmental control unit for agricultural purposes.
(c) Analysis of the structure of cheddar cheese using microscopic and rheological techniques.
(d) A study of the aeration characteristics of animal production system wastes.

The objective of the enterprise project is to design a complete food production and processing system for a particular agricultural product. We feel that this is a particularly useful approach because food production and processing operations in Ireland are frequently undertaken by a single organisation such as dairy co-operatives, semi-state bodies etc.

Current enterprise projects are as follows:

(a) Design of a production and processing system for single cell protein based on an indigenous agricultural by-product.
(b) Potato production and processing system.
(c) Design of a fresh water fish farming production and processing system.
(d) Beef production and processing system.

Postgraduate research and development

Engineering graduates from all five branches in the School of Engineering – Agricultural, Chemical, Civil, Mechanical and Electrical – have conducted postgraduate research in agricultural engineering topics. Most projects are of one year duration leading to a Master of Engineering Science degree. In some cases graduates have elected to undertake a PhD programme which is usually of three years duration. External research conducted in other universities, research institutes or in industry may be submitted for the Master of Engineering Degree.

The most active ongoing research is in the grass handling systems area – a reasonable priority because approximately 90% of Irish agricultural land is under grass. Early work concerned conveying characteristics of forage harvesters. In 1969 the National Science Council (NSC) (under the Scientific Research Grants Scheme) awarded a three-year grant to our department to study 'Design and Performance Parameters for Grass-cutting Machines'. The results of this research stimulated the design and construction of a patented 1.68 m rotary mower in our department. Initial field testing of the prototype by a commercial interest revealed highly satisfactory performance.

Another research area funded by the NSC is reverse osmosis which is related to our commitment to the environmental protection and food processing areas. In 1971 a three-year research grant was awarded to a project entitled An examination of reverse osmosis (RO) as a concentration process for dairy and allied products. This project is particularly relevant to the processing of whey, a by-product of cheese manufacture. The production of cheese and therefore whey is expanding rapidly in Ireland and thus dumping of whey into rivers is now an unacceptable pollution hazard. RO is a 'gentle' dehydration technique which preserves the whey proteins in their undenatured form. Thus whey protein concentrates prepared by RO and subsequent spray drying have useful functional properties which make them attractive as potential ingredients in formulated food products. Our research is orientated towards increasing RO membrane permeability by varying membrane composition in order to improve the economics of the process and thus make it more attractive as a commercial proposition.

In late 1972 a general research programme was established (in collaboration with the Department of Mechanical Engineering) to investigate the mechanical and rheological properties of agricultural materials. This is an important area because the geometry and therefore the design of food production and processing equipment is strongly dependent on the mechanical and rheological properties of the food itself. Current projects include (a) investigation of the structure of cheddar cheese; (b) investigation of the effect of temperature on the rheological properties of a model agricultural material. These projects use the Instron Universal Testing Machine which has recently been equipped with an environmental control chamber permitting a temperature range of – 70 to 300°C.

Considerable research has been conducted in the design of farm structures. Recent work has concentrated primarily on environmental control aspects such as an analysis of temperature control characteristics in heated glasshouses using an analog computer. The latter work was carried out in conjunction with the Agricultural Institute.

Considerable research has also been conducted in the area of soil cleavage. Our present interest lies in the area of the effect of vibrations in soil cleavage and fragmentation.

In general, we try to relate our research to current problems in Irish agriculture. We also encourage non-Irish students to undertake research with us. Further information about our department and its research and development areas can be obtained by contacting the author.

Paul B. McNulty

Field measurements of the performance of a rotary mower.

AROUND THE BRANCHES

East Anglia

THE annual conference of the East Anglian Branch was held on 21 November 1973 at the Norfolk School of Agriculture; about 170 farmers and engineers attended, the subject being mechanical livestock feeding.

Speakers at the East Anglian Branch conference. From left to right, Messrs B. J. Bell (Branch Chairman), W. R. Butterworth, G. Shepperson, C. J. V. Baskerville, R. H. M. Robinson, J. B. Finney, D. Chalmers, R. A. den Engelse and H. W. Whitton.

