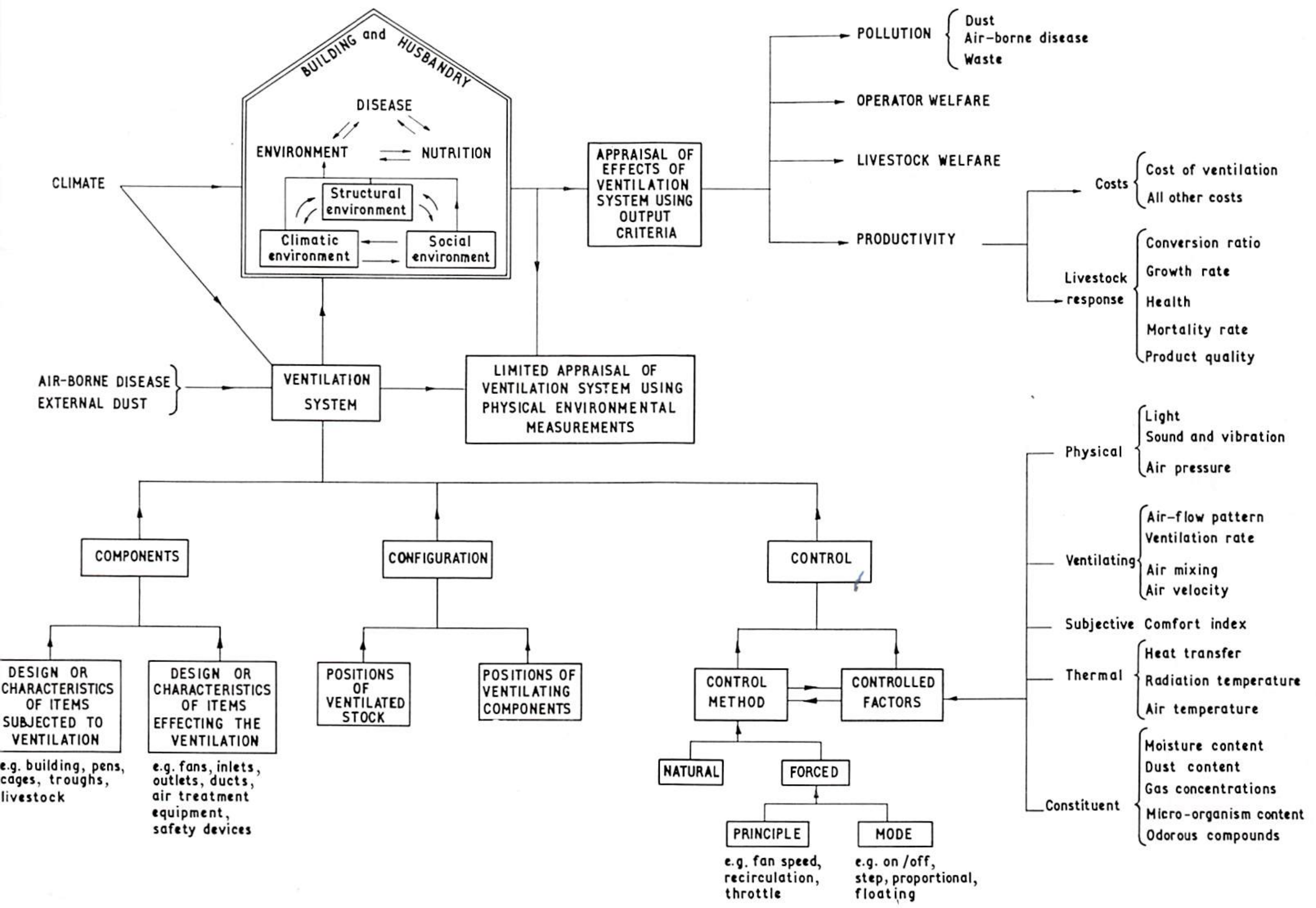
The AGRICULTURAL ENGINEER

JOURNAL and Proceedings of the INSTITUTION of AGRICULTURAL ENGINEERS

Volume 27 | Autumn 1972 | No 3

The Ventilation of Livestock Buildings: its Scope and its Relationship to Output Criteria and Other Factors



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Volume 27 AUTUMN 1972 No. 3

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The AGRICULTURAL ENGINEER is published quarterly by the Institution of Agricultural Engineers

ABC
MEMBER OF THE AUDIT BUREAU OF CIRCULATIONS

Price: 75p per copy, annual subscription £3 (post free in *UK*)

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Printed by Vale Press Limited, 20 Wates Way, Mitcham, Surrey CR4 4HR

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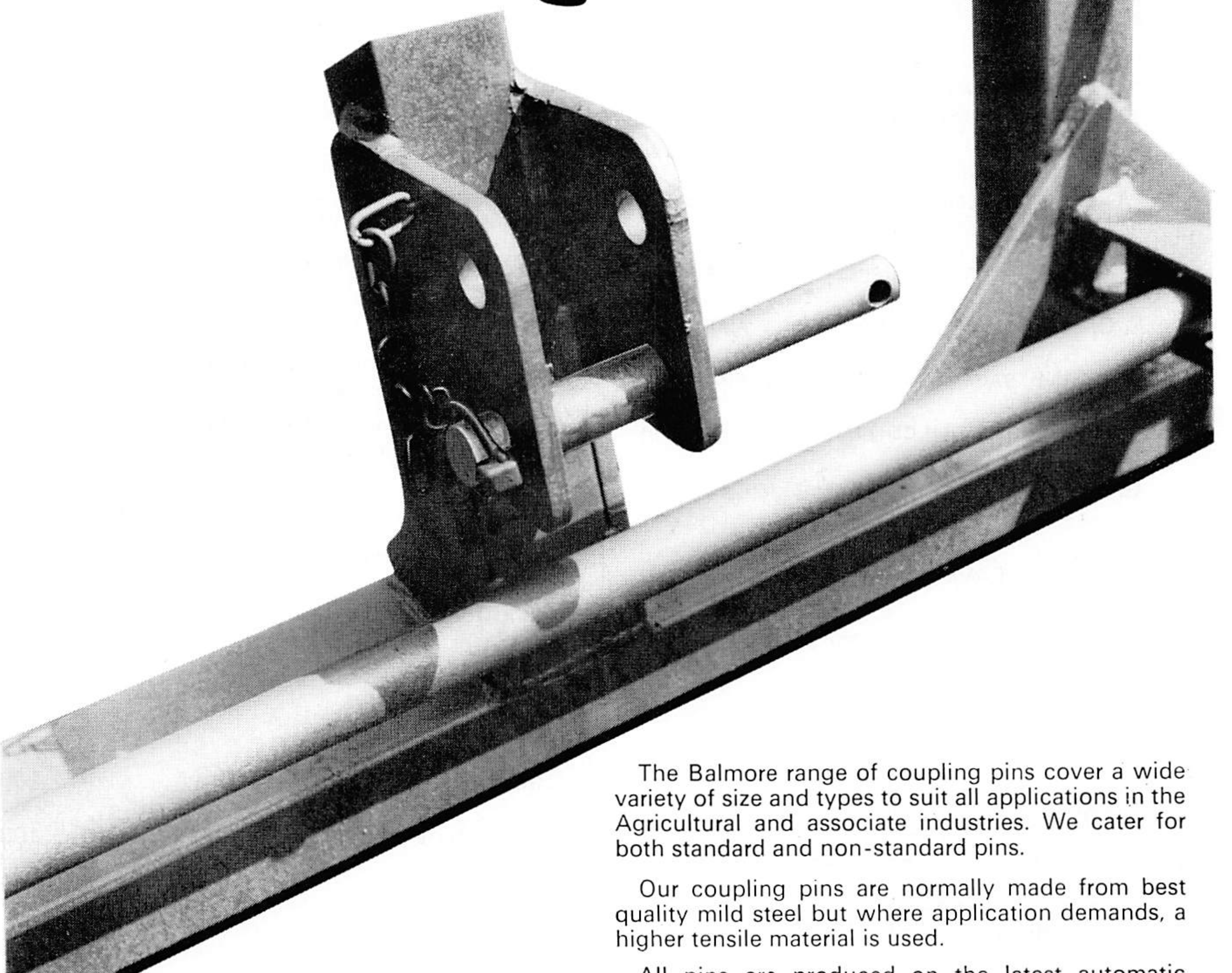
we make a nice couple...



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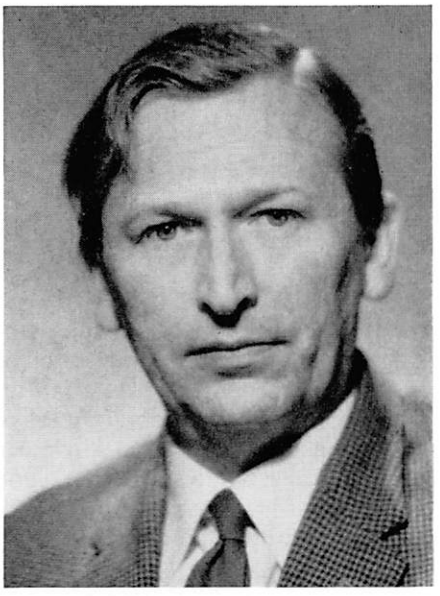

Pig Husbandry

By Brian Finney*

AGRICULTURAL engineering can seldom be detached from at least one branch of husbandry, and the pig subject is a case where particularly close ties are necessary. For this reason a non-engineering pig specialist was invited to present the opening paper, setting out the basic husbandry needs of the pig, at the annual meeting in London on 9 May. It is in fact surprising how few engineers are working on the engineering aspects of pig production and how much of the subject is covered by animal husbandry and veterinary specialists. It might be stated that the object of the exercise in this case was to assist engineers by filling in the husbandry background and not to suggest to them what areas of work might be taken over from other disciplines!

Important aspects of the subject were intentionally omitted from the conference. These included manure handling and disposal, much of which is not a problem peculiar to the pig industry, and which will be the subject of a future conference. Farm milling which again is not peculiar to pigs and which has been the subject of earlier meetings, was also avoided.

The paper on mechanical feeding seemed appropriate in view of the pending publication of a major survey of pipeline feeding systems by *ADAS* (Farm Mechanisation Study No. 22), the appearance of papers which cast some doubt on the advantages of pipeline feeding, and the official statistics' indication that an increasing number of pig herds were reaching an economic size for mechanical feeding installations.

The control of environment is important in the pig industry and one of the few engineers engaged in research on the subject agreed to present a paper. This appears as the only paper with little or no husbandry content and with a full measure of engineering. It contrasted with the paper on equipment for early weaning which described the hardware required and the husbandry needed to match. It was clear that the equipment was satisfactory, but under commercial conditions it was seldom possible to maintain the level of husbandry (and hygiene in particular) necessary to make the system work.

The discussion on the papers centred largely on non-engineering problems such as conversion ratios and stock comfort. A number of queries on the function of agricultural engineers and the content of such conferences come to mind: Should research work on feeding equipment or environment control equipment, for example, be carried out by engineers with appropriate husbandry advice, or should an animal production expert take charge and call in engineering advice when necessary? The equivalent situation is an agronomist seeking occasional advice from a professional statistician —an everyday procedure.

Does research on such a subject call for a team approach, with several workers accepting a similar share and with one leader/co-ordinator? This is where the agricultural engineer, with some knowledge of a range of disciplines, would be in a strong position to act as co-ordinator.

Does the agricultural engineer proceed largely on his own account, relying very much on his own background information and experience of animal husbandry? This situation suggests a jack-of-all-trades type of worker and may lead to lowered scientific standards.

My choice is the team approach, even if the papers reporting the work separate into disciplines so that they can appear in appropriate journals. I leave it to others to arrange for the various workers to be placed geographically close enough to each other to co-operate. The universities are probably best suited to such arrangements.

How general should our approach be to a conference on a naturally multi-discipline topic? There is no doubt that this conference could have been solely devoted to the engineering aspects of pumping air through ducts or slurry through pipes. But that would have omitted a large amount of recently available information which would be especially important to those in commerce, farming and advisory work. As long as we have "Agricultural" in our title we will need to concentrate on the application of engineering principles to the industry and will need general information on each section of the industry in turn. We hope that the opening paper on the *Pig's Requirements* may illustrate the range of information which might be required and indentify the disciplines—architecture, engineering, bacteriology, veterinary science, and others that need to be considered in this work and that might eventually be involved in such a conference.

ADAS, Cambridge.

The Pig's Requirements*

by C. G. Pointer†

ANY consideration of environment in pig production will bring into account many factors including—

air temperature,
relative humidities,
air velocity
presence of noxious gases, spores, dust,
ventilation system,
floor space and floor type,
feeding and watering systems,
group size,
penning and bedding system,
sound,
light,
hygiene,

together with other factors which are not yet clearly indentified. Some of these factors will, in turn, bring into account other considerations such as the degree of insulation of sleeping accomodation and the cubic capacity of air space per pig, which may need to be taken into account in the development of management and housing systems.

Whilst the agricultural engineer will not primarily be involved in the planning of all facets of pig production, it is appropriate that he should have an interest in and broad knowledge of the pig's needs. This summary is produced with this in mind and is not a full review of environment and pig production.

In some ways we are fortunate that pigs are, to a degree, tolerant and adaptable but, in consequence, it is unlikely to be possible to define their optimum requirements with precision. Neither have all the necessary experiments been completed that would allow the parameters to be established.

In many cases it is not possible to consider in isolation the pig's responses to some of the factors listed. For instance, the effect of an air temperature of 10°C on growing pigs of, say, 45 kg (100 lb) live weight will depend on the air movement rate, the relative humidity, the penning and the bedding system, the group size and on the amount of feed consumed daily by each pig and its energy value.

Air Temperature

Within a fairly wide range of temperatures animals maintain a balance between their heat loss and the heat they produce as a product of food metabolism. The thermo-regulatory mechanism is, however, poorly developed in the very young animal.

a Farrowing Accommodation

Experiments show that body temperatures of baby pigs fall in the first half-hour after birth and, under cold farrowing conditions, this fall may be up to 6°C (Newland 1952). Under normal farrowing room temperatures piglets will attain normal body temperatures by 2 days of age but, under cold conditions, this will take perhaps 10 days and piglet mortality is likely to be higher. Recommended temperatures are—

farrowing rooms 15 to 20°C,
piglet creep 22 to 27°C.

b Rearing and Finishing

It has frequently been shown that feed conversion figures worsen at low environmental temperatures. The following figures, derived from Moustgaard *et al* (1959), are illustrative:—

The influence of air temperatures on feed conversion ratios

Air temperature °C	Feed conversion ratio
23	3·4
15	3·4
8	3·8
3	4·3

(Based on group fed Landrace, up to eight pigs per pen, without bedding and on moderately restricted feed from 40-90 kg [88-198 lb] lw.)

The same workers also showed that groups kept at 3°C with a deep straw bed had similar feed conversion efficiencies to groups without bedding at 8°C, putting an equivalent value of about 5°C on a good straw bed under those adverse conditions.

In another of their experiments where temperatures were allowed to vary regularly between 4°C at night and 14°C by day—a range sometimes found in commercial piggeries in winter—they found that the well bedded group converted 0·3 better (3·5 to 3·8) than the one without straw but, when both groups were kept under constant day and night temperature of 14°C, there was virtually no difference in performance between those with straw and those without it.

Several workers, including Moustgaard *et al* (1959) and Close *et al* (1971), have shown some nutritional/environmental interactions and, in the latter paper, it was postulated that for each 1°C drop in temperature (in their experiments) below 12°C the same energy retention (for growth) can be maintained by giving an additional 1·3 g feed/kg (0·0013 lb feed/lb) body weight per day.

Pig behaviour is affected by air temperature. When cold they huddle closely, when warm they lie

**Presented at the Annual Conference of the Institution of Agricultural Engineers at the Institution of Civil Engineers, George Street, London SW1, on 9 May 1972.*
†ADAS, London.

apart. When temperatures get above about 21°C in densely stocked finishing pens with low air movement rates the pigs tend to dung and urinate all over the floor in an attempt to create wallows and so enjoy an evaporative cooling effect. This can be a problem in floor fed houses. Also pigs will tend to lie in the warmest part of a pen in cold weather and dung in the coldest part, and care must be taken with the inlet air design otherwise there many be dunging in the sleeping area. A practical temperature recommendation for the sleeping area of finishing piggeries would be from 12°C to 21°C according to weight of pigs, level of feeding and system of keeping.

Dry Sows and Boars

There is little experimental evidence on the effect of low air temperature on dry sows, but there is considerable evidence from farms that, where sows are kept in cold surroundings—and perhaps especially when in cold sowstalls or tiestalls and so unable to huddle—more food is required to keep them in satisfactory body condition. When cold sows are not given this extra food they become thin and the "thin sow syndrome" is often associated with cold, wet sow housing. The temperature in stall houses should preferably not fall below 15°C.

A high proportion of boars are culled before the end of their useful working lives because of rheumatic or arthritic conditions which, in some cases, are associated with cold, damp housing.

There is evidence from abroad that when newly served sows are exposed to air temperatures of around 32°C they return to service more frequently and tend to have smaller litters. There is also evidence that boars are more fertile when housed at around 15°C than around 32°C.

With all types of pigs widely fluctuating temperatures are to be avoided, and they may be a contributory factor in pneumonia and vice.

Relative Humidity

The pig is a non-sweating animal and, in consequence, is not greatly affected by the range of humidities found in piggeries. Humidity seems to have little effect on pigs except at high or low temperatures, ie under stressful conditions. In conjunction with high temperatures, high humidity will restrict evaporative cooling and help to depress appetite (particularly for dry feed) and weight gain. At low temperatures high humidity will increase the chilling effect of the atmosphere and keep floors damp. Irish evidence suggests that pneumonia may be less of a problem in housing that provides a high level of humidity and is maintained at a high temperature. A satisfactory range of humidity is 60 to 80 per cent RH.

Air Velocity

Under relatively still air conditions a layer of warm air is trapped in and around the hair coat of an animal and this helps to insulate it from its environment. As the air speed increases the insulation value of this falls and thus the effect of air temperature cannot be considered in isolation from air velocity and humidity. Bond, Kelly and Heitman (1965) presented information from laboratory and field trials. We are, however, more concerned generally with the deleterious effect of draughts, whilst Californian workers tend to be more interested in the beneficial effects of a higher air movement in their warmer conditions. In general, at temperatures above about 18°C, heavy pigs—particularly on *ad lib* feed—benefit from a relatively high air movement rate.

Mount and Ingram (1965) measured the effects of air speed on heat loss. They found that raising the air movement rate over the baby pig from 0·1 0·3 m/s (20 to 60 ft/min) was approximately equivalent to a fall in air temperature of 5°C. Piglets tried to limit the impact of this by changing posture and huddling.

In some finishing piggeries high air movement rates in the sleeping area have been a contributory factor to dirty pens.

Guideline air movement rates might be—

Piglet creep—preferably below 0·1 m/s (20 ft/min)

finishing pens—0·1 m to 0·2 m/s (20 to 40 ft/min), depending on environmental conditions and stocking density.

The writer has observed air movement rate of over 0·5 m/s (100 ft/min) in piglet creeps, especially when there have been windy conditions outside. Under those conditions piglets may desert the lamp or creep and huddle elsewhere, possibly being overlain by the sow.

Noxious Gases

Whilst the potential danger of these, especially at times of electrical failure, are obvious, there is really little evidence that the levels found in normal finishing piggeries are reducing feed conversion efficiency.

Guideline figures for concentrations at pig position in the pig sleeping area of othodox finishing piggeries might be—

CO_2—0·12 to 0·20 per cent

NH_3—5 to 15 parts/million

H_2S—trace—often unregistered at 1 part/million.

Often in poorly ventilated pens the CO_2 concentration rises to 0·25 to 0·30 per cent. Comparative figures for solid and slatted floored houses are given by Madsen (1970). When slurry is agitated or removed, ventilation should be increased, also care taken at all times that air is not drawn in through the slurry channels by the fans.

Van Putten (1967) demonstrated that tail biting appeared to increase as the carbon dioxide and ammonia concentrations in the piggery atmosphere increased, at least up to air temperatures of about 23°C. It may have been only the increasing concentration of the smells generally in the piggery that increased the irritability of the pigs.

It has frequently been observed by the writer that stressful conditions, including high stocking density and poor ventilation at the pig's level, often lead to tail biting and that the CO_2 concentration, under conditions of fairly standard stocking density gives some indication of the ventilation rate at pig level. On the other hand, the writer has recorded CO_2 concentrations of up to 1·2 per cent in sweathouses at 29°C in winter when ventilation was restricted to give then 27°C lift in temperature observed and yet, under these conditions (which include high stocking density), tail biting and ear nibbling are not normally seen.

Ventilation

In many piggeries air inlet and outlet design is unsatisfactory and so unable to promote good air circulation, without draughts, round the pigs or to keep out the winter winds. Pen divisions are sometimes too solid or too high to allow adequate air circulation.

For piggeries with reasonable levels of insulation (walls about 0·2 u, ceilings about 0·12 u) maximum ventilation requirements can be summarised thus—

farrowing house—per sow and litter—0·12-0·15 m^3/s (250 to 300 ft^3/min)

finishing pig—0·0003-0·0005 m^3/s kg (0·3 to 0·5 f^3/min lb lw)

dry sow—in sowstall or tiestall—0·05-0·08 m^3/s (100 to 170 f^3/min) depending on size of house and presence of glass windows.

It is important to be able to reduce these ventilation levels by stages to 10 per cent or 15 per cent of maximum in winter.

