PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Versatility Versus Specialization in Cultivation and Harvesting for Crops and in Livestock Production [and Discussion]

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Versatility versus specialization in cultivation and harvesting for crops and in livestock production

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[Plates 1 to 4]

Agriculture sets difficult problems for the engineer because, although it is a vast industry in many countries, it is frequently organized in comparatively small production units. Furthermore, much of the work on the farm has to be done for short periods. Thus, the economics of farming often dictate that the engineering products to be used must be low in capital cost. These factors are discussed in relation to future developments.

The tractor is usually the source of power in many farm machines. Compared with other farm equipment, tractors are manufactured in large numbers in plants where capital investment is high and where radical changes in design are costly to introduce. In the last 30 years tractors have shown steady increases in power and sophistication which have enabled them to be used more productively. They are the outstanding example of versatility in farm equipment but their value could be increased in the future if research in progress on using the power of the tractor in different ways from the traditional for soil cultivation is successful. Consideration is given to the implications of this important aspect of husbandry practice.

The early tractor-drawn combine harvesters for cereal crops soon became self-propelled. Over the years, they have become more powerful and more complex; attempts by the research worker to produce an alternative way of separating grain from straw and chaff have shown promise and may lead to simpler and lighter machines by the 1980s.

At the other extreme, there are many valuable crops produced in relatively small quantities, but they are, nevertheless, an important constituent of the improving quality of life. The problems in harvesting such crops are often acutely difficult to overcome and a high degree of specialization in operation, and therefore of design, is essential. Attempts over many years to make some harvesting machines suitable for a wide variety of crops by successful and ingenious engineering design and development have, at best, enjoyed limited success and farmers will most probably require more and more special purpose machines for individual crops. However, it may prove possible to make economies in manufacturing and production costs by using common components and common sub-assemblies.

In future, livestock farms will need to use much specialized engineering equipment to maintain production with a much smaller labour force. The dairy parlour will require data processing equipment to enable men to milk and feed large herds of cows. It will be necessary to provide improved means for transporting and weighing food, better control of the environment for stock, and less time-consuming and unpleasant means of treating farm wastes.

The first two papers in this session on 'Power on the farm' have underlined the close relation between economics and engineering. This relation is one we cannot escape in agriculture any more than in other industries and we have to bring it into sharp focus if we are to use our resources to the best advantage. This is difficult but we should not lessen our efforts because of the difficulties but rather redouble them in order that our work shall be of the greatest possible benefit to the farmers of the world. In North America and Western Europe the farmers have in the last 30 to 40 years adapted themselves to very great changes; in many countries the horses have gone and have been replaced by tractors while manpower has been halved and the output of food markedly increased. These great changes have been accomplished by the efforts of many different kinds of men working on both commercial and experimental farms, in production plants, design departments, and in research laboratories. A number of factors should be mentioned: the first is that farmers themselves have contributed much to the development of new equipment because of their own resourcefulness in overcoming problems; the advisory services, which scarcely exist in other industries, have done much to encourage progress; and manufacturing companies both small and large have played a vital role. Last, but by no means least, it is relevant to note the long and splendid tradition of research stations in agriculture.

Throughout this period there has often been excellent cooperation between the various men involved, but the question needs to be asked if this cooperation has been consistently good enough. Perhaps during the three or four decades when engineering came to play a prominent part in agriculture, a more highly organized cooperation was not possible and maybe it was not desirable, but we are now entering a period when progress will require a closer cooperation between all concerned. I think that the first two papers today have already given support to this conclusion and I hope I shall be able to take the arguments a little further.

Agriculture sets difficult problems for the engineer because it is frequently organized in small production units. Furthermore, much of the work on the farm has to be done for relatively short periods. Thus the economics of farming often dictate that the engineering products to be used must be low in capital cost and therefore also low in design and development costs. The tractor is usually the source of power for most farm machines; hence tractors are manufactured in, by comparison with other farm equipment, large numbers in plants where capital investment is high and where radical changes in design are costly to introduce. Thus the history of tractors in the last 30 years has revealed a steady increase in power and sophistication which have enabled farmers to use them more productively with each passing decade. They are the outstanding example of versatility in farm machinery.

The tractor is the most versatile machine on the farm; it evolved as a replacement for a team of horses and its design has been dictated by the need to pull mouldboard ploughs through the soil. Thus the tractor must develop draught forces and to do so it must be heavy and have large driving wheels. It is designed for this specialist role but it is also used for a very wide variety of other work. Hence since the days when Harry Ferguson so markedly improved the performance of the tractor it has evolved in two important ways. Its power and ability to transmit high draught forces has steadily increased and at the same time it has increased in sophistication so as to make it indispensable in so much of the other work of the farm. For example, the tractor provides the power for grass cutting and loading, for harvesting potatoes and sugar beet, and for spraying pesticides and distributing fertilizers. While it must perform its specialized function in cultivations it must be versatile enough for its numerous other roles.