The morning session was chaired by David Richardson, farmer and broadcaster, who said that he thought agricultural wages would be in the region of £60/week by 1980. The first speaker, Bill Butterworth, machinery lecturer at Writtle Agricultural College, gave a paper on materials handling in which he impressed upon the audience the need to plan new buildings for ease of servicing and expansion in the future. So often buildings were put up with insufficient space between to use bigger machinery like feed boxes.

Pig feed systems was the title of Brian Finney's paper. Brian is Regional Mechanisation Adviser for ADAS at Cambridge. He said that ADAS had found pipe line systems to be extremely accurate but thought that the future may be in pellet feeding as in Holland. The last speaker in the morning was Gordon Shepperson, Head of the Forage Conservation Department at NIAE, who made the point that although the industry was going for larger parcels of fodder at present, he thought it should eventually end up with small egg-sized packages which could be handled more easily mechanically.

Rob den Engelse, general manager of East Anglian Real Property Co. Ltd, chaired the afternoon session. The first speaker was

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concluded from page 22

Rule of thumb conversions

A few easily remembered relationships between SI and imperial units will enable a large proportion of everyday conversions to be made with reasonable accuracy. The following relationship may be found useful:

		relationship	*accuracy %*
length	2 in	= 5 cm	1½
	5 miles	= 8 km	½
	100 yd	= 90 m	1½
area	5 acres	= 2 ha	1
volume	7 pints	= 4 litres	1
	2 gal	= 9 litres	1
mass	11 lb	= 5 kg	¼
	1 cwt	= 50 kg	1½
	1 ton	= 1000 kg (1 tonne)	1½
force	2 lbf	= 9N	1¼
	1 tonf	= 10 kN	½
pressure	15 lbf/in²	= 100 kN/m²	3
yield	8 cwt/acre	= 1000 kg/ha	¼
		= 1 tonne/ha	¼
power	4 hp	= 3 kW	½

Further reference

Farm and Estate Metric Conversions, published by The British Agricultural and Garden Machinery Association Ltd, Penn Place, Rickmansworth, Herts. WD3 1RQ is a very comprehensive booklet providing many conversion factors particularly appropriate to agricultural use.

Herbert Whitton, farmer, who described his system of feeding grass silage from horizontal silos. He based his system on the American Oswalt Ensiloader and forage boxes with load cells mounted between box and chassis for weighing.

Dick Robinson, farmer, followed with an appraisal of the growing and feeding of maize. He thought that the crop had great potential, mainly for silage and one would see its growing increased at a very great rate.

The last paper was a joint effort between David Chalmers and Charles Baskerville, Livestock and Mechanisation Advisory Officers respectively with ADAS in Norwich. They discussed the value and problems of feeding by-products. Sugar beet tops were likely to be saved for stock feed much more in the future; soil contamination was likely to be the biggest problem.

Northern

THE shield and cup awarded annually by the Northern Branch of the Institution of Agricultural Engineers to the best practical student in agricultural engineering was presented to Mr Michael Pearson at Kirkley Hall's prize giving day. Michael (18) who works for B. H. Brown, Alnwick, was top student in the three-year block release course leading to the City and Guilds of London Institute's Agricultural Mechanics Certificate. He follows in the footsteps of his brother, who was top student in 1967 and is now service manager of the same company.

During the summer, small but enthusiastic parties of Institution members have visited the new Alcan Aluminium Smelter, Blyth, and have been down a coal-mine at Westoe Colliery, South Shields.

Developments in rotary parlours

**Paper given by Miss T P Thomas BSc Dip Agric-ADAS, at Northern Branch meeting on 3 October 1973.*

MILKING machine manufacturers in the UK were between them offering seven different basic types of rotary parlour and there were at least 20 different models on the market. In these parlours operator movement had to be minimised and automation of the work routine maximised so that more units could be handled per man. In good milking practice the routine should include feeding, taking the foremilk, washing and drying the udder, attaching and removing the cluster and test disinfection. In addition, the cows had to move or be moved into and out of the parlour. Yield recording was optional. The throughput of any milking parlour was determined by the length of the work routine. With manual operation of a full routine it was hardly possible to reduce the time taken to less than 0.80 min cow giving a throughput of 75 cows man hour.