Written ventilation control instructions should be insisted upon from piggery manufacturers or suppliers of ventilation equipment. It has frequently been found (Pointer 1970) that neither the farmer nor the pigman fully understand how to manage the system until they have had the piggery for a couple of years.

Floor Space

This will depend on the system of husbandry. Knap (1965) recommends the following sleeping areas for intensive finishing houses, based on his experiments:—

Pig weight		*Sleeping area*	
kg	*lb*	*m^2*	*ft^2*
20	44	0·16	1·75
40	88	0·25	2·75
60	132	0·35	3·75
100	220	0·51	5·50

These might be regarded as minimal.

The dunging areas will depend on the house design, group size and whether slatted or solid. A normal range is 0·14 to 0.28 m^2 (1·5 to 3 ft^2) per finishing pig for intensive houses.

Floor Type

Where pigs have to sleep on unbedded or sparsely bedded floors, it is important that floors be well insulated and kept as dry as possible.

The baby pig will lose a lot of heat to a concrete floor irrespective of the level of insulation. Unless such floors used for baby pigs have underfloor heating, they should be well covered with dry bedding to reduce heat loss.

Floor finish is important—neither too smooth (particularly for older pigs) nor too rough. Roughly finished slats with sharp edges have been a serious problem in many new pig units. Slat and gap width must be considered carefully for the purpose intended.

Feeding System

a Finishing Pigs

The feeding system is very much part of the total house design and, in some cases, cannot be considered in isolation from it.

Braude (1972) reviewed the literature on the effect of feeding systems on pig performance. Experimental results were summarised and expressed in terms of numbers "for" and "against".

Pellets v meal—effect of pellets

	Growth rate	*Feed/gain ratio*	*Carcase quality*
Improvement	39	48	
Deterioration	2	1	
None	16	7	
No information	–	1	
	(57)	(57)	

Ad lib v restricted—effect of ad lib feeding

	Growth rate	*Feed/gain ratio*	*Carcase quality*
Improvement	88	13	1
Deterioration	–	60	72
None	1	12	10
No information	–	4	6
	(89)	(89)	(89)

Wet v dry feeding—effect of wet feeding

	Growth rate	*Feed/gain ratio*	*Carcase quality*
Improvement	29	25	6
Deterioration	3	4	1
None	12	15	16
No information	–	–	21
	(44)	(44)	(44)

These results confirm that pellets are preferable to meal for dry feeding and wet feeding of meal is preferable to dry feeding. *Ad lib* feeding of pigs over 32 to 36 kg (70 to 80 lb) liveweight can only be justified by special circumstances as it leads to poorer efficiency and over-fat carcases.

The scale of feeding should be adjusted to the genetic potential of the pigs. The experimental results summarised above cannot alone form the basis of the decision as to feeding systems. The circumstances of the farm, the preference of the farmer and an estimate of the relative returns on capital must be considered. Maclean, A. (1972) suggests that the break even point between floor fed pellets and trough (pipeline) wet feeding occurs at about 16 per cent extra pigs in the piggery permitted as a result of the absence of troughs and assuming ventilation is adequate for the more dense stocking. When floor feeding consistently permits more than an extra 16 per cent of pigs then it can give a better return on capital, although it may well demand a higher standard of management.

As guideline figures, wet meal feeding gives an average feed conversion ratio of about 0·2 better than dry meal feeding in the trough. Pellets fed in the trough are about 0·1 better than dry meal fed in the trough. Floor fed meal gives perhaps 0·2 worse conversion ratio than trough fed meal but is highly dependent on management, pen design and feeding scale.

Pigs prefer wet feed and eat it quicker.

b Frequency of Feeding

The effect of feeding at 3, 6 or 12 hourly intervals has been compared by Walker (1970) who also briefly reviews experiments. In his experiments he found no effect of frequency of feeding on daily gain, feed efficiency or killing out percentage. Backfat thickness at C and K was increased by four times a day feeding compared with feeding twice or eight times a day, but this increase in fatness was not confined by sample joint dissection. Experiments generally have found no benefit in feeding more than twice daily, and some none from feeding more than once.

c Time and Regularity of Feeding

Braude (1972) has reported an *NIRD* trial where, under the conditions of his piggery, irregular feeding has not worsened pig performance.

d Delayed Protein Supplementation of Cereals

Eggart, Brinegar and Anderson (1953) and Yeo and Chamberlain (1966) show that the protein supplement can be utilised just as efficiently if fed at every other feed (ie 24 hour intervals) as when a balanced diet is given at each feed.

e Water

Considerable variation has been found in individual feeding trials of the voluntary water intake of pigs, but controlled exepriments (summarised by Braude 1967) indicate very little difference in performance of pigs receiving 1·5, 2·5 or 3 kg (1·5, 2·5 or 3 lb) water/kg (lb) of feed.

Farm observations suggest that many pipeline feeders deliver the feed too wet for young pigs, so restricting their nutrient intake. Unless management and equipment are very good, it is a safe recommendation that piglets should not be dependent solely on orthodox pipeline feeding below about 32 kg (70 lb) lw.

f Trough Length

The following figures are guidelines for pigs on restricted rations:—

Weight of pig		Trough length	
kg	lb	m	in
36	80	0·20	8
54	120	0·23	9
91	200	0·28	11

g Feeding System—Sows

There appears to be little advantage in the mechanisation of feeding dry or suckling sows. Individual feeding by hand allows the quantity to be readily adjusted according to need.

Watering systems need careful design to ensure that beds do not become flooded due to the playful actions of bored sows.

Group Size

Under experimental conditions for close grouping of pigs by weight Scholtz (1966) found that groups for rationed feeding should not exceed 30 pigs and, for *ad lib* feeding not more than 90. Under practical farm conditions it is thought generally that these figures might be halved but we lack experimental evidence. Where carcase grading is of prime importance, it is probable that, under farm conditions, 15 is the maximum number of fattening pigs per group.

In the case of newly weaned and dry sows the optimum group size is quite possibly one sow.

Light

Experiments have shown that growth and feed conversion efficiency in finishing piggeries have not suffered in windowless houses that provide only a twilight for pigs except at feeding time. In some cases the darkened houses have given improved feed conversion efficiencies of up to 5 per cent. In some cases also, darkened houses appear to have given less vice.

There is Russian experimental evidence (Klotchkov 1971) that gilts exposed to an 18 hour day length exhibit stronger and longer heat periods at shorter and more regular intervals than gilts exposed to a six hour day length. They may also have slightly larger litters. He found sows to be less susceptible to day length variation. It is possible, however, that some of our housing for suckling and newly weaned sows may be too dark.

There is French work (du Mesnil du Bouisson, F. and Signoret, J. P. 1970) which suggests that boars used in artificial insemination may be more fertile with a ten hour day length than with 16 hours. The effect of high air temperatures and long daylight period appear to be cumulative in reducing boar fertility, at least by AI.

Welfare

The recommendations of the Code of Welfare for Farm Animals (Pigs) should be borne constantly in mind.

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Mechanised Pig Feeding Systems*

by J. I. Payne†

MECHANISED feeding systems for pigs may enable more pigs to be fed per man, reduce drudgery and possibly reduce stress on the pigs under some housing conditions. However, proving an economic case for the mechanised feeding of pigs is not an easy one and this must be assessed on each individual farm relating:—

- available labour;
- possible future or immediate expansion programme;
- type of housing existing or proposed;
- available capital.

The labour cost in an efficiently run finishing house represents only 6-9 per cent of the total production cost of pigs or 9-16 per cent when breeding and finishing. Feed costs amount to approximately 80 per cent, so, even a 50 per cent reduction in labour cost would only be equal to 4-8 per cent saving in feed cost. However, mechanised feeding systems may enable more pigs to be looked after by the existing labour force, the same number of pigs to be handled by a reduced labour force, or enable more time to be devoted to stockmanship. The return on good stockmanship can be very high.

Requirements of Mechanised Feeding Systems

Any mechanised feed system should be designed to:—

be reliable mechanically, electrically, in repeatability or ration and should *fail safe.*

Reliability

The mechanical reliability of feeding equipment must be of the highest order if mechanised systems are to succeed. Any delay in feeding induces stress in the pigs, and stockman, and adversely affects production.

The use of plug-in modules in electrical control gear is a move in the right direction and enables a rapid fault finding procedure to be adopted and of course spares to be carried economically.

Fail Safe

It is important that in the event of one part of the feeding system failing, then either an immediate or brief time lag lock-out occurs and the system stops preferably giving either an audible, visual, or audible and visual warning to this effect.

Repeatability of Ration

The repeatability in quantity of feed delivered is important to the extent that the pigs are not under or over-fed, although it does not seem to matter whether they get exactly the correct quantity of feed each day providing over a period of say one week they get the required quantity to maintain growth and grade.

Adjustment for Variation of Ration

In practice as pigs are reaching slaughter weight it will be necessary to extract varying numbers of pigs from the individual pens and adjustments must be made to the feed dispensers to compensate for the reduced numbers. It is important therefore, that this adjustment can be carried out easily and that the calibration is adequate to avoid over-feeding.

Avoidance of Waste

With feed representing such a high proportion of production cost it is important that any mechanised feeding system does not in any way contribute to waste either by bad design or incorrect installation.

Extension at a Reasonable Cost

The size of herds is increasing rapidly. For example the average herd size increased from 51 pigs in 1963 to 121 in 1967 and Table 1 shows that there are now 8,841 herds with over 200 pigs or 3,017 herds with over 500 pigs. There was in fact an increase of 400 herds with over 500 pigs from 1970-1971.

Feed Uniformity

The system should be designed to ensure that no separation of feed takes place between the first

** Presented at the Annual Conference of the Institution of Agricultural Engineers at the Institution of Civil Engineers, George Street, London SW1, on 9 May 1972.*

† National Specialist Livestock Mechanisation, ADAS.

concluded from page 81

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Table 1

Herd	1970 Number		1971 Number			
Size	*Herds*	*Pigs*	*Herds*	*per cent*	*Pigs*	*per cent*
1 - 49	35,830	592,064	32,613	15	543,893	8
50 - 99	9,001	637,674	8,640	57	609,793	9
100 - 199	6,854	959,398	6,838	12	959,080	14
200 - 499	5,557	1,713,080	5,824	10	1,810,782	26
500 - 999	1,883	1,283,300	2,123	4	1,442,592	21
1,000 - 4,999	714	1,152,462	879	2	1,440,245	22
5,000+	11	70,413	15		97,008	
Total	59,853	6,408,391	56,932	100	6,903,393	100

and last pen of pigs: otherwise the mineral composition of the feed could be impaired.

Ability to By-Pass Pens

There are many instances when it may be necessary to by-pass particular pens and a lock-out mechanism must be provided to enable this to be done without difficulty.

Stockmanship

The system must be designed to give the stockman more time to observe his pigs or handle more pigs without reducing the quality of stockmanship.

Feeding Systems

Feeding systems (Payne[1]) for pigs are proceeding along two lines:—
dry feeding
liquid feeding.

Within these two lines a number of alternative systems are being developed.

Dry Feeding System

Dry feeding systems have developed in two ways, trough feeding and floor feeding with either meal or pellets. Four basic systems of feed dispensing are in use:—

1. *Fixed Hoppers:* ad lib feeding, ration feeding.
2. *Mobile Hoppers:* ration feeding automatic or semi automatic control of dispensing.
3. *Fixed Hopper Dispensers:* ration feeding manually-adjusted volume calibration and auto dispensing.
4. *Conveyor Trickle Feeders:* ration feeding manually-adjusted slide opening and auto dispensing.

Fixed Hoppers

These are available as ad lib or ration feeders. The majority of these hoppers are, of course, commercially produced. Points of importance in the construction of the hoppers are:—

a. Hopper should be designed to give minimum obstruction to the flow of meal or pellets.
b. It should be of robust construction.
c. The amount of wasted meal should be reduced to lowest possible level, and design of feed trough is an important factor, particularly when ad lib hoppers are bing used. Steel bars across the feed trough help in this respect as do feeding place flaps.
d. A method of agitation should be incorporated to prevent meal bridging. The agitator should preferably be activated by the pigs during feeding.
e. Hopper capacity should be considered relative to required interval between re-charging, four to seven days being usual.

Fixed hoppers with ration control are usually designed with a volume measuring device under the main hopper. Operation of a lever allows the meal to fall from the main hopper into a measuring box, the size of which can be adjusted to give a range of approximately 0·75 to 5·25 kg of meal per metre ($\frac{1}{2}$ to $3\frac{1}{2}$ lb/ft) length of the feed trough. On the return of the lever the box is sealed off from the hopper and food falls down into the feeding trough.

Some farmers prefer to make their own hopper using such materials as 12·7 mm ($\frac{1}{2}$ in) weather proofed plywood; when this is done a simple agitation system may be adopted such as a spring loaded hinged flap at the bottom of the hopper; the pigs pressing against the flap create sufficient agitation to cause meal to flow, but it must be remembered that if the design of the hopper is bad then meal will require very violent agitation to cause it to flow. One vertical side and one 65 to 70° side to the hopper will give good flow results with meal, providing surfaces are smooth. Another simple agitation system consists of a chain suspended from a point high up inside the feed hopper and hung down into the feed trough. The pigs move the chain sufficiently during feeding to cause the meal to fall into the feeding trough.

The feed trough space allowed per pig will depend upon whether ad lib or ration feeding is practised; general recommendations are 200 mm/45 kg (8 in/100 lb) pig up to 300 mm/ 90 kg (12 in/200 lb) pig when ration feeding and 50 to 100 mm (2 in to 4 in) per pig when ad lib feeding.

Mobile Hoppers

Mobile feed hoppers range from the very simple to the quite sophisticated. They may be manually or mechanically operated and deal with meal or pellets although, if floor feeding, pellets are best.

Manually Operated, Mechanically Assisted

Many farmers are getting very good labour utilisation results, with pig observation opportunity, using simple two or three wheeled feed barrows with dial type weighers and feed buckets. This system can be very effective when operated from a central feeding passage or catwalk above the pens when floor feeding pellets. A variation of the bucket and weigher system is to use a hand-operated proportioning device such as an auger or other volume measurer to deliver the meal or pellets either direct on to the floor, into a feed trough or into a bucket. The system may be partly motorised in which case the hopper may be suspended from a monorail and an electric motor arranged to drive the auger measurer dispenser; the unit is hand pushed along the line of pens.

Mechanically Operated Hoppers

Mobile hoppers with a mechanical dispensing system for meal or pellets are usually mounted on, or suspended from, tracks above the pens. When frequent feeding on the little and often basis is to be adopted, in which case four to six feeds/day may be given, this makes stockman participation at every feed very difficult and it would be extremely wasteful, even if possible, in terms of labour content: therefore automatic systems on time control are necessary. Within this range of hoppers are:—

a. Electric motor driven units which have driving systems for propelling the hopper along the track, and also for driving a volume proportioning auger.

These units will handle meal or pellets or cubes of up to 12·7 mm ($\frac{1}{2}$ in) dia and 19 mm ($\frac{3}{4}$ in) long at a rate of approximately 0·9 kg (2 lb)/second. The food may be delivered in a continuous flow over a pre-set distance governed by start and stop switches fitted to the hopper support track. The actual distance between stop and start switches may be adjusted by the stockman to govern the amount of food delivered into each pen. Alternatively arrangements may be made to stop the hopper at one point over each pen, and to deliver the required amount of feed on a time basis from single or double outlets. The appropriate amount to be delivered to each pen can be pre-set by dial-type control units on a console conveniently placed; and the number of feeding sequences each day may be set by the time control.

b. The other types are those mechanically propelled hoppers which dispense the food by means of:—

1. Force feed units: these take the form of drums with flights attached. The drums are driven by external sprockets,
2. Adjustable volume sliding boxes which have no fixed base. The box compartment is moved in one direction across a base plate underneath the feed hopper outlet for recharging and in the opposite direction over an area with no base plate to dispense feed.

These units are propelled along the pens by a wire rope and winch system at between 0·15 to 0·20 m/s (30 and 40 ft/min). The dispenser units are activated by removable trigger trip pins. The number of trip pins inserted at each pen governs the amount of food delivered. One commercial unit is designed with a pin rail, having two rows of holes, capable of holding seven pins /91 cm (yard) along each row of holes. The force feed dispensers on this unit are drums with four flights or blades fitted to it. The drums are rotated one quarter of a turn for each peg passed and they deliver approximately 0·68 kg ($1\frac{1}{2}$ lb) of feed per drum. The exact weight delivered will vary with type of food, and spot checks should be made. The hopper may be divided into two sections and carry two types of feed at the same time. The double row of pegs enables a choice to be made on which feed is to be delivered to individual pens. The hoppers can have triggering devices fitted to activate automatic supply of a pre-set quantity of water to be added to each feed trough. Spouts are arranged along the length of the trough for even distribution of water, and the pigs mix the meal and water together during feeding.

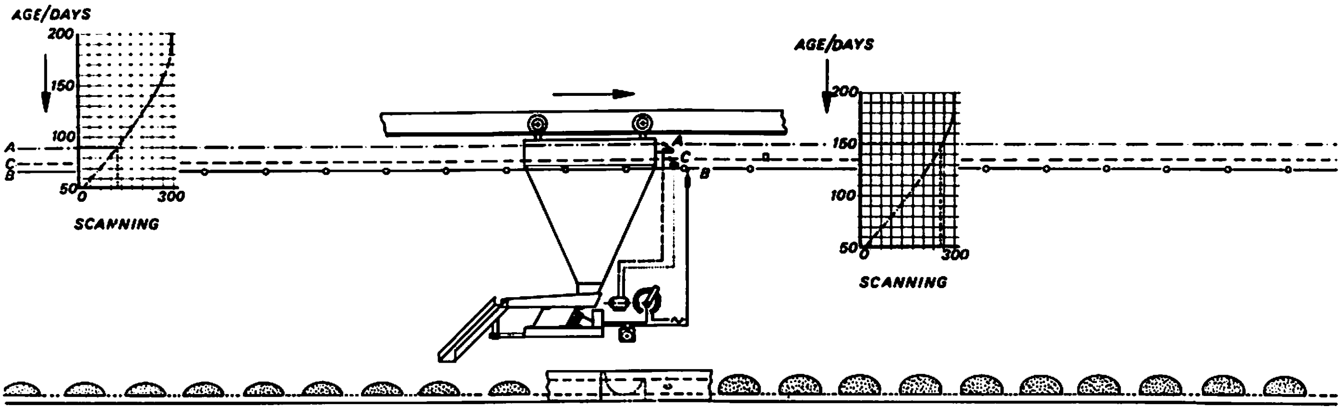
Dr Weidinger[2] has reported the development of a battery operated self-propelled unit that may service a number of houses, and which is designed to run along guide rails within the piggery but may be steered quite freely outside the houses.

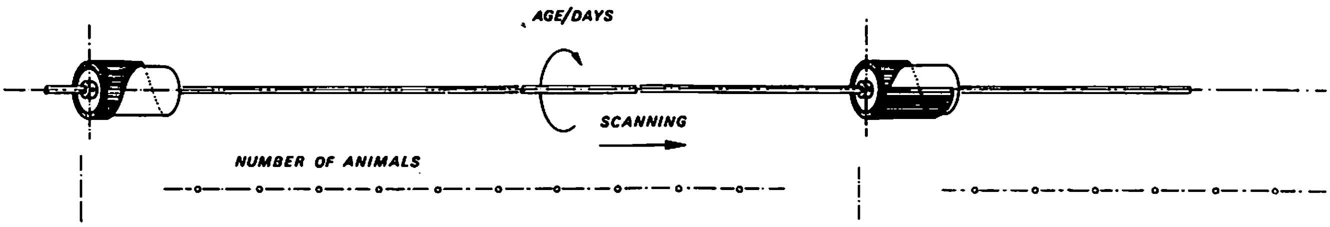
The unit is designed to enable feed mixtures to be dispensed by volume automatically. Two types of feed may be carried and fed into the feed troughs on each side of a feed passage by means of a conveyor belt. A projection (boss) with adjustment for ten or more different positions is fitted to each trough and according to its position then the boss corresponds to a specific ration to be dispensed. As the vehicle moves along the feed passage the boss touches the switch fitted at the same height as the boss and the appropriate ration of feed is delivered. Liquid and wet mash feeds may be rationed on the same principle providing the unit is fitted with the necessary tanks and minor modifications made to the control gear.

Forecasting

Breeders and nutritional chemists are approaching the stage when fairly accurate forecasts can be made of potential liveweight gain provided the pigs are correctly housed and fed. This information enables graphs to be plotted relating time with weight and the amount of feed required so that increase in feed requirement with growth can readily be seen. Existing mechanical feeding systems do not at present fully utilise all of the information available.