While farming remains organized as it is at present this need for versatility cannot be escaped but the interactions of farming, engineering and social organization may change over the next decade or so to make different solutions to the problems of providing power for the farm worker acceptable. Men are becoming more scarce on our farms and, as Professor O'Callaghan has said, the rate of increase of wages is likely to be faster than that of the cost of machines. If that process continues and perhaps even accelerates, then the need for more specialized machines is likely to increase. It is, however, necessary to consider this problem more fully.

The design of the tractor can change to advantage for its other work if we find better tools than the mouldboard plough to cultivate our soil. We now have large power units on the farm which can be used to cultivate soil in different ways than those employed when less power was available. We can take high powers from the tractor mechanically or hydraulically instead of as draught forces from heavily loaded large wheels or we may be able to use the tractor to provide draught forces but to do cultivations at much higher speeds. We know a little about these possible developments, but we do not know nearly enough and it is one of the tasks of the next decade to explore them and to seek solutions to them. Soil working tools rotated about a horizontal shaft and powered by tractors have been used by farmers for some decades and the N.I.A.E. Scottish Station has for a number of years been experimenting with mechanically or hydraulically powered rotary ploughs for cultivation for the potato crop. In 1969 research started at N.I.A.E., Silsoe, in an effort to increase the speed and reduce the cost of cultivations for the cereal crop by studying a wide range of mouldboard, shallow mouldboard, and chisel ploughs, and reciprocating and rotating tools used either singly or in various combinations, and with tractors of various powers. The results to date suggest that combining operations hitherto performed separately in four or more crossings of the field into a single operation is possible, but the rate of work is low even with relatively expensive high powered tractors. At this time it appears to be less attractive than less ambitious methods in which combinations of tools, some powered from the tractor and some drawn through the soil, are used to reduce the number of times the tractor has to cross the field from an average of four to two. One of the methods which at present looks promising requires little or no draught force from the tractor. (See figures 1 and 2, plate 1)

However, it is still far too early to be confident of the results achieved because the work needs to be done for many years to establish significant results. However, the data obtained already are interesting and promising and it will indeed be surprising if appreciable economies in tillage costs cannot be made by the 1980s by using tractor power in different ways from the traditional. Much will depend on the relative costs of the wages of our few remaining tractor drivers and of, for example 113 kW (150 hp) two-wheel drive tractors. Much will also depend on the possibility of working faster in the field and completing cultivations early enough in the autumn to sow winter wheat which gives the farmer higher profit margins than spring wheat. 'Timeliness' is a word heard frequently enough in farming circles but it is nowhere more important than in soil cultivations for our cereal crops. This work costs British farmers about £50M per annum and imposes heavy demands on labour at a time when there is much other work to be done on the farm. If only a small reduction in this work could be achieved it would outweigh costs of the research by a very large factor. The potential benefits are indeed substantial.

Of course, we must consider all aspects of the problems and use all the developments of other scientists in seeking solutions to them. Much has been done already in this respect but there is still too great a tendency for each discipline to work in its own field and not have sufficient regard for progress elsewhere.

In summarizing this part of the paper, therefore, we cannot fail to recognize that the tractor is the most versatile tool on the farm, but it has achieved its adaptability as a mobile power unit almost despite its primary function of hauling mouldboard ploughs in primary cultivation and certainly despite its high weight and large wheels. Progress depends upon improvements in our methods of soil cultivation and if these are to be achieved then it will be possible to make tractors more useful to the farmer in his other work.

A severe limitation in the output of work of the tractor is the speed at which it can be operated in fields. Much has already been done to improve the safety of the tractor driver and to reduce the noise to which he is exposed, but much remains to be done to make it possible for him to continue to work at high efficiency during a long working day. Here the problems are of two kinds. The first is the bumping and the vibration to which he is exposed in the course of his work in the fields, and clearly in studies of man's tolerance to such conditions close collaboration is necessary with the medical profession. Surfaces of agricultural fields and tracks can scarcely be compared with those of our roads and yet we expect a man to sit all day on the tractor and to maintain a high degree of concentration and watchfulness. We shall expect him to have an even higher output of work as his wages steadily increase and come to match more closely those in manufacturing industries. That being so, we must provide a physical environment for the driver that makes concentration possible. We must increase productivity, yet the physical conditions of the fields and roads of farms can scarcely be changed with present methods of agricultural production, so we must try to solve the problems of improving the physical environment of the tractor driver by improved design. The problems here are difficult and require much research if the vibration to which the driver is exposed is to be reduced markedly, and when the research is done skilful design will also be necessary if the improved tractor is not to be excessively expensive (see figure 3, plate 2).