Except for taking the foremilk, attaching clusters and drying the udders, automation of all other routine jobs was possible, reducing the operator's time to as little as 0.40 min cow or 150 cows man hour. But what in fact was the present state of parlour automation and where did the problems lie? Moving cows into and out of the parlour in the larger rotaries was done by a system of moving gates on the rotary platform but it was essential to provide good collection facilities in the yard to keep the cows close up to the parlour entrance. Automatic cluster removal was not altogether satisfactory in its present form and most of the designers had gone back to the drawing board. In spite of continuing research effort, automatic test disinfection was not yet available. Automatic washing devices had been tried but the wash was not thorough enough without some additional hand work. Work was being done at NIRD and elsewhere on automatic identification and yield recording. Even without automatic identification, a good operator who could recognise individuals quickly took next to no time to press the appropriate feeder button. Automatic feeding was well advanced but it still depended on accurate dispensing into the manger and after many years of parlour feeding there was still no accurate means of dispensing.

High yielding cows needed up to six minutes to milk out and must also have sufficient time to eat their concentrates. The table shows the relationship between throughput and rotation, milking and feeding times in four sizes of rotary parlour.

The relation between work routine, rotation time and maximum milking and feeding time.

Work routine time min/cow	*No. of cows milked man hour*	*Continuously rotating herringbone and tandem parlours* *Max Time min/cow*	*12/12*	*14/14*	*16/16*	*18/18*
		rotation	8.0	9.3	10.7	12.0
0.67	90	milking	5.7	7.0	8.4	9.7
		feeding	6.1	7.4	8.8	10.1
		rotation	7.2	8.4	9.6	10.8
0.60	100	milking	5.1	6.3	7.5	8.7
		feeding	5.5	6.7	7.9	9.1
		rotation	6.0	7.0	8.0	9.0
0.50	120	milking	4.2	5.2	6.2	7.2
		feeding	4.6	5.6	7.6	7.6
		rotation	4.8	5.6	6.4	7.2
0.40	150	milking	3.7	4.5	5.3	6.1
		feeding	4.1	4.9	5.7	6.5

Source: P Clough, NIRD

If the present mechanical problems of automating udder washing, cluster removal and teat disinfection could be overcome, throughputs in excess of 100 cows man hour could be achieved but only the larger rotaries (16 units and above) will allow sufficient milking and feeding time for these high performances to be obtained.

A lively discussion, opened by Mr John Moffit, followed the paper. Mr Moffit made a plea to engineers to design and produce a reliable and accurate feed dispenser for parlour feeding concentrates. It was pointed out that in a rotary parlour only one dispenser was required so that cost was not such a limiting factor in the design.

Finance for farm machinery — the present position*

Paper given by D L Torrance — ADAS at Northern Branch meeting on 7 November 1973

ONCE the decision had been taken to acquire a new machine there were a number of different methods of obtaining the required finance. It should be remembered that the use of contractors, co-operation, borrowing and short-time hire, were alternatives to buying which should be explored.

The straight cash buy was obviously the cheapest source of finance, but successful businesses with 'spare cash' should probably use it to expand. →page 27

A bank overdraft was the traditional source of cheap finance, and interest was paid only on the actual debt. This could cut the cost for businesses which were in credit for part of the year. Bank loans were more expensive than overdrafts, but were safeguard against overdraft reductions imposed either by the bank or government policy. The cost of both these sources was arranged relative to 'base rate' which changed from time to time and borrowers did not always know what they were paying.

Leasing was a growing method of finance. The machine belonged to the financier but was leased to the farmer for a period, often three years and the farmer paid by regular fixed instalments. At the end of the leasing period the farmer could continue to use the machine for a nominal lease, or trade it in. He was then credited with the value of the machine against his next purchase; hire purchase was generally a more expensive form of finance than leasing or borrowing from the bank.

Each system of finance produced a different cash flow, which could give rise to tax advantages in certain situations. Farmers should get taxation advice from tax consultants and accountants.