Research workers at Waginingen (Huizing[3]) are aiming to convert this information into an electromechanical readable form. The unit being developed comprises:—





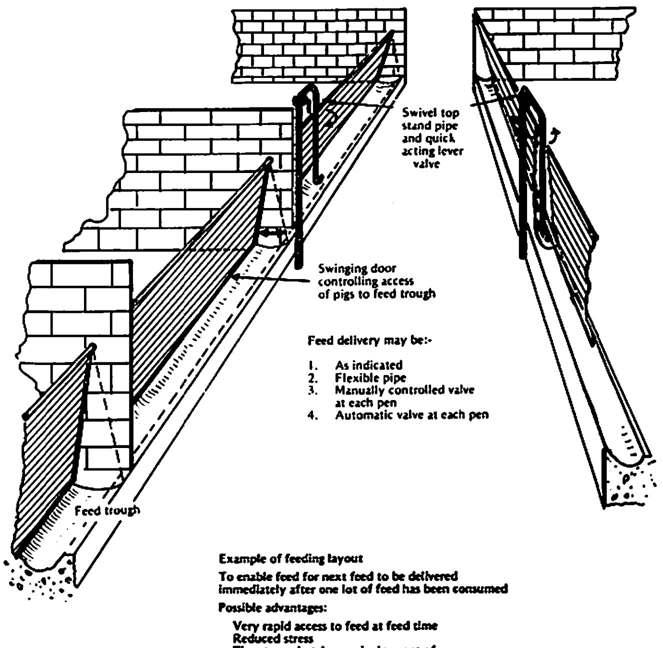
1. A mobile hopper suspended beneath an overhead track and automatically pulled along by means of a winch and wire rope.
2. A vibratory feeder to carry feed from the hopper to the inclined chute which delivers it into the feed trough.
3. A high level shaft along each line of pens parallel with the overhead track. The shaft(s) has large diameter rolls secured to it one at each pen and each roll has a relief form graph attached to it. This is mechanically rotated on a growth/time/rate basis.
4. Switching mechanisms are:—
   a. the relief graph which signals the age of the pigs in the particular pen by activating a scanning system to virtually measure the width of the graph being traversed. This in effect sets the time the vibratory feeder works for each pig in the pen.
   b. a peg arrangement which activates the vibratory feeder to the appropriate number of pigs in the pen.
5. A water dispensing unit may also be fitted to deliver pulses of water at the same time as the dry feed is dispensed.
6. The pens are fitted with swinging front panels to control access of the pigs to the feed trough and the feed is dispensed immediately after the pigs have finished their previous feed, thus reducing possible stress to a minimum level.

This system certainly seems to offer some interesting possibilities.

Fixed Hopper Dispensers

The fixed hopper dispenser systems are well suited to floor feeding. They have developed along two main lines:—viz volume dispensing; weight dispensing.

The dispensers are usually installed above the pens and drop the feed (preferably pellets) on to the pen floor. They may have deflection devices to scatter the pellets over a wide area. However, if part of the pen has a slatted dunging area then care is needed with the design of the pen and positioning of the dispenser to ensure that no pellets bounce on to the slatted area and then into the dung



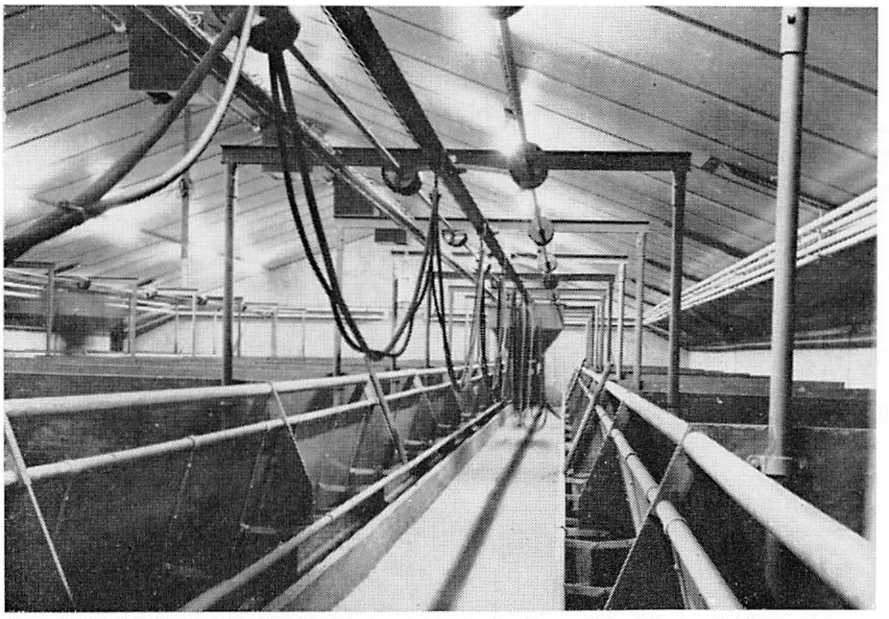
Example of feeding layout

To enable feed for next feed to be delivered immediately after one lot of feed has been consumed

Possible advantages:

Very rapid access to feed at feed time
Reduced stress
Time to undertake repairs in event of breakdown extended
Should a continuous mixer be preferred but soaking of meal also be a requirement then this feed arrangement enables both requirements to be met

"NOT TO SCALE"



General view of a forecast feeder showing feed passage and swinging front panels over feed troughs; twin overhead shafts with relief form graphs; twin lines for trigger pins, power and liquid lines.

channel. Some volume dispensers are designed for attachment to the front of the pen and drop feed into the feed trough.

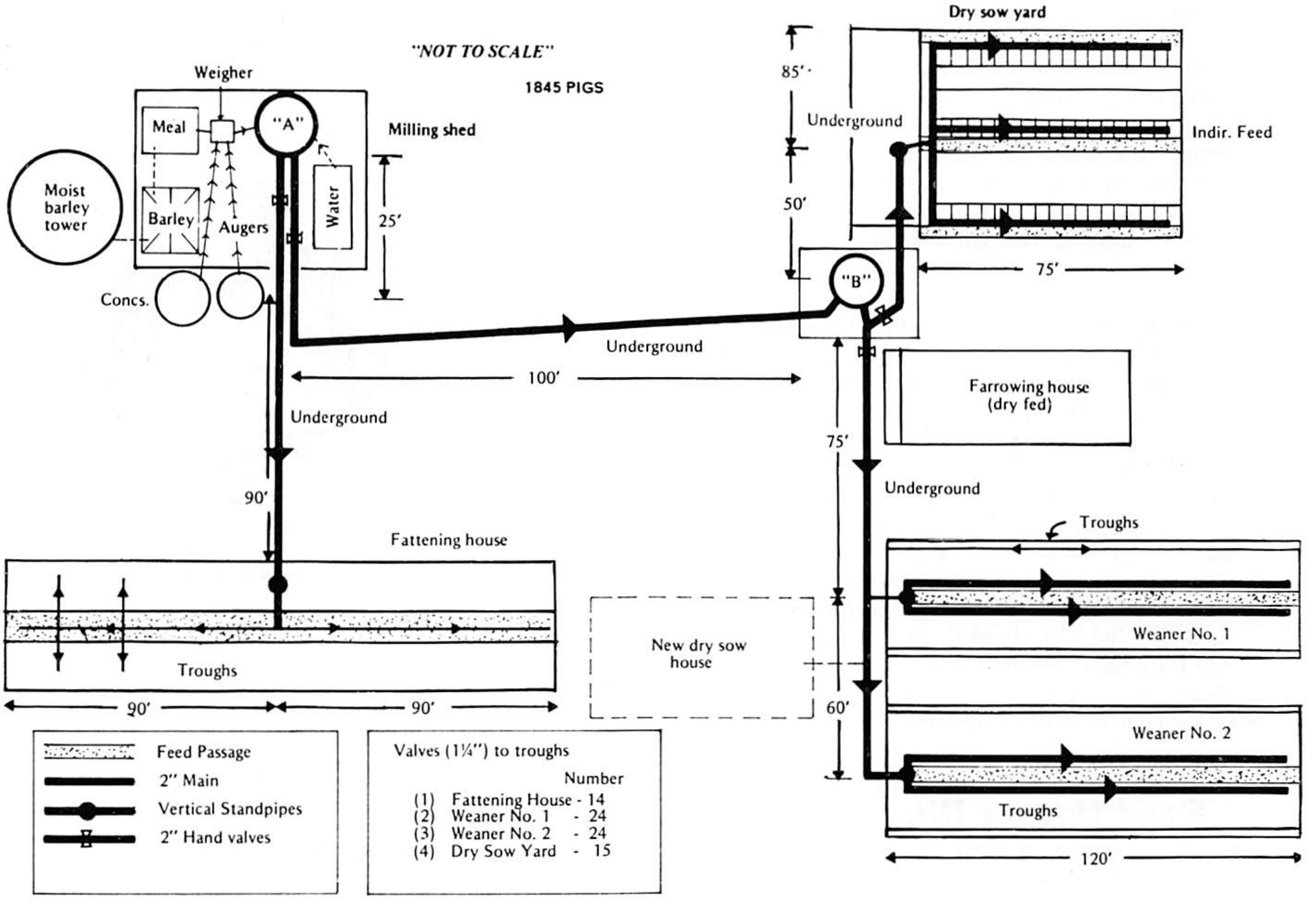
The feed capacity of volume dispensers depends upon the particular manufacturer's equipment and the type of feed to be handled. Meal generally varies between 416-560 kg/m^3 (26-35 lb/ft^3), and cubes or pellets between 640-720 kg/m^3 (40-50 lb/ft^3).

Capacity of dispensers normally ranges up to approximately 0·30 m^3 (1 ft^3) maximum. Volume adjustment of the dispensers is made by raising or lowering the side wall of the dispenser or feed delivery sleeve or in some cases by adjustment of a horizontal slide.

These dispensers dispense feed instantaneously and are usually activated by means of a time switch, examples of feed dispensing mechanisms are:—

A hinged flap door with counter balance weight and spring operated latch. When feed is to be dispensed the latch is forced open by an electrically operated solenoid thus allowing the weight of meal to open the flap door.

A hinged flap door with heavy duty retaining spring holding the door closed. The feed is



dispensed when the door is forced open by a compressed air operated ram.

A cylindrical sleeve which is raised off a base cone by means of cables. The sleeve forms the side wall of the dispenser and the cone acts as the base of the dispenser and also as a spreader for the feed when it is released.

An auger driven by means of a common shaft that runs through each dispenser along the continuous run of pens. When feed time arrives the auger shaft is rotated dispensing the feed from all dispensers in a matter of some 10-15 seconds.

The weight type dispenser may be installed above the pen or feed trough depending upon requirements. Equipment of this type recently introduced into the *UK* has been designed to reduce the distance the food drops from the dispenser outlet to the floor. This has been done by providing a long tube-like weighing dispenser with its outlet arranged about 91 cm (3 ft) above the ground level. The dispenser is protected from the buffeting of the pigs by an outer-sleeve which is securely anchored to vertical supports which are in themselves secured into the floor and forms part of a spreading cone. At least one such unit installed in the *UK* is dispensing meal processed on the farm and the meal is automatically distributed from the processing plant to the pig houses.

Variations in weight of feed to be dispensed is catered for by means of the movement of a weight along a beam arm. The arm has calibration markings along it to facilitate settings.

The volume and weight dispensers are designed for automatic control and usually work under the control of a time switch. The sequence of operations being:—

1. The time switch starts sequence by switching on full lighting in the piggery to awaken the pigs and warn them that it is feed time.
2. A few seconds (5-15) later the dispensers are activated; they drop the feed instantaneously into all pens. The dispenser doors or sleeves, etc, are then closed by their individual means.
3. The feed conveyor serving the dispensers is then automatically started up to re-charge the dispensers ready for the next feeding sequence. The dispensers themselves are topped up in sequence.
4. When the final dispenser has been filled then a micro switch stops the conveyor. An overflow hopper and flap switch is also fitted to act as a back-up switch in the event of the dispenser switch failing.
5. After a pre-determined time lag the main lights in the piggery are switched off again allowing the pigs to relax.

The time switch controlling the dispensers may be set to dispense feed a number of times per day.

Research work at the *NIAE*[4] has led to the development of prototype weighing dispensers which are served by a pneumatic feed conveyor. 13 mm (½ in) pellets have been conveyed at rates in excess of 1 t/h through a pipe line rig of 5 cm (2in) diameter pvc piping approximately 170 m (560 ft) long. An automatically operated diversion flap has been designed to fit into the pipeline and divert pellets out of the air stream into the appropriate dispenser and when the pre-set weight of feed has been delivered the diversion flap is straightened up allowing the feed to proceed along the pipe-line to the next diversion point. Accuracies of better than $\pm$ 5 per cent of the preset level of feed have been achieved. Fully automatic sequence control of dispenser filling is catered for and of course the system may be time switch controlled.

Trickle Feeders

Trickle feeders are designed as combination conveyor feeders of the metal trough chain and flight type. The conveyor passes over the pig pens and the trough has perforated base sections over the pens through which the feed falls to the pigs. The perforations are, in fact, 13 mm (½ in) diameter holes at 20 cm (8 in) spacings; metal slide valves, operated by one handle control and quadrant indicator, control the flow of feed for up to 12 holes for each valve. These feeders will handle meal or small pellets up to a maximum size of 1 cm (⅜ in) although they operate best at low feed rates when handling meal. Range of delivery may be adjusted between 0·266 and 4·53 kg/min (½ lb and 10 lb/min/ft) per 30 cm length of feed section.

The feeder will service up to 183 m (600 ft) total length and maximum conveyor capacity is approximately 2 t/h (40 cwt/h). Control of quantity to individual pens is by slide valve and time control which is adjustable within the range five to 35 minutes/feeding cycle, and up to eight feeds/day may be delivered, but four to six is the usual range.

Feed Hopper Radius Delivery Auger

The introduction of the American designed "Bacon Bin" into this country brought with it a system of feeding consisting of a 2 t capacity pellet hopper mounted on a vertical support in the centre of a 14·63 m (48 ft) diameter building; a 10 cm (4 in) dia auger with one end held in a rotating collar at the hopper and the other end carried on a trackway around the perimeter of pig pens delivers the feed to the pigs.

The housing system is a two deck arrangement with 23 pens on each deck, housing a total of approximately 440 pigs. The auger which is driven by an electric motor sweeps in a radius delivering pellets to the top deck of pens. This takes 3½ min, then the auger is put into reverse, the top deck outlet closed, and pellets pass to outlet feeding bottom deck. The auger delivers up to 90 kg/min (200 lb/min).

Filling Hoppers

The re-charging system for hoppers must be considered very early on in the planning stage to ensure physical effort and labour content are kept to a minimum. Ad lib hoppers may be filled manually, and to reduce physical effort the tops of hoppers should be matched to trailer height, or a catwalk at hopper height could be installed to enable sacks of feed to be taken to hoppers on a sack truck. Alternatively a self unloading trailer may be used in which case it may be an advantage to have a flexible hose attached to the outlet spout from the trailer auger. This enables the operator to distribute the meal along the length of the feed hopper.

The re-charging process may be automated by means of a conveyor system which may be:— chain and flight conveyor; auger conveyor; pneumatic conveyor.

Mechanical conveyors for re-charging dispenser type feed units may be arranged as a ring circuit in which case the conveyor takes meal or pellets from a hopper, fills up the dispenser units and continues around the circuit to the main hopper again. Within this range are:—

a. Chain and flight conveyors which carry the feed inside 38 mm (1½ in) od tube, and can service up to 244 m (800 ft) delivering approximately 453 kg/h (1,000 lb/h) of meal or pellets for each circuit.
b. Chain conveyors which carry the feed in open topped troughs which can service up to 183 m (600 ft) for each circuit and deliver approximately 725 to 816 kg/h (1,600 lb to 1,800 lb/h) of meal or pellets for each circuit. Up to four circuits may be arranged for each hopper and up to 550 m (1,800 ft) of troughing may be driven from each drive unit.

The alternative to a ring circuit is a straight length conveyor with pressure switch control. These conveyors may be either:—flighted augers; spiral spring augers.

They are arranged to fill the dispensers progressively and when the last has been filled, a pressure switch is activated to stop the conveyor. The straight line conveyor hoppers are recharged by a cross conveyor which is also controlled by a pressure switch. The maximum length of straight line conveyors is usually restricted to about 107 m (350 ft).

Careful planning is essential if high capital outlay is to be avoided particularly with mechanical conveyors. Low volume medium pressure pneumatic small bore conveying systems may give greater flexibility.

This system is designed to overcome the inherent problems of low pressure pneumatic conveyors viz dust, and also overcome particle separation. The unit consists of a compressor hopper, feed injector, quick release connection point for conveyor tubes, and one tube to each feed hopper. The appropriate tube is quickly attached to the blower unit as required. A conveying distance of up to 137 m (450 ft) is claimed and a throughput of approximately 1 t/h of meal.

Liquid Feeding Systems

Liquid feeding systems have followed two lines:—

1. Water, skim or whey is used as a carrier for meal, being mixed into a homogeneous mass with meals within a mixing chamber;
2. Water is used as a carrier for swill that has been pre-cooked and macerated, and again mixed into a homogeneous mass.

Liquid meal feeding systems have progressed rapidly, and are now available in three basic types:—

1. *Fixed-Batch Type Mixers:* With mixing by:—
   a. Rotating paddles.
   b. Compressed air.
   c. Recirculation.
2. *Fixed-Continuous Sequence Mixers:*
   a. With mechanical mixing and probe switches to give automatic control of liquid and meal input into a batch type mixer.
   b. With mechanical mixing and probe or reed switches giving automatic control of liquid and meal input into a purpose made continuous mixer of about 25 gallon capacity. The probe or reed switch activates at approximately 1 gallon displacement.
3. *Mobile-Mixers:*
   a. With mechanical mixing.
   b. With recirculation mixing.

Pumps

Most mixers have centrifugal pumps which can handle mixes with up to 2·27 kg (5 lb) of meal per 4·45 l (1 gal) of liquid, but are probably better when working on mixes of 1·8 kg to 4·55 l (4 lb to 1 gal). Some mixers have scroll and stator pumps an almost positive displacement type which can handle mixes with a higher meal content, and have a performance curve well suited to extended pipeline circuits and automatic valve rationing systems.

Compressor System

Compressed air operated mixers may be supplied with compressors of different sizes to suit the duty required, but usually a compressor with a duty of 0·016 m^3/s at 1·055 kgf/cm^2 (34 ft^3/min at 15 lbf/in^2) pressure is used. This is a rotary vane type of compressor and it may be connected to the mixer in such a way as to be able to apply a positive or negative pressure to the vessel. The negative pressure is used to suck liquid into the mixer eg skim or similar liquids and the positive pressure is used in two ways. First with the mixer valve open to atmosphere, the compressed air is blown into the mixer through the annular distribution ring in its base and on passing to atmosphere agitates the liquid and meal in the mixer body into a homogeneous mix. Later the valve is closed and the mixture pressurised to distribute the feed around the branch pipes to the pigs.

Pipelines

Pipelines may be arranged as ring circuits or dead ends: each arrangement has advantages and disadvantages.

Ring cicuits of necessity usually involve considerably more piping than dead end systems and consequently cost more to install. However, they have the advantage that the pipeline may be flushed out frequently without waste of food, and any feed left in the pipe can be recirculated back to the mixer and mixed with freshly made feed thus ensuring that the pigs have a palatable product that is uniformly mixed. The ring system also reduces the risk of some pigs getting a liquid only, or a highly diluted mix as their feed.

Dead end pipe lines are usually cheaper to install than ring circuits, and are necessary for compressed air pressurised distribution systems. Surplus feed may be sucked out of the pipeline back into the mixer after feeding, and if the liquids for the next mix are held in header tanks at the end of the pipeline the liquid may be sucked through the pipeline to the mixer, flushing it out in the process.

Dead end pipelines are at a disadvantage when distribution is by pumping. When the pipeline has to be flushed out it has to be flushed into a portable tank or to waste; and it is not possible to ensure uniformity of feed distribution to pigs at the start of the feeding sequence. This latter feature may also apply to compressed air systems, unless provision is made to overcome this.

The pipeline mains must be correctly sized according to the circuit or branch length, 5 cm (2 in) dia piping being typical. Vertical riser or fall pipes should be avoided, a gentle slope being preferable. If a vertical riser is an essential part of the system the liquid meal should be pumped up the riser and not down it. A plug of meal normally settles in vertical pipes and the supernatant liquor that forms above it tends to act as a cushion against the turbulence of the liquid flow and prevents it from dislodging the plug. Thick mixes accentuate blockage problems.

Valves

The valves controlling the flow of feed to the pigs via the branch lines may be manually or automatically controlled. When manually controlled valves are used, the type chosen should be suitable for the ingredients in the mix; for example, the corrosive nature of whey very quickly corrodes iron plugcock valves and it is necessary to use either gunmetal or nylon covered steel valves if long life is required. Nylon covered spherical lever operated ball valves are now used extensively and are proving to be very satisfactory.

The position of the valve in relation to the main pipe is important. A frequent mistake made is to install the valve underneath the main pipe particularly from overhead mains. The valves should with few exceptions either be fitted on top, or on the side and preferably near to the main, but obviously the layout of the branch pipe will, to some extent, influence this.

Automatically operated valves are controlled by compressed air and are of two types:—

1. Power closed by compressed air acting upon a diaphragm, and opened by an electrically operated three-way solenoid valve, which releases the pressure on the feed valve. This valve is not "fail safe" and if fail safe control is required, this is achieved by pressure controls which ensure pumps cannot start until valves are closed.
2. Piston or ball plug type valves which are power opened by an air ram, operated by compressed air.

   A strong spring or air pressure is used to automatically close the valve, and this is a fail safe type.

The automatic control of valves may be:—

1. A system involving a time sequence controller which provides a means of controlling and counting down a pre-set number of pulses of feed to each pen of pigs. In effect, this is counting the number of pigs, and another section of the control unit provides a means of varying the length of the pulses. The combination of these two controls enables a preset ration to be fed to each pen of pigs.
2. A system particularly associated with continuous mixers involves a sequence in which:—
   a. An air compressor which operates the feed dispensing valves is started up and when working pressure is reached,
   b. the feed deivery pump is switched on and free circulation commences in order to flush out the pipework and re-mix the ingredients it contains with the mix in the mixer itself, so ensuring a thorough mixing

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of all ingredients in pipeline and mixer prior to distribution.

c. The main control unit then checks the position of the first pen selector switch and having satisfied itself that all is in order it activates delivery of the liquid and meal into the mixer in a pre-determined ratio; When the level of the liquid in the mixer has reached the level of the control switch then,

d. the automatic feed valve at the first pen of pigs is opened and remains opened until the required quantity of feed has been delivered. The level switch within the mixer admits more meal and water as necessary.