Because of the necessity to exploit the versatility of the tractor we must consider the second problem, that of functional design. In the field, tractor drivers are often expected to work in a curious way; they have to steer the forward-moving tractor accurately and at the same time to ensure that the machine behind them is operating satisfactorily. This is a combination of functions we seldom expect men to perform elsewhere and it can scarcely be described as ergonomically satisfactory. Presumably it came about when the tractor replaced the horse because at the time no other design solution would have been economically acceptable to farmers. Thus when the early combine-harvesters were evolved they too were pulled by tractors but in a comparatively short time they changed to more expensive machines with their own power units and transmissions. For the combine-harvester for cereal crops the economic advantages of powerful, self-propelled machines fairly soon became established. The need for speedy completion of harvesting makes it possible for farmers to find money for highly specialized machines which usually work for about three weeks a year. Furthermore, the attempts made to evolve self-propelled combine-harvesters in which the power unit transmission, etc., could be detached after harvest and used as a farm tractor have failed. They have failed partly because the resulting tractor is inadequate and partly because the farmer considered that reliability in cereal harvesting was of paramount importance to him. Hence this effort to achieve versatility failed and at the present time it shows little sign of success.

Because combine-harvesters are now large and expensive machines which stand in the barn unused for 90 % of the year many efforts have been made to improve and particularly to simplify them. Not the least imaginative have been the efforts at the N.I.A.E. to replace the cumbersome shakers behind the threshing drum used to separate the grain remaining in the bulky mass of straw and chaff. The research has been directed at exploiting the different aerodynamic characteristics of the relatively dense grain and the light straw and chaff by directing a stream of air at right angles to the material leaving the threshing drum. The degree of separation has been promising in the small field rigs and it is by no means unlikely that this or a similar method of separation will come to fruition in 10 to 15 years' time and will lead to lighter, lower and simpler combine-harvesters on our farms. The path of the research worker is seldom smooth, however, and for the present commercial firms have not found it possible to take up and exploit these promising developments. No doubt it would be costly to do so for a commercial concern because building experimental combine-harvesters is an expensive undertaking, but it is even more beyond the reach of a research station with limited funds.

Progress has been made in the design of self-propelled sugar beet harvesters by mounting the