The money market was competitive and sensitive and would-be borrowers should examine all possibilities to find the best form of finance.

South eastern

JOHN NIX, the well-known economist from Wye College, has suggested that the wages of agricultural workers will tend to rise more rapidly than others in the low paid sector. At a meeting at the Writtle Agricultural College on 16 October Mr Nix also calculated that the agricultural wage by 1980 would be the equivalent of £3300 after having made a small allowance for free housing. He said also that Essex farmers, like others in the country, would be questioned shortly in connection with a survey on tied cottages being carried out by the Tavistock Institute.

The occasion was a joint meeting between the Institution of Agricultural Engineers, South Eastern Branch and the Essex Branch of the Farm Management Association. This was the first meeting of the winter series. Mr Nix was talking on the subject of costs in farming in general but with special reference to mechanisation.

On the subject of over-mechanisation, Mr Nix admitted that there was no clear cut solution to deciding the level of investment in machines. Many farmers were over-mechanised but should always err that way provided it was not grossly overdone. One solution was to buy the larger machines but buy second-hand. Alternatively, machines kept longer would incur lower charges/acre or/year.

ABOUT seventy local farmers and drainage men turned up at Writtle Agricultural College for the monthly meeting on 5 December of the South Eastern Branch of the Institution of Agricultural Engineers.

The big message from Mr Brian Trafford (ADAS) was: 'get the water to the drain'. Mr Trafford suggested that field drains in farm land could only serve their purpose if the water could get to the pipes and this was often not the case in practice. Experiments carried out at Drayton EHF had shown cases of an 8 or 9% depression in crop yields following drainage work carried out during the December period in bad conditions. Mr Trafford gave four basic problem areas that one needed to watch:

The surface. This was basically under the farmer's control, the cultivations and equipment he used affected how water moved through the surface.

The plough layer. This was again basically under the farmer's control. It was the equipment and practice that counted.

The subsoil. Some subsoils obviously drained more freely than others. Subsoiling and/or mole ploughing could have a profound effect.

The pipe entry. Drainage work carried out under wet conditions could (and often did) result in the sludging up of the cracks between the pipes causing the drain to become useless. The only remedy was to lay a new set of drains.

Further work at Drayton EHF showed that there was little difference, *on clay land,* in the effectiveness of drains at different spacings. What did make the difference was adequate mole ploughing. Subsoiling, if it was carried out at least 51 cm deep, could be as effective as mole ploughing because, in effect, it produced a square mole. The round mole should last longer, however.

So the two key points on the drainage front were: drain under reasonable conditions and do not bother with too close a spacing of tiles: go for moles.

South western

THE South Western Branch meeting of the Institution of Agricultural Engineers on 8 November was held at Seale-Hayne Agricultural College when Mrs von Reibnitz of ADAS gave an excellent paper on modern milking, with wide-ranging slides.

The chairman welcomed the Branch's first lady speaker and expressed delight with the new 'Hayter-Hames' lecture hall with its adjoining machinery laboratory where an up-to-date milking set-up was running for Branch members' benefit. The paper was enthusiastically received and provoked intense discussion by members and guests.

South east midlands

THE winter programme got off to a good start with three very interesting meetings and a social evening. John Nix (Wye College) reviewed farm labour and machinery costs, past and present and took the bold step of looking into the future. Whilst the future seemed far from clear, an interesting discussion ensued around manpower predictions and likely costs of capital.

The Bassingbourn meeting, although very poorly attended by Branch members, raised some interesting points on the design of farm machinery from a safety point of view. The extensive survey being carried out on farms by Messrs Abbott and Cooper and their colleagues (RoSPA) should provide a great deal of useful information on the nature of farm accidents and the time lost through them in the near future. The Branch committee were very pleased to welcome members of Cambridge Farm Machinery Club to this meeting.