Fail safe features are provided to detect any faults in the system, identify the fault, signal an alarm, and shut down the system.

Faults covered include too high or too low air pressure, meal not being delivered into the mixer, liquid not being delivered into the mixer, too high or low level of liquid in the mixer, and too much or too little feed being delivered into the feed trough.

In a recent *ADAS*[5] investigation of liquid feeding systems it was found that 38·6 per cent of the pigs on the farms assisting with the investigation were baconers and the herd sizes were as indicated in Table 2. Of the farmers visited 81 per cent were processing their own feed on the farm and the majority of farmers were blending feeds within the range 0·91 to 1·8 kg/4·5 l (2 to 4 lb/gal) of liquid.

Table 2

Herd size	*Number of herds*	*Percentage*
50 - 100	4	4
101 - 200	10	9
201 - 400	22	20
401 - 700	36	32
701 - 1,000	20	17
1,001 - 1,500	14	12
1,501 - 2,500	6	5
2,501 - 3,000	1	1

Methods of measuring the meal into the mixer were:—

19 per cent from sacks;
16 per cent from volume containers;
16 per cent from timed augers;
17 per cent from automatic weighers;
32 per cent by various other methods and combination of systems.

Various methods were used to measure liquid into the mixer for example:—

47 per cent measured by eye observing the level of the liquid through the top of the mixer;
13 per cent measured by eye and sight glass or tube;
5 per cent measured by time;
6 per cent measured by water meter;
5 per cent measured by auto-level switch;
24 per cent measured by various other methods or combination of systems.

It was found that 85 per cent farmers used 2·4 mm (3/32 in) to 3·2 mm ($\frac{1}{8}$ in) screens in their hammer mills.

The methods of rationing feed to the pigs were:—

61 per cent assessed quantity in the trough by eye;
20 per cent assessed quantity in the trough by time;
6 per cent used automatic valves;
13 per cent used other methods or combination of methods.

Grading of pigs was examined in closer detail on 22 farms and Table 3 summarises the results.

The flexibility offered by pipelines being able to service widely scattered houses is attractive to many farmers and the good results obtained in many trials comparing liquid with a dry feeding system have interested them. For example Braude and Rowell[6] in 1966 and 1967 reported results of *ARC* co-ordinated trials as giving feed conversion factors of:—

Liquid feed fed in troughs	3·35
Cubes fed in troughs	3·526
Cubes fed on floor	3·536
Meal fed in troughs	3·590
Meal fed on floor	3·765

Liquid feeding has the advantage of facilitating use of a low-cost home prepared feed as well as the best food conversion factor.

The time it takes to feed pigs may influence the degree of stress on pigs under some housing conditions. Feeding time should therefore, be as short as possible, and when pens of pigs are fed in sequence the number of pigs fed/min should be as high as possible. The *ADAS* investigation indicated that:—

feed distribution rate for manually operated feed valve systems was on average 25·3 pigs fed /min for batch type mixers with pump delivery, 21 pigs/min for compressed air operated systems with manually operated valves, and 66 pigs/min

Table 3 Grade Summary—Bacon Pigs

Grade		Percentage 60·1 to 70	70·1 to 80	80·1 to 90	90·1 to 95	95+
1	*Number in Grade*	11	26	14	4	-
	(Approx) percentage in grade	20	47	26	7	-
1 & 2	*Number in Grades*	-	1	26	17	7
	(Approx) percentage in grades	-	2	51	33	14

This table indicates for example that 26 lots of pigs (47 per cent) were graded with 70·1 to 80 per cent in Grade 1 and as can be seen 26 + 17 + 7 ie 98 per cent were graded with 80·1 per cent plus in grades 1 and 2 the highest recorded data being 99 per cent grades 1 and 2.

for continuous mixer systems with automatic feed delivery valves.

The scatter on all systems was quite wide.

Swill feeding systems require mixing, pumping and piping systems basically similar to the liquid feed systems already referred to, but the additional processes of cooking and macerating, have to be carried out.

Cooking

The swill is usually cooked by a steam injection system in open topped boiling tanks of 4546 to 13638 l (1,000, to 3,000 gal) capacity, but some farmers have used their initiative and converted second-hand tar boilers or similar cylindrical tanks that have been cleaned out by industrial processes, in which to cook the swill. A steam boiler must be installed to supply the steam that does the cooking. The size of this boiler will depend on a number of factors, as for example the time in which the cooking is to be done, the number of litres (gallons) of swill that is to be cooked at any one time, and of course the atmospheric outside temperature will have some bearing as well.

It requires approximately 1,750,000 Btu to raise 4546 l (1,000 gal) to boiling point and many farmers hold their swill at boiling point for two to four hours, taking about two hours to bring it up to the boiling point.

Macerating

The swill has to be macerated so that it can be mixed into a homogeneous product which can be blended with other ingredients and pumped around the pipeline circuit to the pigs. It is best to macerate the swill after cooking. The turbulence created within the mass of swill during cooking helps to settle out the inevitable cutlery, hardware and very large bones that come with the swill, and this reduces the risk of them causing a breakdown in the macerater.

Two systems of feeding the swill into the macerater are used. Where the macerater is installed on top of the cooking tank and a large diameter suction pipe drops down into the tank to a point within 76 mm (3 in) to 102 mm (4 in) of the bottom of the tank, the pre-cooked swill is sucked up this pipe, but the heavier materials such as large bones and metals remain in the bottom of the tank. These are scooped out periodically. The second system is one in which the macerater is positioned on a level with the base of the cooking tank and the suction pipe is taken through the bottom of the tank and stands approximately 102 mm (4 in) above it, so that the metals, etc, are not drawn into the macerating equipment. In each case after processing the macerated swill is pumped into a mixer blender tank where, as mentioned, other ingredients may be added to the mix. The need for adequate cooking and care in hygiene with a swill system cannot be over emphasised.

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Control of Environment in Piggeries*

by G. A. Carpenter†

Introduction

IN considering the control of environment in piggeries, it is necessary to decide what are the important environmental factors, how these factors can be measured and controlled and what criteria are to be used to judge the success of control. Environment here is looked at from the point of view of the ventilation system, and, bearing this in mind Fig. 1 is an attempt to illustrate the structure of a ventilation system, how it interacts with the other environmental factors and how its effects can be appraised.

Baxter[1] has advocated the idea of an experimental complex consisting of disease, nutrition and environment, environment itself being broken down into structural, social and climatic aspects. The ventilation system, however, is imposed upon the building and predominantly affects the climatic environment. A ventilation system can be broken down into its main configuration (eg positions of livestock, fans, inlets, etc), the design and characteristics of its components, either ventilated (eg building, pens or live stock) or ventilating (eg fans, ducts, inlets, etc), and control (control method and controlled factors). The control method can be natural or forced and, if forced, the principle of control must be distinguished from the mode of action of the controlling device. The controlled factors of which there are at least 15, can be grouped under several headings: physical, ventilating, subjective, thermal and constituent factors. External factors are climate which affects both the building and the ventilation system and air-borne disease and dust which enter via the ventilation system. Once a ventilation system is installed in a building containing livestock, the environmental engineer can appraise the effect of the system in two ways: in a limited manner by physical measurements and comprehensively by co-operative research with workers in other disciplines using output criteria such as pollution, operator and livestock welfare and livestock productivity.

The overall picture is one of complexity because of extensive interaction between most of the items and factors listed. Because of this, research work on the ventilation of livestock buildings must often have limited objectives with a view to isolating an investigation from some of the interactions.

The Purpose of Ventilation

The object of ventilation is to provide an aerial environment that is optimum for productivity and acceptable for livestock welfare and health. This is achieved in two ways—first by supplying oxygen and removing a considerable proportion of the contaminants from the air, namely gases and odorous components, water vapour, dust and micro-organisms and, second, by enabling the ventilating air to act as a heat vehicle for heating or cooling the livestock and the buildings.

A peculiarity of intensive buildings for adult livestock, and particularly for fattening pigs, is that when a certain minimum degree of thermal insulation is provided in the building, the metabolic heat output of the stock is normally sufficient to maintain the required optimum temperature at all seasons, provided there is provision for varying and controlling the ventilation rate over a wide range of values. Thus, artificial heating and artificial cooling are not normally required for adult stock housed under these conditions and the economics of the intensive raising of livestock is closely related to this fact. Intensive livestock buildings therefore have a relatively constant internal heat load varying parts of which need to be dissipated according to the external climatic conditions. Highest ventilation rates occur in summer when metabolic heat and solar gain have to be removed, and lowest rates occur in winter, the range of rates being typically 10:1. In addition, to avoid the possibility of the temperature requirements calling for zero ventilation due to exceptionally cold weather or a reduction in stocking live-weight, a minimum permissible ventilation rate must be ensured so that the concentrations of contaminants do not rise above acceptable values—in many situations water vapour content is the limiting constituent.

Practical Methods of Ventilation

Historically, ventilation was originally natural, depending on the effects of wind and convected heat from the stock. Air inlets in which the connection on the outside of the wall of the building was at a lower level than that on the inside were ascribed to Tobin in 1874[2] and to this day rain-proof inlets are called Tobin tubes. All natural ventilation is variable and difficult to control and with increasing intensification of livestock housing, fan ventilation became necessary with extractor fans situated in the ridge of the building to aid the existing pattern of natural ventilation. Many other arrangements of positions of fans, inlets and outlets exist, together with modern versions of natural ventilation applied to semi-intensive systems. Houses described as "controlled environment" usually have closed-loop control only of temperature, some other environmental factors being merely limited incidentally.

*Presented at the Annual Conference of the Institution of Agricultural Engineers at the Institution of Civil Engineers, George Street, London SW1 on 9 May, 1972.

† Farm Buildings Dept NIAE

For reasons of husbandry related to group size, feeding and inspection of stock, waste removal, access and disease control, intensive livestock buildings tend to be long, narrow, single storey and detached, although exceptions such as circular, square or wide-span do exist. A survey[3] has shown that many fattening piggeries lie between 7·6 and 9·8 m (25 to 32 ft) in width. Such a design has

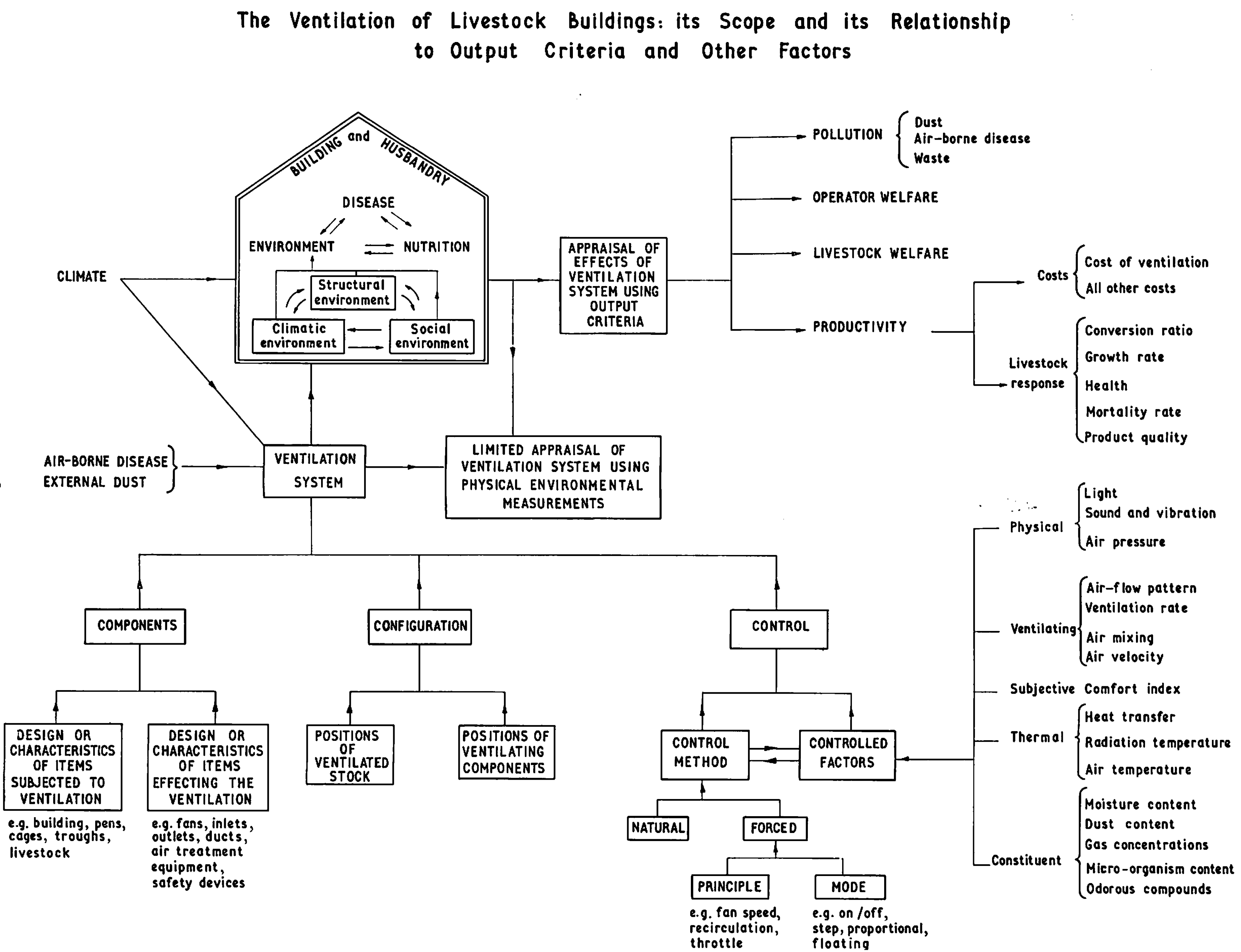


Fig. 1

important implications. Any ventilation system conveying air from end to end would give a mean velocity in, for example, a 32 m (105 ft) long 8 m (26 ft) wide fattening house, four times that for a system conveying air across the building, and also lengthwise gradients of temperature and gas and vapour concentrations would exist. In addition certain types of pen lay-outs would grossly interfere with the air flow. Thus, ventilation systems tend to be designed to have the predominant direction of air flow perpendicular to the long axis of the building, which, because stock are distributed fairly uniformly over almost the entire floor area of the building demands a multiplicity of air inlets and outlets, or a large area of permeable surface through which air can pass. A second important implication is that the air paths are short and uncomplicated and the resistance to air flow is usually quite low permitting the use of standard propeller fans.

Thus, the characteristics of livestock buildings have imposed some limitations on the design of ventilation systems, but in spite of this there remains in practice considerable scope for variations on systems arising from combinations of the three basic factors, namely configuration of air vent positions, design of components such as air inlets, and the method and mode of control.

Configuration of Fan and Vents

Any classification is an arbitrary procedure and Prosser[4] has suggested eight main types including longitudinal flow and pressurisation. A modification to this is to base the classification only on the relative positions of the vents as disposed in the main components of the building and only for air flow perpendicular to the long axis of the building. This gives six relative positions, namely ridge and walls, ridge and floor, ceiling and walls, ceiling and floor, walls and floor and wall to wall. In all cases except the last, the inlet and outlet can be reversed and in all cases the fan can be upstream of an inlet (resulting in a pressurised system) or downstream of an outlet (resulting in an exhausted system). Of these 22 combinations, about ten are encountered in practice. Preliminary experiments using air flow patterns as a basis for comparing the various configurations are described later.

It is worth noting that there appears to be no evidence that there is any important difference between a pressurised or an exhausted system as far as the effects of the static pressure is concerned except that pressurisation can cause condensation in the fabric of the building.

The latter problem can be severe in very cold climates,[5] and even in the *UK*, roof or ceiling insulation must either be air and vapour tight or have a freely naturally ventilated space between the insulation and the roof.

Design of Air Vents

There are three main types of air vent. (i) A direct connection to the outside of the building such as ridge or wall mounted fans, or ridge or eaves slots. (ii) A ducted system, using for pressurised systems, either, inflatable ducts made of perforated polythene film[6] or woven materials, or for either pressurised or exhausted systems, rigid ducts made of perforated sheet material or of imperforate material with periodic apertures. (iii) The use of a continuously permeable material for covering all or part of a wall, roof, or ceiling—for example a ceiling covered with fibre-glass[7] or perforated polythene.

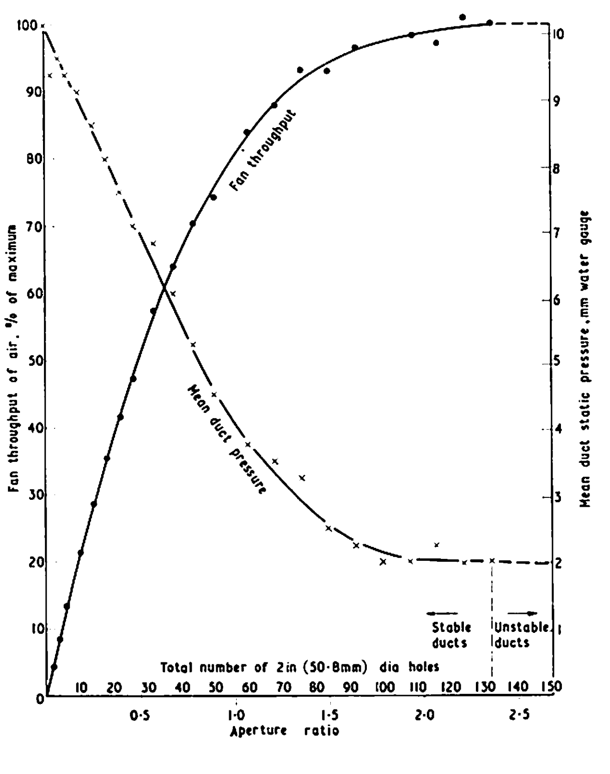
In considering the design of any vent, five aspects must be considered—in all cases its resistance to air flow, its cost, its degree of immunity from the effects of exterior factors such as light, noise, precipitation and wind, its immunity from blockage by dust and, for an inlet in particular, its effect on the the air flow pattern in the building. The details of the design of inflatable ducts and the resistance to airflow of permeable materials are considered here.

Inflatable Ducts

Ducted systems in general are suited to use in livestock buildings because of the long narrow shape of such buildings and because ducts require fewer fans and connections to the outside of the building, thereby making immunity from outside influences easier. Ducts also lend themselves to air treatment such as heating, filtration, humidification, and the use of heat exchangers and air recirculation should these processes become more important in the future. Ducts for use in livestock buildings also need to be inexpensive, light-weight and able to distribute air frequently or continuously along their length. Provided a pressurised system is acceptable, ducts made of perforated polythene film or woven material fulfil these requirements.

Fig. 2

Variation of Fan Throughput and Mean Duct Pressure with Aperture Ratio



For a straight duct closed at its end and inflated by a propeller fan, the basic performance curve with increasing perforation is shown in Fig. 2[8]. At a ratio of total aperture area to duct cross-sectional area of 2·4, the duct becomes unstable and below 1·5 the duct restricts the total air throughput to an undesirable extent. About 1·8 is the best aperture ratio for practical use and is independent of aperture size, duct length and duct diameter assuming that the fan matches the duct diameter.

A disadvantage of all parallel-sided ducts is that due to regain of static pressure as the velocity in the duct decreases towards its closed end, the static pressure and hence the discharge velocity increases towards the closed end (Fig. 3). This can be counteracted by tapering the duct or increasing the spacing between holes towards the closed end. This gradient in discharge velocity increases with increasing aperture ratio and decreases for ducts of the order of 100 m (328 ft) in length.