On a rather cold December night with a minimum of room heating, Ted Bowman (NIAE) gave a very clear and comprehensive review of the extent of existing world energy supplies and of the possibilities of using solar radiation as a direct energy source and indirectly through plants. A lively wide ranging discussion followed, which quickly made members forget about the low room temperature. Ted is intending to put pen to paper on this topic, so that all Institution members can benefit from the information presented, through *The AGRICULTURAL ENGINEER.*

At the end of October, 45 members and wives enjoyed a pleasant dinner and social chat at the Dog and Badger, Maulden. The Branch was delighted to welcome the President and Mrs J. A. C. Gibb, Mr and Mrs Gunn and Mr and Mrs Mitchell (Branch auditors). Speeches were kept to a minimum (2 minutes flat) and wives saw to it that conversation was kept well clear of business.

West midlands

IMPLEMENT makers were lagging behind makers of 149 kW tractors that would give timeliness of operation and when used with big implements would enable one man to cover more acres. Big tractors needed big fields to obtain high output and keep down running costs.

These were the main points in a discussion on the implication of the large tractor organised by the West Midlands Branch of the Institution of Agricultural Engineers at Warwickshire College of Agriculture, Moreton Morrell, on 29 October 1973.

Mr Stephen Bond, of Velcourt, Ledbury, Herefordshire, illustrated how costs on a 243 ha farm could vary from machine to machine. The tractor which worked only 812 hours a year cost 69p/hour to run while an identical machine which clocked up 1,940 hours cost 25p/hour. Repair bills were the same.

The great technological changes in the next decade would occur in the cultivation of arable crops – excluding roots, he said.

Putting the NIAE's viewpoint, Mr Ian Rutherford (ADAS) advocated the use of two-wheel drive for general farm work up to 56 kW. The 75 kW two-wheel drive machines did not give best performance under normal conditions. He preferred 4-wheel drive tractors in tough going with wheelslip.

'I foresee an increase in tractor horsepower ratings. Tractors will become more specialised. Farmers will use larger machines for heavy arable jobs on big farms and a host of smaller tractors for doing the odd jobs,' he said.

The time was right for the development of versatile systems in which a range of attachments could be matched to a single power source. Large farmers involved in forage, grain, roots and cultivation would be prepared to invest up to £20 000 in such a system.

Advocating the use of 4 X 4 tractors of more than 75 kW, Mr David Tapp, of County Commercial Cars, Fleet, Hants., said: 'The reduction in manpower on the land makes it necessary for the remaining men to achieve greater output. Bigger tractors can now cope with up to three or four operations in a single pass.

'An additional factor is timeliness. To farmers it is no longer a question of how and what cultivations are to be done this year, but how quickly this can be done.

'In the last quarter of 1972 one in three tractors of over 60 kW sold in the UK were 4-wheel drive machines and 95 per cent of the 75 kW plus machines were 4 X 4.

'I see no reason why 149 kW tractors will not be in this country in the near future,' said Mr Tapp.

Yorkshire

THE combine harvester present and future was the subject chosen by Mr John Millington, product specialist from Sperry New Holland, who replaced the advertised speaker at the Yorkshire Branch's first meeting of the new session, on 13 September at Holmfield House, Wakefield.

A necessarily brief history of the combine was carefully interwoven with description of the features of the machine as it is known today. Mr Millington also broadly outlined the economic principles of a larger machine, and mentioned the lower volume of sales and the price at which it had to be sold to maintain profit levels.

Discussion of the actual layout of the combine included the facts that 90% of the grain was extracted in the concave, and a further five per cent in the first one sixth of the average straw-walkers. As the remaining five-sixths of the walkers extracted only five per cent of the grain, little would be achieved by merely lengthening the walkers, yet it was true that 60% of the grain loss was from the straw-walkers.

Furthermore, it was dangerous to try and compare combines on the basis of individual parameters and this was no more true than in the case of pan and sieve areas.

Mr Millington warned that monitors had to be understood if they were to be of any use at all. They measured loss in unit time, not loss/acre. At the present time few operators gained any real benefit from monitors, he thought.

Original thinking was producing certain specialised combines, but in Mr Millington's view, the combine as it was known today would not change fundamentally where it was required to cope with a variety of crops, in unpredictable conditions, and at widely varying moisture levels, hour by hour.

MR HORSTINE FARMERY opened the talk he gave to Yorkshire Branch members on 18 October by emphasising the implications of applying insecticides in greater quantities than was recommended, as many of the crops having the insecticide applied to them would eventually be eaten by animals or humans with possible disastrous consequences due to increased concentrations in the body with time.

The problems of spraying insecticides were discussed including the inaccuracy of spray jets for both application rate and distribution pattern, and the difficulty of calibrating polythene tanks because of their lack of rigidity. Pressure gauges were often inaccurate and together with operator error; tachometer error and the variation in effective tractor wheel diameter between a full and empty tank often led to errors of up to 100% in application rates.

On the other hand, granules were much easier to apply accurately as the machines could be designed to accurately apply a given quantity of material and it was therefore left to the chemist to ensure that the correct quality of active material was put in the granules.

Other advantages in the use of granules were that it was possible to cover about ten times the acreage with one payload when compared with liquids. The reason for this was that with granules a much greater percentage of active ingredient was applied on a weight basis — even so the toxicity was not increased from the operation point of view as the granule was coated with inert material and fines were kept to a minimum.

Granules could also give off active chemicals over a much longer period than liquids and were less likely to become inactivated in peaty soils than spray chemicals.

In summing up Mr Farmery did not envisage a rapid swing to granules for weed control, although the active chemicals were translocated into the plant for insect control from the plant roots, it was easier for weed control to translocate the chemical through the leaves and the leaf often has a means of selectivity of chemicals in its own physical make up.

Institution of Agricultural Engineers

Spring Conference

In conjunction with the Institution's Annual General Meeting

A conference will be held in the afternoon of Tuesday 8th May, following the Institution's A.G.M. and Luncheon and the Presidential Address. The theme of the conference will be

Developments in Tractor Design and Application

It is expected that four papers will be presented:

Paper 1

A review of progress and proposals in implement coupling and control, including automatic coupling, methods of draught and depth control and remote monitoring and control of implements.

Paper 2

German tractor developments, including front mounting and platform mounting of implements, tractor suspensions and forward control.