Variation of Static Pressure and Discharge Velocity with Position Along a Duct for Two Aperture Ratios

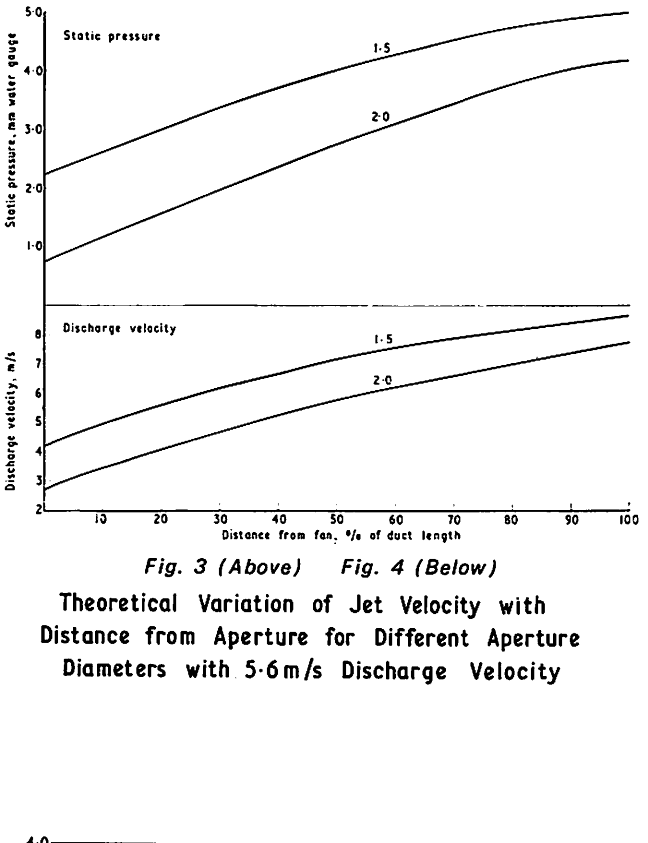
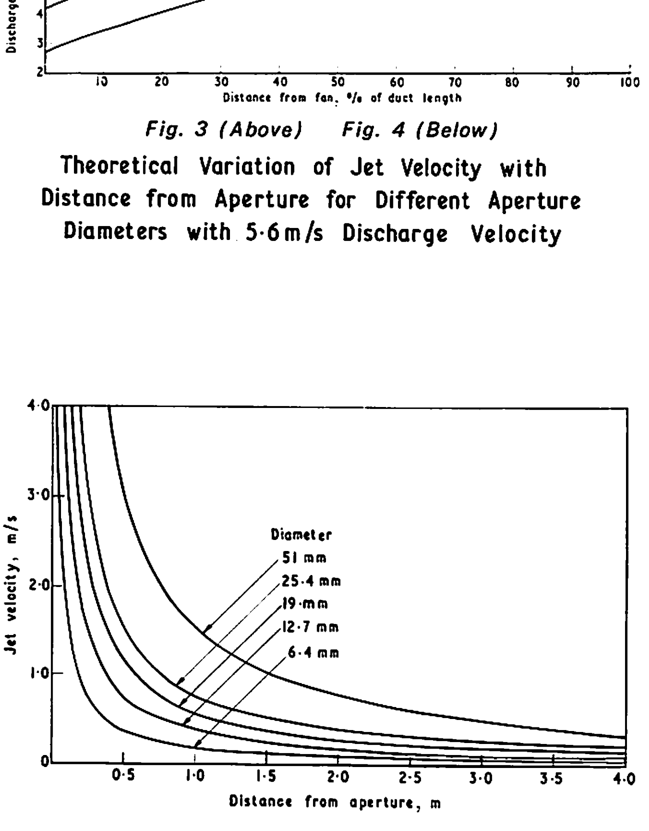


Fig. 3 (Above) *Fig. 4 (Below)*

Theoretical Variation of Jet Velocity with Distance from Aperture for Different Aperture Diameters with 5·6 m/s Discharge Velocity



Two unexpected features of polythene ducts are that they inflate at low fan speeds provided they are straight and suspended from their top edge, and they are also durable because ultra-violet light, which is responsible for rapid deterioration of polythene in sun-light, is absent in enclosed livestock buildings.

Fig. 4 shows how the discharge velocity falls off with distance from holes of different diameters[9]. When headroom is limited, as it frequently is in a piggery, it is important to take into consideration the distance of the stock from the duct and the direction of discharge. Large holes can be used to induce circulating air patterns or to cool stock in hot weather. Holes less than 12 mm (½ in) diameter can clog with dust. Data has been given relating pig comfort to combinations of air temperature and air velocity,[10] but only for velocities below 0·36 m/s (70 ft/m).

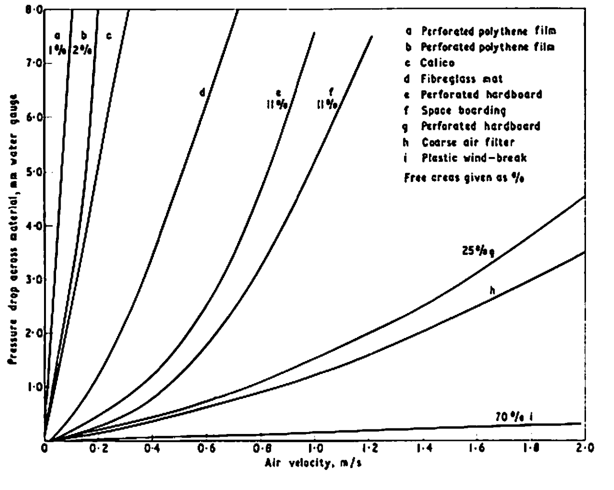
Permeable Materials

A variety of permeable materials are used in livestock buildings to control the air movement through the building and this applies to both natural and forced systems of ventilation. Such materials can be of three general types: building components such as louvred roofing sheets, air bricks and space boarding, materials with discrete apertures of a size range that permits measurement and definition of free area such as perforated hardboard and polythene film or materials with fine or irregular pores such as woven materials, fibre-glass matting and filter fabrics.

Permeability is the volume of air/unit time/unit area of material passing through the material when subjected to a given pressure difference. It has dimensions of velocity divided by pressure. Permeability usually varies with pressure difference. Often the inverse is required, namely resistivity, and Fig. 5 shows typical resistance curves for some well-known materials. The range of resistances is very large and is dependent to a considerable extent on free area. The results suggest that some materials designed as a wind-break have too low a resistance to be effective when compared with a material such

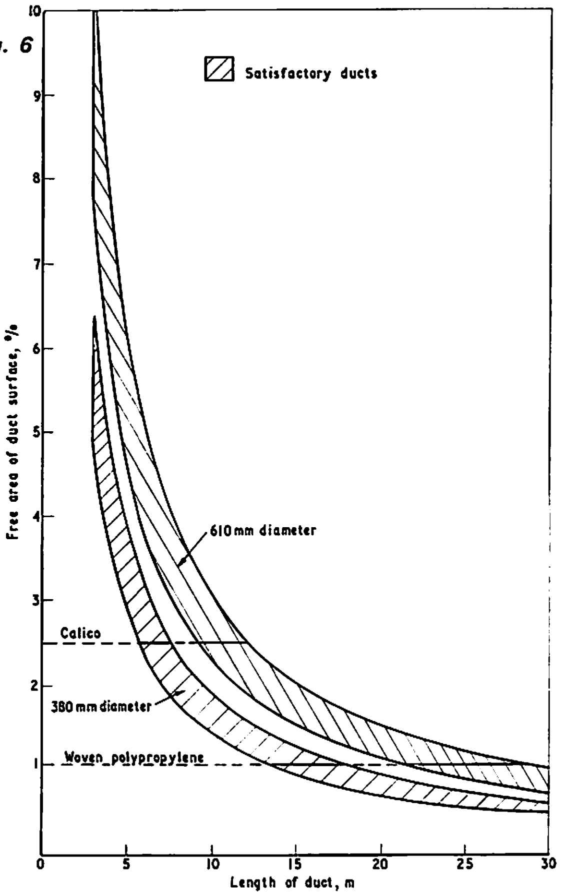
Fig. 5

The Resistance to Air Flow of Various Materials Used in Ventilation



Relationship Between Duct Length and Free Area of Surface for Perforated Polythene Ducts of Two Diameters

Fig. 6



as space boarding. Materials used for inflatable ducts are necessarily of low free area and high resistance in order to maintain a pressure inside the duct. Fig. 6 shows the ranges of free areas encountered in perforated polythene ducts for two diameters of duct, an acceptable range of aperture ratios (encompassed by the shaded area for any particular length) and for a range of lengths. It follows from Fig. 6 that if other materials are to be used for ducts then a given combination of length and diameter (ie surface area) will require a limited range of free area for a satisfactory performance and these principles will apply to rigid ducts and permeable surfaces if the required pressure and airflow are to be maintained over the entire surface of the material.

Returning to Fig. 5, it can be seen that coarse air filters have a substantially lower resistance than materials that are likely to be used for ducts or plenum ceilings and use of such filters to avoid premature clogging of the duct may be justified.

A general problem with air distribution ducts in winter is condensation of water vapour from the livestock on the outside surface of the duct. This does not occur with fine-pore materials as the entire surface is aspirated, and neither does it occur with rigid ducts constructed of insulating material.

Unlike ducts with large discrete apertures which may have discharge velocities in the range 3·0 to 9·0 m/s (10 to 30 ft/s), ducts made of fine-pore materials produce velocities of the order of 0·1 m/s (0·3 ft/s) over the entire surface[8] under which circumstances draughts cannot be produced but neither can the discharge be used to induce a positive pattern of air movement.

Ventilation Rate

Because control of ventilation rate is the basis for control of temperature in most livestock buildings, consideration must be given to the range of values required, the accuracy with which it must be controlled and the methods by which it can be controlled and measured.

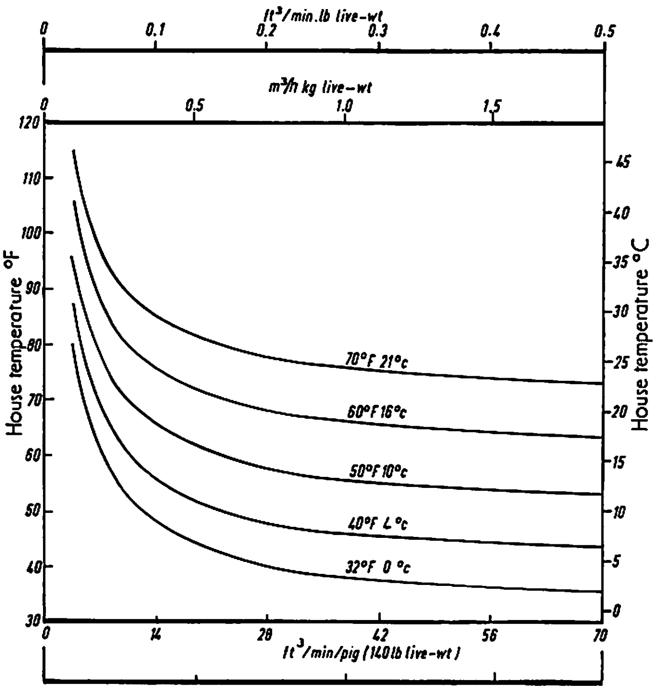
Effect of Ventilation Rate on House Temperature

Basing calculations on a well-insulated fully-stocked Danish type fattening house, Fig. 7 shows how the mean house temperature depends on ventilation rate for various ambient temperatures, the only source of heat being the metabolic output of pigs. In such a building, the conducted heat loss is kept at a low value at all times, most of the heat being dissipated by the ventilating air. This ventilation heat loss is approximately 80 per cent of the total heat loss in winter but is much higher than this in summer depending on factors such as solar radiation.

Several important facts are illustrated by the graphs: (i) The frequently recommended winter rate of 0·00010 m^3/s kg (0·1 ft^3/min lb) liveweight would appear to be unduly high for a system that uses the ventilating air efficiently. In practice, this higher value may be necessary if some of the ventilating air by-passes the stock. (ii) House temperature becomes increasingly sensitive to venti-

Fig. 7

Effect of Ventilation Rate on House Temperature for Various Outside Temperatures



lation rate as the rate is reduced, especially below 0·00016 m^3/s kg (0·15 ft^3/min lb) live-wt. (iii) House temperature becomes increasingly insensitive to ventilation rate above 0·00042 m^3/s kg (0·4 ft^3/min lb) live-wt. The practical implications of these facts are that existing methods for controlling ventilation rate in winter are inadequate both as regards the manner in which the air intake rate is controlled and as regards the elimination of spurious ventilation by wind and leaks in the building. In addition, no purpose is served by providing a massive increase in fan capacity to improve temperature control in hot weather, a more promising approach being to effect local cooling by modifying the air distribution system so that, when required, the air velocity over the stock can be increased.

Methods of Controlling Ventilation Rate

Considering only forced ventilation, there are three basic methods of varying the ventilation rate. These are:—

1) To vary the fan speed, eg on/off, stepwise, continuously variable according to several modes such as proportional or floating control.
2) To keep the fan speed constant and recirculate a proportion of the air, again using a choice of modes of control, but usually proportional.
3) To keep the fan speed constant and choke the fan throughput either adjacent to the fan using a damper or diaphragm or at the inlets or outlets of the building.

The characteristics of these methods need elaborating. On/off control of fans is liable to produce abrupt changes in temperature, although if linked to stepwise switching of speeds or a series of fans, can give acceptable conditions. The continuously variable types now commonly used have the principal disadvantage that at low fan speeds, the pressure difference between the inside and the outside of the building is undetectable and quite moderate winds can modify the ventilation.

Recirculatory systems are not new and at least two packaged designs for roof mounting are available which use this principle. Ducts also lend themselves to use in recirculatory systems, and can be used in conjunction with proportionally-acting servo-operated dampers. The chief characteristic of recirculatory systems in their favour is that the discharge velocities into the controlled space are constant which, provided temperature control is not lost, gives a constant temperature/velocity cooling effect; against such systems is the fact that the air from any one infected animal is passed to all the others, the effects of which do not appear to have been investigated.

The third method entails maintaining the fan speed close to maximum and controlling the air flow by restriction either at the fan or at the air inlets or outlets. This method is only normally used in practice to the very limited extent that inlets or outlets are restricted in winter as an adjunct to the fan speed control method to reduce the effect of wind

Effect of Area of Air Vents in a Building on Static Pressure and Fan Output

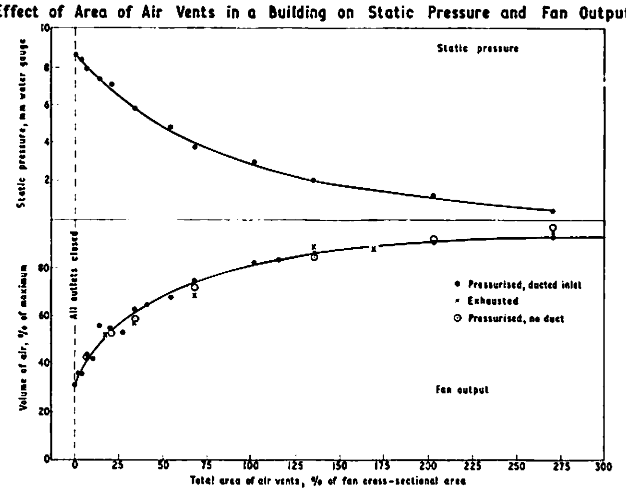


Fig. 8

at low fan speeds. Experiments in a relatively air-tight section of a building have produced some interesting data.[11] Fig 8 shows how the building pressure and air throughput vary with area of outlets when pressurised with a propeller fan at full speed. For a pressurised system, the recommended outlet area is about three times the fan cross sectional area and under this condition, the pressure is 0·6 mm (0·020 in) wg and the throughput is 92 per cent of free air conditions. Thus, the capacity for pressurised systems to counteract wind effects must be very limited as a 9 m/s (20 miles/h) wind produces a velocity head as great as 5·1 mm (0·200 in) wg. With the larger vent area of about ten times the fan area recommended for exhausted systems, the pressure in the building even at full fan speed is virtually undetectable. Fig. 9 shows how air throughput and static pressure in the building depend on fan speed for different vent areas. During cold weather, operation of the fan near full speed coupled with restriction of the vents should result in an effective pressure for counteracting wind, whilst permitting the controller to continue to control over a restricted range of air throughputs. For example, whereas a fan operating at 70-80 volts with vents of large area (Fig. 9, d) gives about 20 per cent of maximum air throughput and an undetectable pressure in the building, with the vents closed (with leakage) (Fig. 9, curves a) the same throughput of 20 per cent is obtained with the fan motor operating at 180 volts and resulting in a pressure of 4·8 mm (0·189 in) wg. There will however be practical aspects that need to be taken into consideration such as door design and the effects of the slightly increased current taken by the fan motor, also found by Wakefield[12].

Methods of Measuring Ventilation Rate

Ventilation rate is the volume of fresh air introduced per unit of time. It can be divided by the volume of the building to give air changes per unit time, by the floor area of the building to give volume per unit time per unit area, or by the live-weight of the stock to give volume per unit time per unit weight.

Effect of Fan Motor Voltage on Static Pressure in a Building and Fan Output

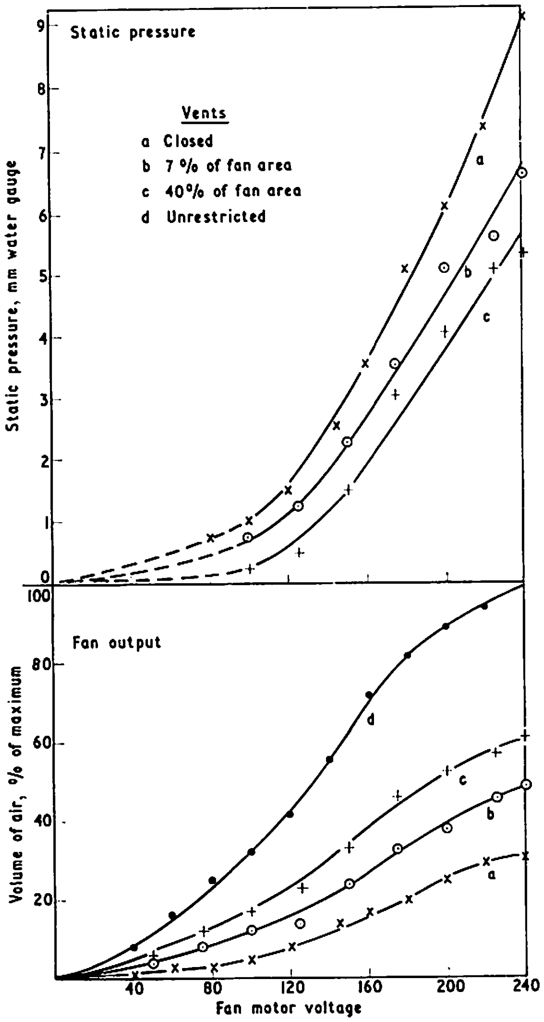


Fig. 9

The concept of air changes per hour, although useful for buildings in general, is best avoided when ventilation rates are critical because enclosures of different height but of the same loading and fresh air rate will give different values of air change rate. For crops in glasshouses and also for human occupancy, the volume of fresh air per unit time per unit ground area is often used, on the assumption that the loading is proportional to the ground area and independent of height for a given building use. This basis, can also be used to show that the ventilation problem in a fattening piggery is about 20 times as severe as in an air-conditioned office the rates being respectively 220 and 12 $m^3/h\ m^2$ (720 and 40 $ft^3/h\ ft^2$), and it is important to bear this in mind when relating designs of ventilation systems for typical human occupancy to those for intensive livestock buildings. For accurate assessment of ventilation rates for livestock buildings however, a constant loading per unit floor area cannot be assumed and air volume rate per unit live-weight must be used.

Measurement of ventilation rate is invariably difficult and can be attempted in three ways:—

1) By direct measurement at inlets or outlets; care is needed to avoid errors and the air input rate should balance the output rate. In practice, agreement is probably possible to within only 15 per cent, and with a leaky building on a windy day, even this will not be achieved.
2) By decay of concentration of a tracer gas; if C_0 and C are the initial and final concentrations of the gas respectively, v=ventilation rate (vol of fresh air per unit time) and V = vol of enclosure, then $C = C_0 \exp - \frac{vt}{V}$

$$\text{thus } v = 2{\cdot}303 \frac{V}{t} \log_{10} \frac{C_0}{C}$$

The tracer gas is injected, mixed, the air sampled, and the gas concentration measured over a period of time. Gases that have been used are CO_2, N_2O, SF_6, NH_3 and radioactive krypton 85. In selecting a gas, the size of the enclosure, cost of the gas, sensitivity of the gas analyser, hazards from the gas and whether the gas is inevitably generated from other sources within the building must be taken into account. In general, a small enclosure presents fewest problems because mixing and sampling is relatively simple and also a high concentration of gas is possible permitting the use of a less sensitive therefore less expensive analyser.

3) By the steady-state concentration of a tracer gas. The same gases as above can be injected continuously at several points and the air sampled at several outlet points; the ventilation rate in volume per hour after a settling down period, is the weight of gas injected per hour divided by the mean concentration of gas at the outlets (wt/unit vol).

The Spatial Environment

Even though ventilation rate may be controlled at the desired value to give the correct mean temperature in the building, the spatial distribution of temperature and velocity may be such that the values at livestock level are far from optimum. Alternatively, unnecessarily high rates of ventilation may be required to obtain the correct mean temperature with a proportion of the fresh air going straight to the exhaust. The existence of temperature gradients also poses problems of control because the sensor needs to be positioned to measure the environment that is representative of that around the stock.

Air-flow Patterns

The manner in which the air passes through the building can be at least described, if not defined by the pattern of the dominant air paths and this is called the air-flow pattern and is of paramount importance for three reasons. First it determines the combination of air temperature and air velocity that impinges on the stock. Second, it affects the degree of mixing, that is, the efficiency with which the ventilating air achieves its object of ventilating the stock. Third, it determines the direction of the concentration gradients of the various constituents being removed eg the gases, odours and particles that are upstream or downstream of the stock and the stockman.

There are seven factors that basically affect the ventilation pattern. These are (*i*) size and shape of building, (*ii*) configuration of the ventilation system, ie the positions in the building of the fans, inlets and outlets, (*iii*) direction of the incoming and outgoing air as determined by the design of the inlets and outlets, (*iv*) the temperature of the incoming fresh air, (*v*) the velocity of the incoming fresh air as determined by ventilation rate and inlet area, (*vi*) the lay-out of the livestock enclosures ie their positions, shape and air permeability, and (*vii*) the number, sizes and positions of livestock.

In order to study the effects of these seven factors, a full-scale section of a building has been constructed in which these factors can be controlled and modified[13] (Fig. 10). The use of a section such as this is valid because of the repetitive nature of the building layout along its length and the type of air flow perpendicular to the building axis as described earlier. A visualisation system[14] is used for displaying the air-flow patterns in which a thin beam of parallel light is shone across the section. Bubbles[15] containing a mixture of air and helium are released in large numbers and the resulting pattern can be viewed and photographed through a transparent end wall. In addition, simulated pigs[16] are used to reproduce the effects of obstruction to airflow and convective heat output.