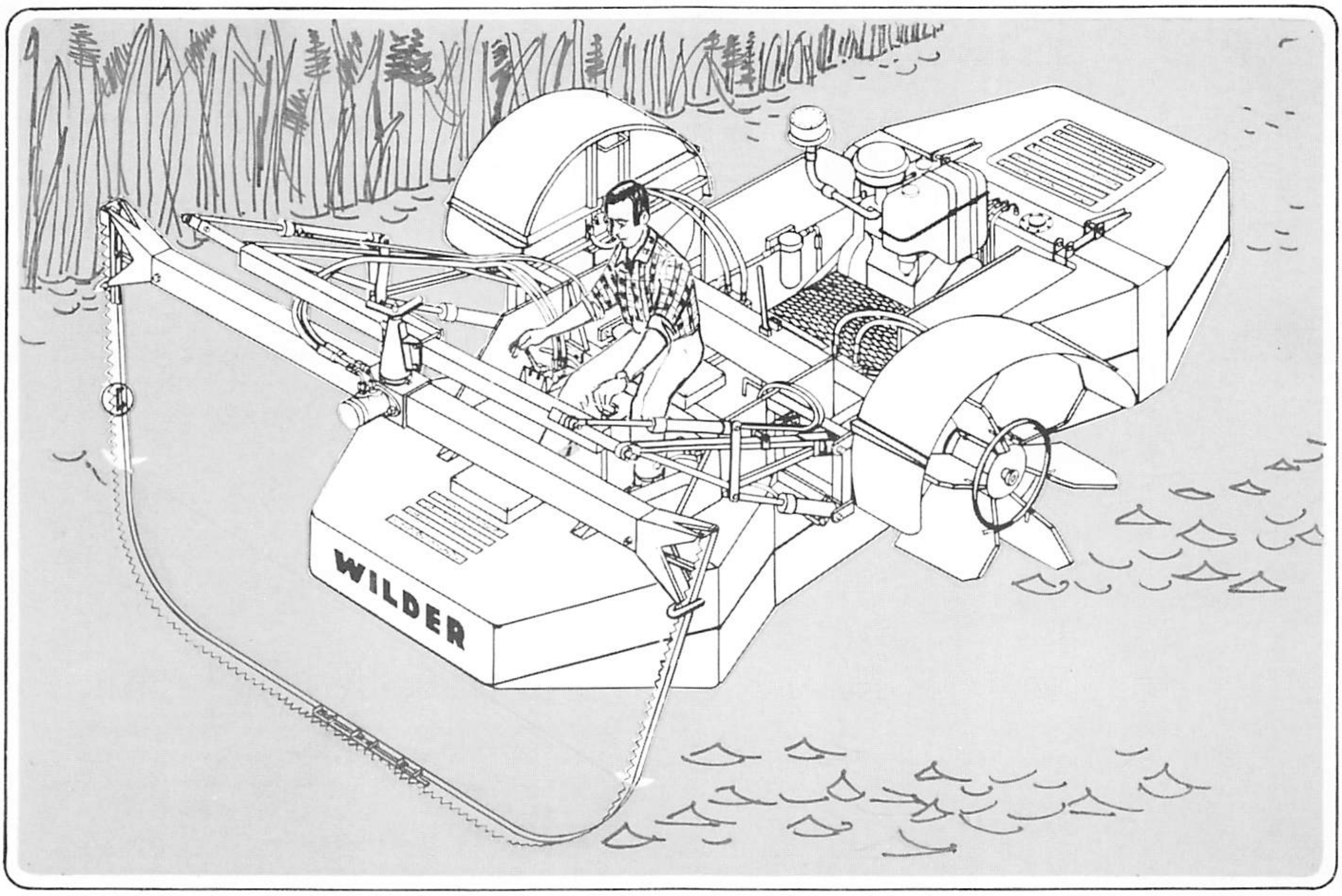
Paper 3

Assessment of the optimum working width and operating speed for least cost primary cultivations.

Paper 4

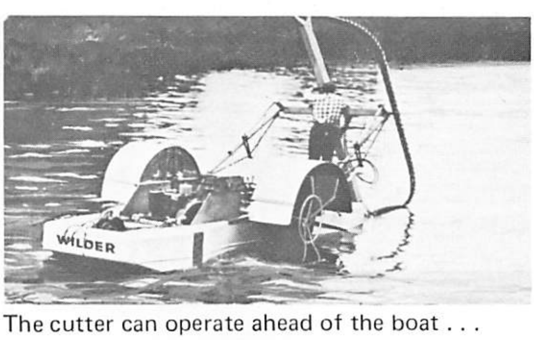
Factors to be considered by a tractor manufacturer in producing a range of tractors. Tractor power, ground drive equipment and implement control will be some of the features discussed.

Names of the speakers and the titles of their papers will be announced shortly.

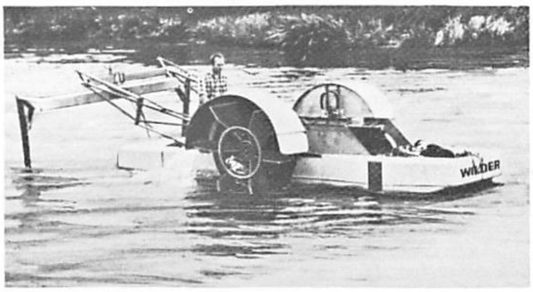


WILDER water weed cutter

clears the waterways



The cutter can operate ahead of the boat . . .



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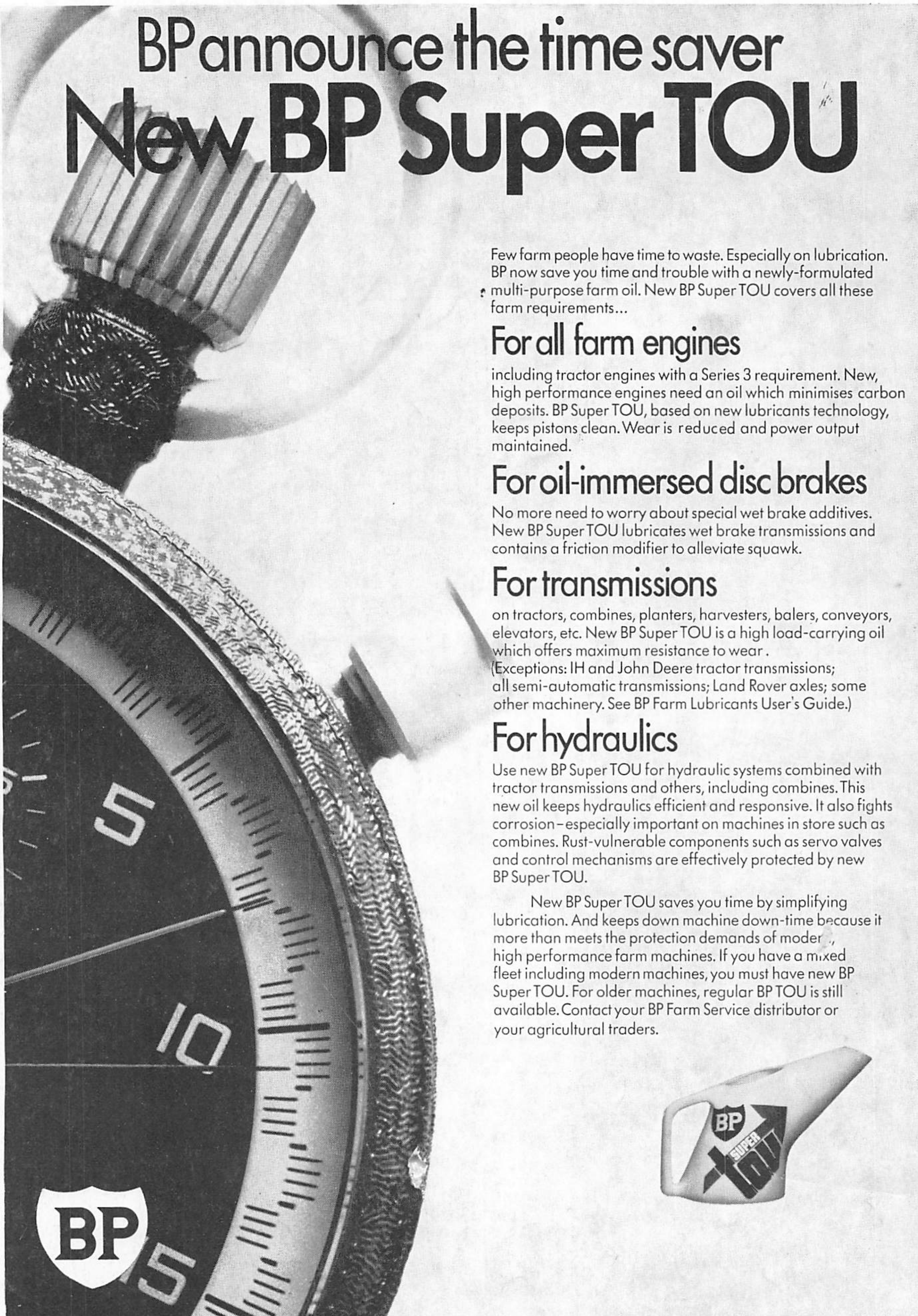
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Few farm people have time to waste. Especially on lubrication. BP now save you time and trouble with a newly-formulated multi-purpose farm oil. New BP Super TOU covers all these farm requirements...
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No more need to worry about special wet brake additives. New BP Super TOU lubricates wet brake transmissions and contains a friction modifier to alleviate squawk.
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on tractors, combines, planters, harvesters, balers, conveyors, elevators, etc. New BP Super TOU is a high load-carrying oil which offers maximum resistance to wear.
(Exceptions: IH and John Deere tractor transmissions; all semi-automatic transmissions; Land Rover axles; some other machinery. See BP Farm Lubricants User's Guide.)
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Use new BP Super TOU for hydraulic systems combined with tractor transmissions and others, including combines. This new oil keeps hydraulics efficient and responsive. It also fights corrosion–especially important on machines in store such as combines. Rust-vulnerable components such as servo valves and control mechanisms are effectively protected by new BP Super TOU.
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