Photographs are taken through a rotating shutter that has the effect of producing tracks of bubbles that are a series of dashes, each dash having a 'head' to indicate direction, and the distance between successive dashes being a measure of velocity if required. Using the information given by the patterns, detailed study of velocity and temperature can then be made in any region of the enclosure using miniature omni-directional sensors[17,18] carried on a vertical arm that traverses the enclosure on a rail. Also, attempts can be made to quantify the degree of mixing using a tracer gas. Initial experiments suggest that some tentative conclusions are possible from the ventilation patterns:—

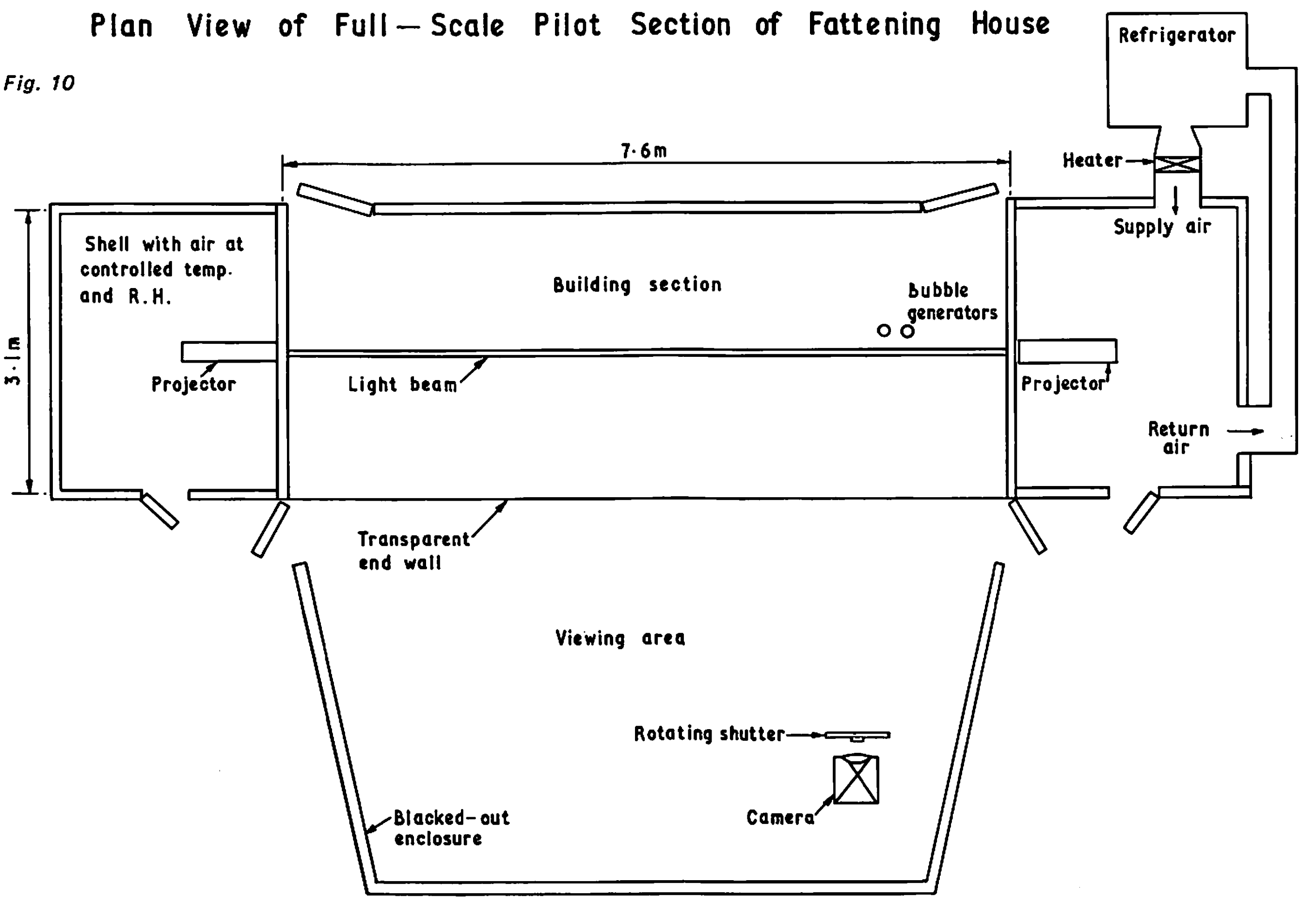
(a) the pattern is determined largely by the directional characteristics of the inlets;
(b) a given pattern is most marked for summer rates of ventilation and in winter, can be completely changed by the low inlet air temperature and presence of the stock;
(c) air moving along a surface can be deflected by quite small obstacles, eg a feed trough can cause a deflection of 90°;
(d) certain arrangements of inlets and solid pen divisions can destroy the kinetic energy of the incoming air and result in turbulent low-speed motion. Other arrangements permit high speed circulation.

Measurement of Environment at Stock Level

Detailed environmental measurements inevitably lead to the necessity of having to take measurements close to and around stock in a realistic situation.

Plan View of Full—Scale Pilot Section of Fattening House

Fig. 10



Measurement of air velocity under intensive conditions amongst pigs may well prove to be an insurmountable problem but other factors such as temperature, humidity, dust content etc can be measured by the use of a cage.

A pig-proof cage for example requires a strong outer frame-work free from sharp corners or edges, an inner mesh cage to prevent the stock from penetrating the frame-work, a water-proof lid, liquid deflectors, a strong form of mounting, and an outlet in metal conduit to carry signal or power leads. Air must be able to pass freely through the cage to avoid stagnation inside. Such a cage may need to be quite large to accommodate a recording thermo-hygrograph or a thermostat but a small temperature sensor would enable it to be miniaturised.

Actual differences in temperature between the environment at stock level and at higher levels will depend on many factors, but, to illustrate the size of difference possible, an initial trial of a cage mounted 102 mm (4 in) from the floor on a solid pen wall and surrounded by pigs in a fattening house with an overhead central duct showed a temperature 6°C higher in the cage than at the thermostat.

Present Situation

The complexity and interaction of the environmental factors in livestock buildings is such that progress in research is unlikely to be rapid or spectacular. It seems inevitable that the subject of controlled environment must be approached in several ways: theoretically using physics and livestock physiological data, experimentally in the design of engineering components independent of livestock, then combining the components with simulated livestock using part of a full-scale building and finally using buildings containing actual livestock.

Some progress has been made in fulfilling the needs of controlled environment research which are (i) a closer definition of performance of components for example, air discharge from inlets, ducts and ceilings, the mode of action of controllers, the air-tightness of buildings, the wind resistance of air vents and the causes and prevention of fan overloading; (ii) improved methods for measuring environmental factors, for example, display of airflow patterns, measurement of low air speeds on a multi point basis and measurements in the immediate vicinity of stock; (iii) facilities for relating the ventilation system, its lay-out and components to the micro-environment, health and productivity of the stock.

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Equipment for the Artificial Rearing of Piglets*

by Dr. G. C. Perry†

INTEREST in artificial rearing of piglets has existed for many decades but it is only in the last ten years when, after much experimental work, systems of rearing piglets away from the sow have been commercially available. There are several reasons for this slow progress and some, for example subsequent reproductive capacity of the sow, are not fully understood today. However, by comparison with other meat-producing species the breeding sow is perhaps the most inefficient breeding female on the farm. She has a gestation length of just under four months and under a traditional management regime, a period of lactation for one to two months. Her litter is then weaned and she is re-mated. By comparison, cattle have a gestation length of nine months and can be re-mated six weeks post-partum and continue lactation during the ensuing pregnancy. A system of sheep management is currently practised in which ewes, with a gestation length of five months, produce two lamb crops in 13 months.

Apart from the relatively long period between pregnancies the sow does not fulfil her maternal role with complete success. A Veterinary Investigation Service survey in 1960 revealed a 20 per cent loss of piglets to eight weeks of age. This figure excluded still-births. Three-quarters of these deaths occurred by seven days of age. Little progress has been made towards reducing these mortality figures despite advances in management techniques, including a better understanding of sow nutrition, the provision of farrowing crates and extensive use of controlled environment farrowing accommodation. Therefore there exists considerable scope for improvement and many people consider artificial rearing as the only technique to significantly increase piglet output per sow per year.

Approximately 15 years ago a commercial system of early weaning was developed and marketed. Developed by a feed compounder the system required little equipment. It involved weaning between three and ten days of age and rearing the piglets on a milk substitute. Initially the results were promising but within a short time problems arose. The piglet is a simple-stomached animal and its digestive system is not well-developed at birth. The acknowledgement that cleanliness is a vital factor in satisfactory calf rearing was overlooked and the piglets were expected to drink out of pans or trays in which they could also urinate, defaecate and generally contaminate. Consequently, the immature digestive system was subjected to bacterial invasion. Additionally, the instinctive ingestive behaviour patterns were overlooked. When reared on the sow, newborn piglets suck approximately 30 times/24 hours. During the post-partum period the sow regulates the quantities of milk secreted. This is extremely fortunate for the piglet is unable to control milk intake at this time. An ad-libitum availability caused overconsumption leading to scouring and death.

Faced with these results, modern and more successful systems have evolved. Basically there are three possible approaches. These are:—

1. Removal from the sow at birth and placed on a liquid diet.
2. Removal from the sow at three to four days, transferred to a liquid diet, which is gradually replaced with a solid diet.
3. Removal from the sow at eight to ten days and placed on a solid diet.

Many factors influence the choice of system. Method 1 gives the farmer an opportunity to save the 15 per cent of pigs that die in the first week. However, one must feed a liquid diet because the digestive tract cannot handle solid feeds until approximately eight days of age. One must also control the volume of food intake and the frequency of feeding. Above all, cleanliness is of paramount importance and this necessitates the provision of a washing, and preferably, a sterilising facility. The net result is that such equipment carries a very high overhead cost which, in addition to the technical expertise required to oversee, is too much of a burden for commercial pig production. However, for research purposes such an investment could be justified.

Method 2 has been used in commercial practice. Basically it is the Biehl system which was developed in Germany in the mid-1960's. Weaning at four days of age or 1·2 kg (2·65 lb) (Biehl regarded weight rather than age as the important parameter) still permits a fairly high mortality during the sow-rearing stage. Again, the piglets must be weaned on to a liquid diet with the additional conditions liquid feeding requires. Biehl maintained his piglets individually in cages 305 mm x 457 mm (12 in x

** Presented at the Annual Conference of the Institution of Agricultural Engineers at the Institution of Civil Engineers, George Street, London SW1 on Tuesday 9, May, 1972.*

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18 in) until 28 days of age and feeding was adjusted so that 28-day weight was 11 kg. From 28 days until three months of age 25 kg (55 lb) the pigs were housed in flat-deck wire cages in groups of 20-25. From three months onwards the pigs were moved to the fattening units where they were housed on concrete floors.

Method 3 is currently the latest commercial introduction. This system also subjects piglets to the dangers of life during the first seven to ten days post-partum. However, weaning to a solid diet has several advantages. Piglets appear to regulate their food intake adequately. The risk of bacterial contamination of the feed is much reduced and consequently the elaborate cleaning facilities necessary in a liquid system of feeding are not required. Again, piglets are weaned preferably on a weight basis and 2 kg (4·41 lb) is recommended. At first the piglets are placed in tiered cages in groups of nine. They are transferred to second stage flat-deck cages when they reach 7 kg (15·5 lb) (at approvimately 30 days) where they are maintained in groups of six. At 23 kg (51 lb) (eight to nine weeks) they are removed and can be placed in conventional fattening pens. The developers of this system claim a mortality figure of 1 per cent or less from the time the piglets are placed in cages (cf 4·5 per cent mortality among conventionally reared piglets between one and eight weeks of age). However, the assertion that a 1 per cent mortality may occur can mask one inherent danger encountered in artificial rearing. Most workers employing artificial rearing techniques have reported considerable success initially followed by a major loss or breakdown.

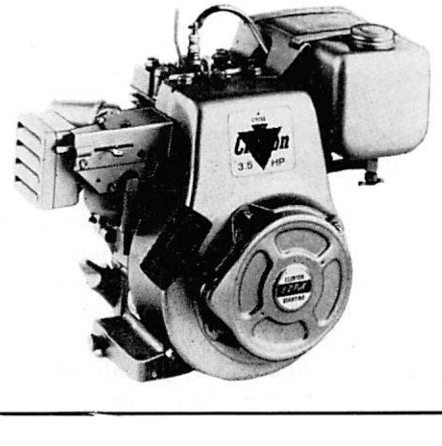
At the National Institute for Research in Dairying, Dr Braude has suggested that it is the complete or almost complete loss of a batch of pigs which illustrates the problems still involved in artificial rearing. However, there must be a causative agent in these breakdowns.

Three obvious factors present themselves; nutrition, hygiene and the physical environment. If one follows a tested and previously successful nutritional regime, it is unlikely that it will lead to heavy losses if the feeding programme is followed carefully. Poor management standards may implicate nutrition by allowing contamination of feed, etc.

The maintenance of a high standard of hygiene is imperative. Piglets are immunologically insufficient until they are approximately three weeks of age and a severe bacterial challenge will prove fatal. Consequently equipment should be designed in which there are no corners or ledges where feed can accumulate and any wasted food should fall away from the reach of the pigs. Perhaps the most important design feature is the facility to partially dismantle and thoroughly clean between batches of pigs.

The importance of the physical environment cannot be over-emphasized. The thermo-regulatory mechanism is poorly developed in young pigs, and it is essential to maintain a draught-free environment. At birth a temperature of 31°C is required. This should be reduced by 1°C per week. Humidity also has an optimum level and most workers agree this lies between 40 and 60 per cent with the higher levels during the first week post-partum. The ventilation requirements recommended for the third system described are 1-3 m^3/hour kilo (0·27-0·80 ft^3/min lb) liveweight. To prevent draught problems it is suggested that the maximum air speed entering the room should not exceed 60 m/min (197 ft/min). These recommendation must be regarded as guidelines for work in North Carolina has shown that piglets can be successfully reared from birth using a similar temperature programme but without forced ventilation. This led to humidity levels in excess of 90 per cent at certain times of the year. In that situation success may have been to the constant nature of the environment.

The Winter 1972 and Spring 1973 issues of THE AGRICULTURAL ENGINEER are being combined and published on 15 February 1973 in order to include in full the papers read and discussions on Sugar Beet and Potato Production in Europe, at the Autumn National Meeting on 2-4 October 1972, at *NCAE*, Silsoe.



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ENGINEERING FOR PIG PRODUCTION

Edited Summaries of Discussions

Morning Discussion

President (Mr C. Culpin, *ADAS*) invited Mr Michael Nicholson to open the discussion saying that he was well qualified to do this job as a farmer who followed new developments in pig husbandry wherever they occurred and was an authority on this subject.

Mr M. Nicholson (Farmer, Bicester) took up the point that Mr Payne made in his paper that savings in labour through mechanisation may not appear particularly attractive. He said that claims had already been made for increases in agricultural wages by as much as 50 per cent and in the future it would probably mean making better use of expensive capital equipment with this valuable labour, or, in fact, in the farmers doing the jobs themselves. He quoted an American farm he had visited where there were 500 head of beef cattle, and a pig herd of 180 sows selling over 3000 pigs for slaughter each year. One man did all the growing of the corn for the animals and took care of the livestock and managed generally to finish pig work by noon each day. It was also clear from this example that automation did not necessarily lead to bad husbandry.

In a further reference to Mr Payne's paper he pointed out that there was no mention made of pneumatic feed conveying. Again quoting from American farming Mr. Nicholson stated that he seen farmers whose size of enterprise was limited by the number of units that could be fed from one mill and this depended on the distance that these units could be sited from the blower on the mill. Mr Nicholson asked for information on the control of electric heating lamps for piglets since he felt that the only control available now was to raise the height of the lamp and in that way electricity bills became unnecessarily large. He also made the point that weighing is an extremely difficult job, particularly on a family farm, and that information on automated pig weighing would be an advantage. In a final question he asked for information on the effect of light on the heat cycle of pigs and on the intensity of the cycle, since farmer friends of his had been caught by power failures and had found that their sows were delayed in coming into heat by as much as six days from normal.

Mr C. G. Pointer (*ADAS*) answered the question on temperature control for the sow and piglets. The Americans have used piped cool air directed towards the sow's head and directed away from the piglet lying area for control of temperatures. He had no personal experience of thyristor control of lamps in farrowing rooms, but felt that there were those present in the audience who could give some information on this question. On the question of light and sows the Russians have shown that gilts come on heat for longer periods more strongly and at more regular intervals when exposed to 18 hours day length rather than six hours. The response with sows however is less marked. They are now interested in exposing sows to 18 hour day lengths from the time of farrowing right the way through to the service period in the belief that they will get responses in this way.

Mr J. I. Payne (*ADAS*) took the opportunity of quoting labour utilisation figures for pig feeding that he had not had time to quote when reading his paper. For example, continuous mixers with manual valves at the pens averaged 4·7 man minutes per 100 pigs fed per feed and the same system with automatic valves at the pens averaged 1·5 man minutes per 100 pigs fed. On the question of the cost of automation he quoted from his survey of pig feeders that the least expensive continuous mixer with automatic valves cost in 1970 £1·67 per pig place installed. The least expensive continuous mixer on a manual system cost £1·37 per pig place in 1969 and was for 1700 pigs rather than 3000 pigs as was the case for the automated system. These figures suggest that the difference between manual and automatic systems may not be enormous, but it should be borne in mind that these quoted figures are for quite large herds.

Mr P. O. Wakeford (Electricity Council) stated that thyristor controls for infra red lamps are available but cost was a problem. There are dimmer switches available but the cost is about £5 for each 250 watt lamp. A less expensive way may be to use auto-transformers to control four lamps at a time.

Mr M. J. Stansfield (*NIAE*) described the *NIAE* pig weigher incorporating a handling crate followed by a weighing crate, each with automatic gates operated by compressed air to control the movement of the animals. The weighing crate made use of an electrical transducer, and the output was displayed or printed and could control colour marking of the pigs or a divertor gate. The machine was in the prototype stage and would be shown at the Royal Show.

Mr W. Marshall (*BOCM*) made the point that a manufacturer would be demonstrating a power reducing control for infra red lamps at the forthcoming Pig Fair at Stoke Mandeville.

Mr F. Roberts (Big Dutchman) thought that the conversion ratios quoted by Mr Pointer were exceptionally high and he would be seriously concerned if his customers operated at this level. He made a plea for specialised labour for pig work and a high degree of mechanisation to feed pigs and remove manure and so free the specialised labour for the more highly skilled husbandry work. Mr Roberts stated that gas heating has been used for warming piglets with individual thermostat control of each unit, and was apparently successful.

Mr C. G. Pointer (*ADAS*) said Mr Roberts appeared to have misunderstood his statement. The conversion ratios he had quoted were not put forward as an optimum but solely as the result of the experiments which showed clearly that within reason the warmer the piggery the better the pigs did.

Afternoon Session

The Chairman (Mr J. C. Hawkins, *NIAE*) invited Mr ffiske (Stockbuild Ltd, Salisbury) a farm buildings consultant, to open the discussion from the floor.

Mr G. D. ffiske congratulated the speakers on the excellence of their papers. His first question to Dr Perry concerned the possibility of using a second stage cage alone for rearing from three weeks onwards. He had two years experience of cage rearing where a high cost was involved in providing the suitable environment but where they could still not achieve the 2·7 litters required for economic operation. His second question addressed to Mr Carpenter was on whether or not it was possible to discover the efficiency of the utilisation of air within a building.

He asked Mr Pointer if any work had been done on linking the ideal environment with the nutritional values of feed fed to pigs. The final point made was that it was not simply the cost of feed distribution or capital cost of equipment that interested the farmer most. It was the cost of the total installation and the economic return from the installation at the end of each batch of pigs that was of importance.

Dr G. C. Perry (Bristol Universtity) said he was quite sure that the reproductive performance of the sow was still the major stumbling block. He had not yet found anyone who had consistently been able to get sows back in pig within two weeks of weaning although this is possible experimentally with the use of hormone injections. On the question of moving pigs straight into a second stage cage this is probably on. There seems to be little problem in getting sows back on heat after three week weaning and generally the quicker pigs can be got away from the sow the less variable is the performance of the litter likely to be. If there are underweight pigs in a litter they will suffer less disadvantage the earlier they are taken off the sow and the sooner you start regulating food intake to all pigs. Much work still remains to be done on this subject.

Mr G. A. Carpenter in answer to Mr ffiske said that the techniques for tracing air movements by bubble patterns were useful for the dominant air paths only and they did not determine the degree of recirculation. Work was in progress at the *NIAE* using sulphur hexafluoride as a tracer gas in an attempt to sort out this problem. The work will be difficult.

Mr C. G. Pointer answered the question on nutritional/environmental interactions. He quoted work of the 50's and early 60's which showed that a higher energy level diet led to pigs withstanding cold slightly better than ones on a lower energy diet. This work is being continued at Babraham. While this is obviously of considerable interest it is not only the energy of the diet that is important but the wide range of feeding levels practised on commercial farms.

Mr J. I. Payne answered the question on total pig installation rather than feeding equipment only costs. There is a wide range of floor area used per pig in pig buildings and a considerable range in the area occupied by trough space per pig. The normally accepted figure for increase in population when pigs are floor fed rather than trough fed is of the order of 14-16 per cent. With dry feeding systems all the pens are fed simultaneously so that there is no stress on the pigs, whereas with liquid feeding, even with automatic valves, there will be some delay. The extent of the delay will depend on the type of system and the number of pigs being fed and the investigation carried out by *ADAS* showed that pigs were being fed at the rate of about 66 pigs per minute, or roughly 10 minutes to feed a house of 600 pigs. The actual value of that time in terms of stress is not known. An advantage of liquid feeding is that a relatively unsophisticated farm food processing plant can be used because the mixing can be done in the actual liquid mixer. Dry feed systems generally require pellets, and once you are committed to pellets you may require a much more expensive farm food processing plant.

Mr R. B. Osborne (Meat and Livestock Commission) mentioned the 0·2 food conversion advantage in wet feeding mentioned by Mr Pointer. This figure was arrived at putting water on top of meal already placed in the trough by hand rather than by a mechanical pipeline feeding system. He questioned whether in the light of *MLC* work on pipeline feeding whether the advantage in conversion ratio was dependent on engineering limitations.

Mr C. G. Pointer had reservations on the use of uncontrolled survey data for this type of calculation. An unsophisticated pipeline system at Great House *EHF* had shown an advantage for liquid feeding.

Mr J. I. Payne (*ADAS*) confirmed the satisfactory results obtained at Great House where the liquid feed fed in troughs conversion was 2·95, and meal fed on the floor was 3·8.

Mr W. T. A. Rundle (Wright Rain) said that Mr Pointer had been quite specific on widths of slats and gaps between slats in his talk. He asked for information on current research work on this question.

Mr C. G. Pointer (*ADAS*) said that a great deal more information was still required about slats. He felt that the problem had been more in quality of slats, particularly very sharp edges to the slats and irregularly sized gaps rather than the exact dimensions. Some work had been done in Scotland and in Europe but there was very little fundamental work that had been written up in this country as far as he knew.

Mr A. M. Robertson (Scottish Farm Buildings Investigation Unit) said that they were involved in a limited study of slats for dry sow stalls and they considered design and installation to be critical. He felt that with many more firms now involved in the manufacture of slats there was if anything more room for quality than there had been previously and there were some very badly cast slats on the market.

Mr R. Q. Hepherd (*NIAE*) pointed out that one advantage of dry feeding systems for pigs was that when they fail it is possible to repair the system before the next feeding time comes round. With pellet feeding the dispensers can be filled while the pigs are eating the feed that had just been dispensed and you have a 12 hour period in which to put right any mechanical problem that may have arisen. People did not generally like to have a lot of liquid feed lying around for 12 hours before feeding. He went on to ask Mr Payne how important he thought that dust problems were going to be in the future. One of the obvious advantages of liquid feeding systems is that there is very little dust except dust from the pigs themselves which he thought could be significant.

Mr J. I. Payne (*ADAS*) agreed with Mr Hepherd that there was an advantage in dry feeding in that more time could be available for repairs. He pointed out that the Dutch are using a swinging front gate to pig pens so that liquid feed can be placed in the troughs but not made available to the pigs until the gates are released. This would give the same available repair time as a dry feed system but is, of course, an expensive addition to a piggery. On the question of dust he agreed that it was important but felt that there were ways of overcoming dust problems with dry feed systems. Developments which would allow relatively dust free feeding of dry feed would be seen in the near future.

Mr G. D. ffiske (Stockbuild Ltd) agreed that dust should be eliminated and felt that an improved form of pellet was the best possible line of development.

Mr C. G. Pointer (*ADAS*) said that work published by the *NIRD* showed that dust from spores in hay and straw might be a serious problem in calf rearing. In pigs the situation is slightly different in that the animals themselves generate a lot of dust and there is undoubtedly still plenty of dust in wet fed houses. On the question of the economics of dry versus wet feeding he thought there was very little in it unless the farmer could be sure of maintaining high stocking densities throughout the year in ordinary fattening houses. If he was not able to maintain these superb stocking densities it became a matter of what suited the farmer as to what he installed.

Mr M. J. B. Turner (*NIAE*) had been working on one man pig weighing systems for about six months and made two comments. The first was that one man pig weighing is all very well provided one man can get the pigs out of the pen. This is difficult in many cases and is a point that should be noted by building designers. The second point was that he had noted as much as 40 lb weight range in a pen of 15 pigs and found it difficult to see how you could accurately restrict feeding with this range of pig weights.

Mr C. G. Pointer (*ADAS*) said that Mitchell of *NIRD* had published a paper on the variation of feed taken in and also the feeding position of the pigs at the trough. Near the outside of the pen the same pigs appeared nearly every time but in the middle of the pen there was a certain interchange of position. You therefore have to have reasonable distribution of feed because pigs tend to have habitual spots at which they feed. The second point was that there was something like a 20 per cent variation in feed intake, for pigs of roughly the same weight at the start of the experiment, with the same opportunity to take in the feed. This suggests that any work pretending to confer too great a degree of precision on the question of feeding is not possible. Further work indicated that it didn't really matter to the pig if it had $4\frac{1}{2}$ lb of feed one day and $5\frac{1}{2}$ lb the next day provided it got its complete entitlement of possibly 35 lb per week.

Mr J. R. Latta (Ardleigh Spraying Co.) asked what proportion of ventilating air was used for noxious gas removal and what proportion for heat removal or how much oxygen is actually required by the pig.

Mr G. A. Carpenter (*NIAE*) replied that if humidity is satisfactory oxygen concentration is not likely to be critical. Although ventilation rates are greatly reduced in winter they are normally above the minimum safe limit below which high humidity, high carbon dioxide content, high ammonia content, high dust content, and high micro organism content will cause problems. Under these winter conditions, 80 per cent of the heat may be leaving the building in the ventilating air while the remaining 20 per cent is conducted loss through the structure.

Dr G. C. Perry (Bristol University) agreed with these comments. He mentioned a unit in which the ventilation system maintained house temperature satisfactorily but when the unit was opened first thing in the morning there were ammonia levels of over 60 parts per million present which, when considered against levels of five parts per million that can be detected by smell, was fairly strong. It is possible in this situation that reproductive problems may arise because boars may not be able to detect heat in sows as the smells are lost in the noxious gases. A further problem with the design arose because the air was extracted immediately above the boar pen, the smell was immediately removed from the building, and the sows missed the stimulation to come on heat normally provided by the smell of the boar.

Mr C. G. Pointer (*ADAS*) quoted carbon dioxide levels of up to 1·20 per cent in sweat houses, against 0·30 per cent as a high figure in the normal fattening house, without any vice or other problems appearing. This was in conditions of high temperature and high humidity and would probably have lead to serious tail biting in orthodox houses. Danish work showed an increase in vice as stocking increased but the problem should not be taken out of proportion. For example *NAAS* did a survey of 69 fattening piggeries three years ago and was surprised how little vice was found.

Dr G. C. Perry (Bristol University) said that cage reared pigs generally have no vice problems either of tail biting or licking the skin of other pigs. He stated the need for care in the definition of boredom and pointed out that a well satisfied pig was prepared to sleep for 80 per cent of its time and apparently does so without becoming bored. At intervals something appears to go wrong and vice begins. We don't really understand what boredom is in this context.

Mr J. A. C. Gibb (Reading University) asked about an American commercially built cage rearing system aimed at rearing batches of about 180 piglets up to 21 or 28 days of age. In a second question he asked if it was not the case that the engineering aspects of artificial rearing systems are fairly straightforward but that the management problems of pig production make it difficult to operate.

Dr G. C. Perry (Bristol University) replied that the American commercial system had not been popularly taken up. He thought the success of such a system must depend on an all-in and an all-out system, which demanded 180 pigs coming in at one time with a thorough cleaning programme between each batch. He felt that the general cause of failure was slackness in hygiene and that in most commercial cases the story is one of complete success followed suddenly by complete failure.

The reason for failure is poor hygiene and problems of getting a proper throughput of pigs are more an excuse than a reason for failure. In reply to a further question from Mr Gibb, Dr Perry agreed that in fact you had to have an additional system to take care of overflow piglets. In practice only a small proportion of the total number of piglets born are cage reared and the rest are either conventionally reared or sold off at an early stage.

Mr K. A. Pollock (Newcastle University) asked if any of the speakers saw any moral constraint on the pig production systems in use today.

The Chairman (Mr J. C. Hawkins, *NIAE*) asked if the speakers in turn would attempt to answer this difficult question.

Mr J. I. Payne (*ADAS*) pointed out that his chief concern was feeding and removing waste from piggeries and that everything he was concerned with was complementary to good husbandry.

Dr G. C. Perry (Bristol University) said that much depended on the news media passing information to the public. For example in recent weeks the *News of the World* had discovered sow farrowing crates, although they have in fact been in use for many years. It is likely that legislation is imminent on certain issues and it was his personal responsibility at the moment to attempt to assess the position of the animal in the intensive production situation and to measure such factors as "stress". In most cases the reason for objecting to present pig keeping systems is solely emotional since there is no evidence that the performance of the animals in economic terms is being impaired.

Mr C. G. Pointer (*ADAS*) said he felt that farmers had the welfare of their animals very much at heart although some suffering had perhaps been inadvertently caused by things like slats and neck ties for sows in the early stages of their development.

Mr G. A. Carpenter (*NIAE*) thought that while many farm animals are to some extent restricted there is no evidence that they are being subjected to any cruelty. He thought however that the atmosphere in some piggeries that he had visited was very poor and he would be concerned about it if it were his own piggery.

The Chairman (Mr J. C. Hawkins, *NIAE*) said that work was going on at places like the Institute of Animal Physiology Babraham, and Liverpool University aimed at quantifying some of the emotive subjects involving animals.

Mr M. Nicholson (farmer and member of the Farm Animals Welfare Committee) took up Mr Pointer's earlier remark that pigs are very adaptable animals. He felt that this may be unfortunate since if they were less adaptable they may have been subjected to much less strain. He felt that not enough farmers were dissatisfied with the way they were putting sows into stalls initially. Mr Nicholson felt that things were not good enough yet and much work remained to be done.

Mr E. H. Mander (Farm Buildings Association) wondered if dust from the skin of the pigs which causes an allergy in some humans may not be a possible reason for tail biting and vice in the pigs themselves.

Mr P. G. Finn-Kelcey (consultant, Hampshire) asked Mr Carpenter about an index of comfort which he mentioned in passing in his paper. The principle is that pigs would be kept at one temperature but at reducing humidity as they grow older.

Mr G. A. Carpenter (*NIAE*) said that he had personally done no work on this subject and felt that it was an extremely complicated combination of temperature, air velocity, and humidity which needed further investigation.

Mr G. C. Pointer (*ADAS*) said that there was no British experimental work on humidity levels and he questioned the need to start small pigs at very high humidity levels. In fact with cage rearing systems there is a tendency to start them at low humidity levels in order to keep floors dry in an attempt to minimise cross infection. This however may be a completely false line. The first paper in this country on comfort index was by David Sainsbury in his *PhD* thesis in 1954. This related air speeds with air temperature for different weights of pigs based on measurements that he had made in commercial piggeries.

The Chairman (Mr J. C. Hawkins, *NIAE*) closed the discussion with the comment that we had today heard from engineers and animal husbandry specialists dealing with their particular parts of the subject. There were however many other specialists, for example animal behaviour specialists, veterinarians and architects as well as husbandry specialists who could have been included in such a discussion. The one person who could act as leader of such a team is likely to be the agricultural engineer because his training spans several of these disciplines.

The President (Mr J. A. C. Gibb, Reading University) finally thanked the speakers, the chairman, and those concerned with the organisation of the day's conference.

THE INSTITUTION TIE

Members of the Institution are entitled to wear the Institution tie. As well as being an attractive emblem of membership in its own right it is also a particularly useful means of recognition at meetings, exhibitions, agricultural shows and other events at which members are likely to congregate. The tie is made of crease resisting and hard wearing terylene to a pleasing design displaying in silver the Presidential Badge of office on a background of navy blue, dark green or wine, according to individual taste. Institution ties are available strictly to members only and cost £1 each; any number may be obtained in any of the three colours mentioned. Remittances should be made payable to "I Agr E" and crossed.

ADMISSIONS AND TRANSFERS

AT a meeting of the Council of the Institution on 20 July 1972 the following candidates were admitted to the Institution or transferred from one grade to another.

ADMISSIONS

MEMBER

Badola, J. R.	*London*
Green, E.	*Essex*
Herbert, J.	*Netherlands*
Izugbokwe, I. S.	*Nigeria*
Jackson, A. K.	*Bedfordshire*
Saywood, A. E.	*Essex*
Veall, F.	*Berkshire*
Watt, C. D.	*Bedfordshire*

GENERAL ASSOCIATE

Barclay, A.	*Kilmarnock*
Eglin, D. M.	*Warwickshire*
Gormley, M. W.	*Wiltshire*
Hiscox, C. L.	*Norfolk*
Lanning, E. C.	*Surrey*
Leith, W. F.	*Midlothian*
Scott, R. N.	*Malawi*
Smithwaite, T.	*Yorkshire*
Teale, W. G.	*Nottinghamshire*
Turner, W. D. G.	*Fife*

TECHNICIAN ASSOCIATE

Britain, J. W.	*Yorkshire*
Parminter, I. D.	*Huntingdonshire*
Sangster, G. B.	*Selkirk*
Southcott, T. J.	*Devonshire*

GRADUATE

Kyei, N.	*Ghana*
Rice, J. S.	*Hertfordshire*
Richardson, L. I.	*Lincolnshire*
Thirtle, P. J.	*Shropshire*
Williams, W. A.	*Sierra Leone*
Yardley, R. W.	*Lincolnshire*

STUDENT

Bowler, D.	*Bedfordshire*
Endale, D.	*Bedfordshire*
Johnson, G. C.	*Bedfordshire*
Tobutt, J. H.	*Kent*

TRANSFERS

FELLOW

Baldwin, A. L.	*China*
Moorhouse, K.	*Sussex*

MEMBER

Abanyie, G. A.	*Ghana*
Beatty, J. D.	*Stafford*
Bennett, C. J.	*Portugal*
Carpenter, P. W.	*Cambridge*
deHeer, J. P.	*Ghana*
Fry, J. R.	*Somerset*
Lyne, J. W.	*Berkshire*
Redman, P. L.	*Caernarvonshire*
Saunders, P.	*Kent*
Smith, E. T.	*Roxburghshire*
Stevenson, R. M. A.	*Swaziland*

TECHNICIAN ASSOCIATE

Cox, L. K. O.	*Bedfordshire*
Duncan, R. D.	*West Indies*
Hawthorne, M. A.	*West Lothian*
Haynes, J. R.	*Essex*
Hulbert, P. J.	*Yorkshire*
Lydford-Smith, A.	*Worcestershire*
Massey-Crosse, A.	*South Africa*
Parkin, R.	*Suffolk*
Watson, D. J.	*Suffolk*
Whittall, R. W.	*Rhodesia*

GRADUATE

Moseley, B. A.	*Lancashire*
Scaramanga, D. G. A.	*Zambia*

Display advertisements are now being accepted for the combined Winter/Spring issue, published 15 February. The copy date for these and all Editorial contributions is 1 December.
Branch secretaries please note the latter.

AROUND THE BRANCHES

South Eastern

THE South Eastern Branch of the Institution held its last function of the season on 8 June, when about 30 farmers joined another 30 people comprising officers of the Institution and students from the Mechanisation Department of the Essex Institute of Agriculture. The Institution organised a tour of the Ely-Ouse water scheme. This £9,000,000 feat of engineering can bring up to 100,000,000 gallons of water a day from the fens down into Essex.

The first season of this new branch produced a quite reasonable response. Attendance at meetings was over 70; the lowest was about 40 and that was during a scheduled power cut during power cuts in the Spring. Participation by local farmers and manufacturers was most encouraging.

Yorkshire

MANY agricultural engineers have only the vaguest notion of the extent of "environmental control in glasshouses". At the Yorkshire Branch's first meeting of the season on 15 September, many eyes were therefore opened in the course of the presentation of a paper under this title by Mr R. E. G. Kendall, *ADAS* Horticultural Advisory Officer. The subject was made even more meaningful in that the evening's programme included a tour of the glasshouses at the Askham Bryan College of Agriculture and Horticulture, York, where the meeting was held.

Three aspects of the environment must be considered: atmospheric, terrestrial and radiation, and Mr Kendall in turn discussed the various components of each. The temperature, humidity and gaseous concentrations in the atmosphere are of course closely related and any absolute, independent and uniform control of each is not practicable, even if there were a concensus of agreement as to what are the optimum levels of each for any particular crop at a given stage in its growth.

Programmed watering devices coupled to the automatic addition of nutrients, give the grower great advances in control of his crops and are much improving productivity.

Radiation is very much accepted as "sent" but Mr Kendall sounded a warning regarding "plastics houses" in which the net radiation can often be out of the house, resulting in soil temperature in the house being lower than that outside.

BRITISH STANDARDS

Tightening Up on Loose-Leaf Publication

INFORMATION which is issued in loose-leaf form for "easy amendment" has for many years been a source of annoyance and inconvenience to librarians and other users. The task of sorting amendments and then up-dating the existing information is tedious and time-consuming. After a time binders become bulky and awkward to handle, and sometimes it is difficult to tell whether a work is fully amended. A new Draft for Development *DD* 20 *Recommendations for loose-leaf publications,* published by the British Standards Institution, attempts to solve some of these problems.

BSI has published the recommendations in the form of a Draft for Development because more information is needed to show what degree of uniformity can be applied to all the different kinds of loose-leaf publication.

The draft points out that loose-leaf publications have disadvantages as well as advantages and that it is sometimes simpler to publish revised editions at frequent intervals than to provide an amendment service. It draws attention to matters which should be considered in the choice of binders, paper and other materials and recommends methods of amendments which provide for such matters as recording amendments, identifying amendment slips, ensuring continuity of page numbering and up-dating indexes.

DD 20 Recommendation for loose-leaf publications, price including postage £1 (plus 20p for orders under £2). From BSI Sales Branch, 101 Pentonville Road, London N1 9ND.

Profiled Aluminium Sheets for Building

THE British Standards Institution has published *BS* 4868: 1972 *Profiled aluminium sheet for building,* a new British standard which includes both the corrugated and troughed aluminium sheet previously covered by *BS* 2855 and *BS* 3428, and supersedes these specifications. The dimensions of the sheets are now expressed in metric terms and tolerances are included.

Details of the material to be used, the profiles of three types of sheet, dimensions and tolerances and finish are given.

BS 4868: 1972 Profiled aluminium sheets for building, price, including postage 85p (plus 20p for orders under £2). From BSI Sales Branch.

Metric Standard for Farm Buildings of Framed Construction

THE British Standards Institution has published *BS* 2053: 1972 *General purpose farm building of framed construction,* a revised standard which is in metric units for the first time. Certain basic data have been brought up to date in this edition and dimensional co-ordination has been introduced.

The standard sets out basic design data and recommendations for general purpose single storey farm buildings of framed construction, adequate for a wide range of farm uses.

The revision of this standard is intended as an interim measure pending the publication of a new Code of Practice, now in course of preparation, which will embrace all types of farm construction.

BS 2053: 1972 General purpose farm buildings of framed construction, price, including postage 85p (plus 20p for orders under £2). From BSI Sales Branch.

The Editor regrets any inconvenience caused by the late publication of this issue of THE AGRICULTURAL ENGINEER, caused by the late arrival of essential editorial matter and non arrival of other matter.

FORTHCOMING EVENTS

Dates in this diary are published in good faith, but readers are asked to check with official sources as an alteration may have occurred after publication.

November	
16	*IAgrE* East Anglian Branch Conference. *Home Grown Cereals—Economic and Engineering Aspects,* at Norfolk School of Agriculture, 10 45 h.
18	*Change and Adjustment in Agriculture and the Countryside,* one day conference organised by The Association of Agriculture, at The London School of Economics, Houghton Street, Aldwych, London WC2.
20	*IAgrE* South East Midlands Branch meeting. *Design of Agricultural Machinery in Relation to Safety, Operator Comfort and Convenience,* at the National College of Agricultural Engineering, Silsoe, Bedford, 19 30 h.
23	*IAgrE* Yorkshire Branch Forum. *Tractor Test Reports—the Farmer's "Which?",* at Lupset Hotel, Horbury Road, Wakefield, 19 30 h.
January	
18	*IAgrE* Yorkshire Branch meeting. *Farm Transport and Bulk Handling,* at College of Agriculture and Horticulture, Askham Bryan, York, 19 30 h.
22	*IAgrE* South East Midlands Branch meeting. *Probelms in Fen Drainage,* at the National College of Agricultural Engineering, Silsoe, Bedford, 19 30 h.
31	*CIGR* Section IV 5th International Working meeting, in West Berlin, until 3 February.
February	
15	*IAgrE* Yorkshire Branch meeting. *Our Mechanised Farms and the EEC,* at Lupset Hotel, Horbury Road, Wakefield, 19 30 h.
16	*IAgrE* East Anglian Branch dinner dance, at Kings Head, Diss, 19 00 h. for 19 30 h.
22	*NIAE* Subject Day on the *Mechanical Behaviour of Agricultural Soils,* 09 15 h.
March	
5	*IAgrE* South East Midlands Branch meeting. *Herbicides and the Agricultural Engineer,* at the National College of Agricultural Engineering, Silsoe, Bedford, 19 00 hr.
15	*IAgrE* Yorkshire Branch annual general meeting, followed by *Steering Layouts of Large Agricultural Tractors,* at Griffin Hotel, Boar Lane, Leeds 1, 19 30 h.
23	*IAgrE* East Anglian Branch annual general meeting, followed by *The Fisheries Laboratory, Lowestoft,* at Scole Inn, Diss, 19 30 h.
15	*IAgrE* Yorkshire Branch meeting. *Articulated and Conventional Steering,* at the Griffin Hotel, Leeds.
April	
6-15	*FIMA/73,* Zaragoza, Spain.
8-13	1st International Green Crop Drying Congress, at Oxford University.
10	*IAgrE* Yorkshire Branch meeting. *The Effect of Regulations on a Tractor Braking System,* at University of Leeds, Department of Mechanical Engineering, 19 30 h.
12-14	5th International Agricultural Mechanisation Conference, *Irrigation and Drainage—New Mechanical Technologies,* at *FIMA/73.*

The Editor welcomes notification from branch secretaries of dates of future branch meetings and events of interest. Each notification should include the date, venue, time and names of any guest speakers. Notifications of events taking place after 15 February must be with the Editor by 1 December.

INSTITUTION NOTES

Institution Council for 1972-73

President:	*Mr J. A. C. Gibb MA(Cantab) MSc FRAgS MemASAE FIAgrE.*
President-Elect:	*Mr J. V. Fox NDAgrE NDA FIAgrE.*
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Hon. Treasurer:	*Mr J. C. Turner FIAgrE.*
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	Mr F. Inns BA MA(Camb) MSc(AgrE).
	Mr R. H. Miers BSc CEng MICE.
	Mr R. F. Norman MSc(AgrE).
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	Mr E. H. Mander.
	Mr K. A. Taylor.
Graduate:	*Mr P. R. Phillips PhD BSc(Hons).*
Representative for Scotland:	*Mr C. J. Swan NDAgrE FIAgrE.*
Ex Officio:	*Chairman of the Examination Board Representatives of Branches.*

LETTER TO THE EDITOR

I HOPE that the article on *ERB* registration in the Spring issue does not reflect the considered attitude of the Council of the Institution towards negotiations with *CEI*. The use of emotive phrases like "pressure on the ring-fence" and "building a bridge into the jealously-guarded compound" will not improve the reputation of the Institution.

The issue is quite simple. *CEI* and the Chartered Institutions have been charged with the duty of establishing standards for professional engineering. I think that most of us who are both Agricultural Engineers and Chartered Engineers look forward to the time when we can be Chartered Agricultural Engineers; but the rules for admission to any professional organisation can only be made by the organisation, not by those who wish to join. The Institution of Agricultural Engineers has raised its standards a lot in recent years but not to the point where these are comparable with those of the Chartered Engineering Institutions. Instead of talking about building a bridge to *CEI*, it would be more appropriate to talk about building a ladder to reach the required level.

N. W. HUDSON *FIAgrE,*
Asian Institute of Technology, Henri Dunant Street, P.O. Box 2754, Bangkok, Thailand.

I agree entirely with your remarks about the question of maintaining standards and would emphasise the reference in my article to "suitably-qualified members" and "Institution members who already meet the criteria for Chartered Engineers, but cannot yet be registered because they are not members of a CEI *institution". Certainly we all have to abide by the rules and the point of the whole exercise is to find an approach for those who already meet the established criteria. As you will be aware, it is not a question necessarily of raising the technical standards of the whole Institution—desirable as this may be—but of enabling appropriately qualified members to fit into the established engineering hierarchy.*

I am sorry if you thought the phrases you mentioned were somewhat emotive, if so, I am sure that it only reflects the approach to the whole matter, which cannot be entirely free from emotion.—JACG.

METRICATION

Metrication Guides for Management

THE Metrication Board has produced a series of ten leaflets for managers in industry. This *MM* series gives simple guidance on the main points for consideration when a firm goes metric.

Check List for Managers MM1 suggests a ten-point approach to the task. These points are developed further in the other leaflets in the series.

Guidance on when and how to inform and train staff is contained in *Informing Personnel MM2* and *A Simple Training Plan for Industry MM3.*

Standards for Industry MM4 shows how international standards, British standards and company standards are related. It lists some useful reference publications. *Industrial Purchasing MM5* describes the important role of purchasing officers in implementing their company's metrication programme. *Engineering Design MM6* offers advice on how to go metric in the design office and on the benefits to look for. *Storekeeping in Industry MM7* outlines ways of approach-the storekeeper's task during the changeover.

Engineering Production MM8 deals with the basic approach to the conversion of machine tools. *Engineering Inspection MM9* considers how the inspection function is affected with particular reference to measuring and gauging equipment. Ways in which the sales department is involved in metrication and the opportunities provided are outlined in *Engineering Sales MM10.*

Leaflets in the MM series are available free from the Information Office, Metrication Board, 22 Kingsway, London WC2B 6LE. The reference numbers of the leaflets should be quoted as well as the quantity required.

NEWSDESK

CEI and RS on Metrication

THE Council of Engineering Institutions and the Council of the Royal Society have jointly studied the White Paper which sets out the timetable for metrication of weights and measures in the United Kingdom. They welcome the Government's initiative in this matter and wish to emphasise the importance of these decisions to British work in engineering, in technology, and in pure and applied science. The ultimate benefits to this country from adoption of a simplified and international common language of measurement will be very great. They will arise above all from improvements in communication between engineers, technologists and scientists; between them and their opposite numbers abroad; and between them and the general public. In an age when the benefits of technology need to be realised to the full, these matters have become of great importance, and it is therefore hoped that the momentum of the changes will be vigorously maintained.

Terotechnology in Action

THE Institution of Plant Engineers is to hold a series of conferences on applied terotechnology. The first such event—Terotech 1—will be held in Bristol from 9-12 May 1973.

Under the general heading of *Terotechnology in Action,* the programme will offer papers and discussion facilities for sounding out new ideas for industrial cost reduction.

Later terotech conferences will deal with more specialised aspects of terotechnology and a large scale terotech European international convention is another possibility being explored.

OBITUARY

E. B. Black

Mr E. B. BLACK *BSc(Eng) FIMechE FIAgrE* of Markhams, Church Street, Coggeshall, Colchester, Essex, died in July 1972.

C. A. Cameron Brown

Mr C. A. CAMERON BROWN *FIAgrE*, a past President and currently on the Council, died on 17 August aged 71 years.

Charles Alastair Cameron Brown was born in Leven, Fife, in November 1900. After graduating at Edinburgh University with a science degree he was initially employed as a trainee with the English Electric Company.

In 1924 he started work with the Institute of Research in Agricultural Engineering at Oxford—the predecessor of the National Institute of Agricultural Engineering—and this was the start of what was to become his life's work.

At that time only a very few farms had electricity and his terms of reference then were to look at ways in which electricity was at that time being used in farming, and how much various processes cost.

In 1938, the Electrical Research Association, then at Savoy Hill, London, set up a Rural Electrification Section and Mr Cameron Brown was the obvious choice to lead the venture as Senior Technical Officer.

During the next seven years, apart from his duties as a member of the Home Guard during the War, *CB*, as his colleagues came to know him affectionately, was mainly responsible for setting the pattern for rural electrical development after the War. He was actively associated with the *ERA* 11 kV single-phase line, which was used after D-day in France to set up distribution lines quickly, and was the basis for large scale development of electricity in rural areas in the post-war period.

But *CB* always had his feet firmly on the ground, and knew that apart from providing a supply of electricity to farms, it was in the *utilisation* of electricity in ways which were economic both for the farmer and the supply industry, that the best prospects for future development lay.

With very limited resources he set about finding ways of applying electricity more usefully on the farm. His policy was to get a new application out on the farm and tried there, as soon as he possibly could, but he was always wary of making claims for a process until thoroughly tried and tested under practical conditions.

Either directly or indirectly *CB* was involved as the *ERA's* Senior Technical Officer in the early and mid 40's in the development of the small automatic hammermill to replace the labour-intensive tractor driven mill, in the use of low loading storage steam to replace high loading steam raisers for sterilising dairy utensils, in the development of chilled water milk cooling, and in experimental work as early as 1945 on barn hay drying. He was also concerned in the development of uses of electricity in horticulture.

In this work he had the enthusiastic backing of a small band of supply engineers, particularly men associated with Edmundson's Electricity Corporation, who prior to nationalisation, were pioneers in rural development in several areas of the country.

It was therefore no surprise when Edmundson's offered *CB* an appointment as their Rural Development Superintendent in 1945, where he continued to develop the economic use of electricity on farms in a commercial atmosphere.

With the nationalisation of the supply industry in 1948, Mr Cameron Brown was appointed Agricultural Electrification Adviser to the then British Electricity Authority (later the Electricity Council), and this position he retained until his retirement in 1966.

This responsibility involved working with all the area electricity boards in England and Wales, and the south of Scotland. Each board was charged to supply electricity to the countryside as soon as practicable, and at the same time develop its use on farms.

In this latter responsibility boards' farm engineers were able to call on specialist advice from the Agricultural Section *CB* had set up, and this was backed up where necessary by ad hoc investigations carried out by his staff.

There developed a fruitful period of co-operation between boards' agricultural engineers and the Agricultural Section, led by *CB*.

CB was also associated with the setting up of several now well established organisations including the Society of Dairy Technology and our own Institution of Agricultural Engineers, and was honoured in 1962 by becoming its President.

The responsibilities which Mr Cameron Brown carried also involved overseas commitments and he was for many years this country's representative on the Rural Electrification Working Party set up by the Economic Commission for Europe's Committee on Electric Power.

In this role he was able to see developments in farming on the Continent, and one practical result of this was the introduction of the Dutch method of hay drying into this country.

One significant result of the Working Party's investigations showed that the *UK* has the highest average electricity consumption per farm of any country in the western world, except the American State of California.

Colleagues who worked with *CB* will remember him as one whose judgment they respected and many had cause to be grateful to him for practical help given. It is perhaps too soon after his death to assess the significance of his work objectively, but it would at least be fair to say that his pioneering spirit, enthusiasm and technical ability have had a lasting effect on the staff who worked under him.

Mr Cameron Brown leaves a widow and two sons.

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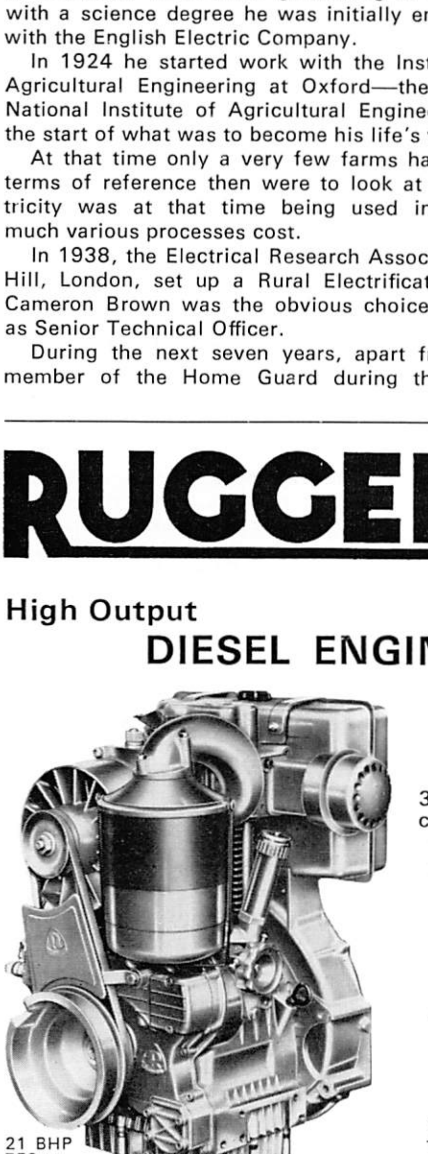
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J. F. Rickerby

Mr JOSEPH FORSTER RICKERBY *FIAgrE*, who was 53 years of age, died on 15 September as the result of a motor accident on the *M*6 motorway. Joe Rickerby, as he was known to his many friends and business acquaintances, was President of the Agricultural Machinery and Tractor Dealers Association for the years 1958-60, and followed this three years later as Honorary Treasurer. More recently, as Chairman of the Working Party, he took *AMTDA* into the computer era eventually bringing into being *AMTDA* Services Ltd (the Association's own "computer club").

A memorial service was held on 22 September at St Michael's Church, Stanwix, Carlisle.

PERSONAL

THE Agricultural Engineers Association have appointed a technical consultant. He is **Mr Claude Culpin OBE MA Dip Agric (Cantab) FIAgrE**, formerly Chief Mechanisation Adviser to the Ministry of Agriculture, Fisheries and Food, who will advise on technicai matters.

Mr Culpin was President of the Institution of Agricultural Engineers in 1971 and is the author of two standard books on farm mechanisation—*Farm Machinery* and *Profitable Farm Mechanisation.*

CHAIRMAN of the *AEA* Technical Policy Advisory Committee is **Mr Horace F. Howell**, European Engineering Liaison Manager of Massey-Ferguson Holdings Ltd. He is a Chartered Engineer, Fellow of the Institution of Mechanical Engineers and Fellow of the Institution of Agricultural Engineers.

THE governors, advisory committee members and staff of Rycotewood College set up a fund soon after the death of **Mr Douglas Bomford** to provide an award which would commemorate his long association with the College and help on innumerable occasions. The award was held in abeyance until a suitable occasion arose, but on 12 July a silver cup was presented by **Mr John Fox**, managing director of Bomford & Evershed Ltd, to **Mr J. R. Munro** (22), the outstanding student on the new City and Guilds 465 Part III course, which leads to Graduate membership of the Institution.

Sir Cyril English, Director General of the City and Guilds, was guest of honour at the prizegiving, but he stepped aside for Mr Fox to make the presentation because of the special associations relating to the award. Mr Munro is employed by Knee Agricultural Machinery Ltd.

PUBLICATIONS

NIAE Annual Report 1971/72

AMONG the many items included in the Annual Report for the National Institute of Agricultural Engineering 1971/72 are the undermentioned.

The introduction by the Director, Professor C. J. Moss, in which he emphasises the considerable efforts made to secure the best possible advice before starting new research.

A table showing how the Institute's budget of £1·2m for 1971/72 was allocated to various branches of agriculture and horticulture.

A list of the subjects on which there has been active collaboration between the *NIAE* and the *ADAS*.

Avoiding soil smearing and compaction by out of furrow ploughing: work on self-steering devices for out of furrow ploughing has continued and consideration is now being given to the construction of a third prototype for use with a reversible plough on a hydrostatically steered tractor.

Economy of cultivations: a description of recent trials to determine how best to reduce labour by using more tractor engine power. One year results suggest that two-pass cultivations using a bridge link to enable the use of combinations of complementary implements are economic and effective.

Wind tunnel simulation of fruit spraying in real orchards.

Progress in studies of engineering aspects of slurry disposal.

Work completed on mobile soil sterilisation steaming grid, now commercially available.

Annual Report, 1st April 1971—31st March 1972, price £1 from National Institute of Agricultural Engineering, Wrest Park, Silsoe, Beds., or Bush Estate, Penicuick, Midlothian.

1972 Yearbook of ASAE Standards

THE 1972 Agricultural Engineers Yearbook of official *ASAE* Standards, Recommendations, and Data is now available from American Society of Agricultural Engineers. This 610-page soft cover book includes 11 standards never before published. These involve such key subjects as the safety-alert symbol, hand signals, sleeve hitch for small tractors, and waste storage tanks. *ASAE* standards on safety for agricultural equipment, aluminium irrigation tubing, lighting of agricultural equipment on highways, design of surface drainage systems, are among those published with major technical revisions.

In addition to the 128 voluntary standards covered in the 1972 Yearbook, this edition also includes a classified directory of components, materials, and complete units of equipment manufactured by over 2,100 companies. A feature of this year's edition is reader service card for use in obtaining additional product information from the 81 Yearbook advertisers.

Other regular features of the Yearbook include Nebraska tractor test data; roster of *ASAE* committees, members, consulting engineers; educational programmes in agricultural engineering; and Society information.

Overall page size is 8¼ by 11¼ in. Scaled drawings indicate key items in specific standards. Price for the current Yearbook is $10.00. Contact:

American Society of Agricultural Engineers, PO Box 229, St Joseph, Michigan 49085, USA, price £ ($10.00).

Power on the Land

A NEW title in My Life and My Work—a career series by Educational Explorers, of Reading, England, is *Power on the Land (Agricultural Engineering)* by Mr Brian May *BSc CEng MIMechE NDAgrE MIAgrE*.

With 136 pp, hard covers, and measuring 5¾ in by 8⅜ in, this book, which is based on the author's own experiences in agriculture, is an excellent lead in to the industry for anyone undecided about his or her future.

Power on the Land (Agricultural Engineering) by Brian May, published by Educational Explorers, 40 Silver Street, Reading, Berks., price £1·50.

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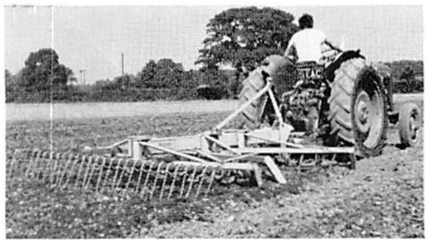

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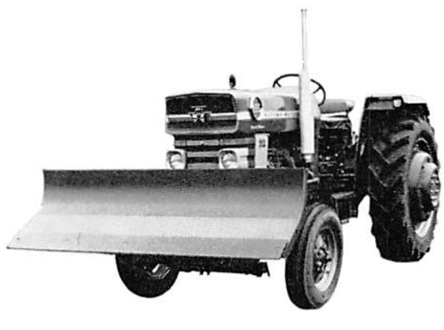

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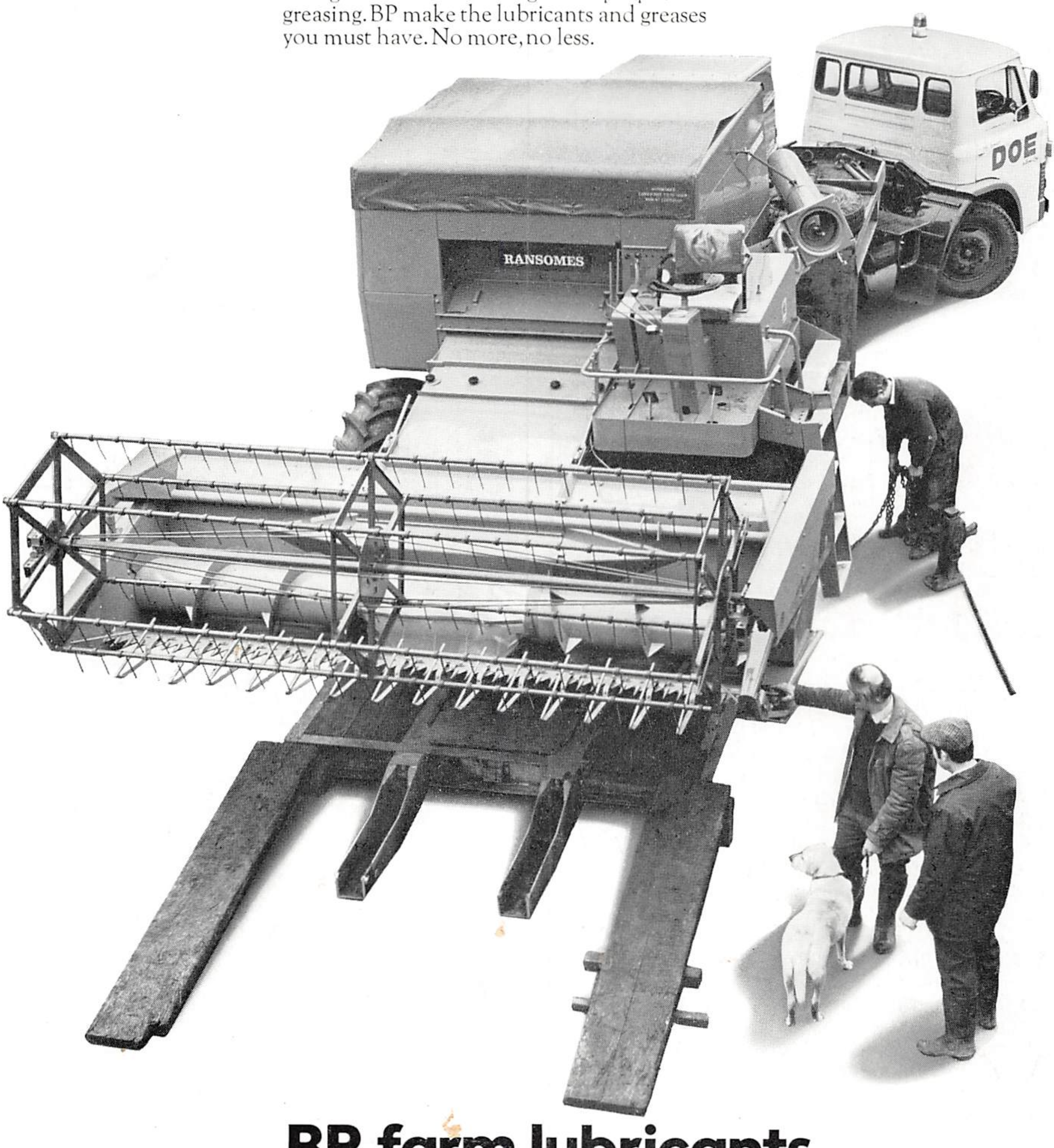

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