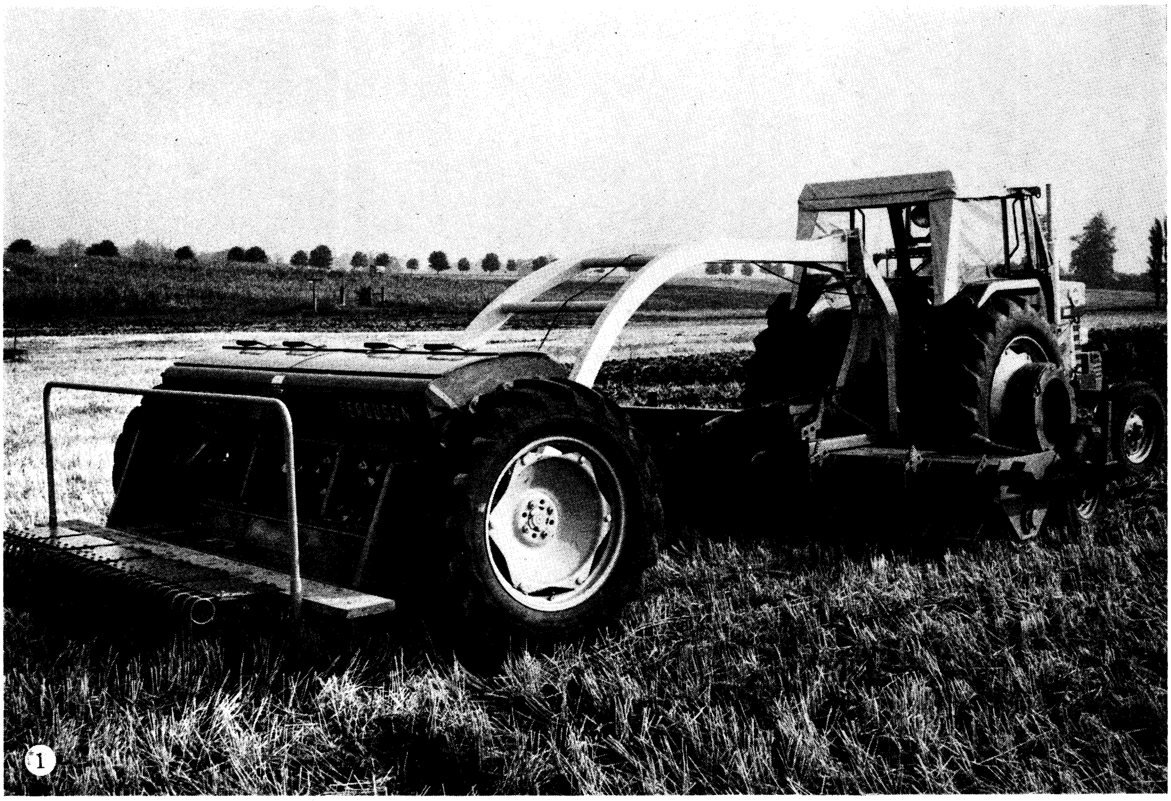

FIGURE 1. In future it is hoped that soil cultivation will require less passes over the field. Powerful tractors make it possible to combine operations hitherto done one at a time.

FIGURE 2. Skilful design should make it possible to cultivate in the 1980s without heavily loaded rear wheels of tractors running in furrow bottoms.

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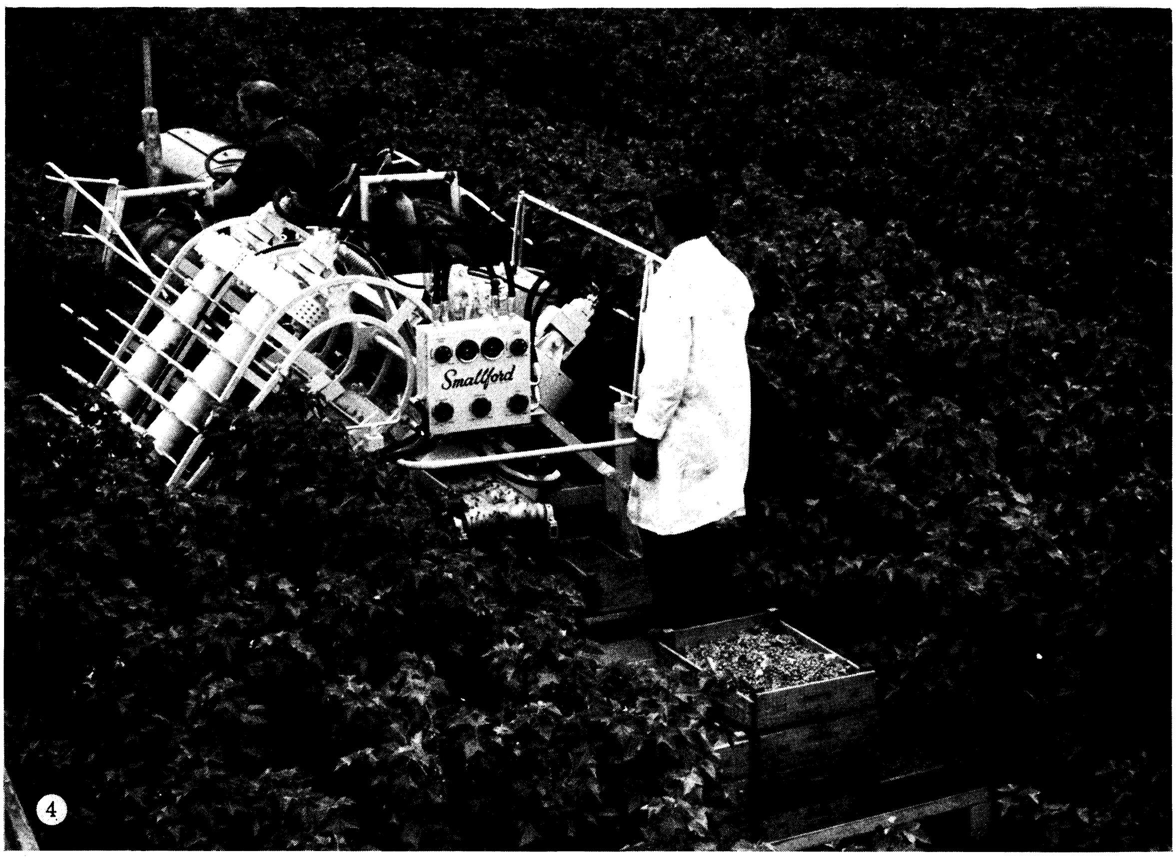

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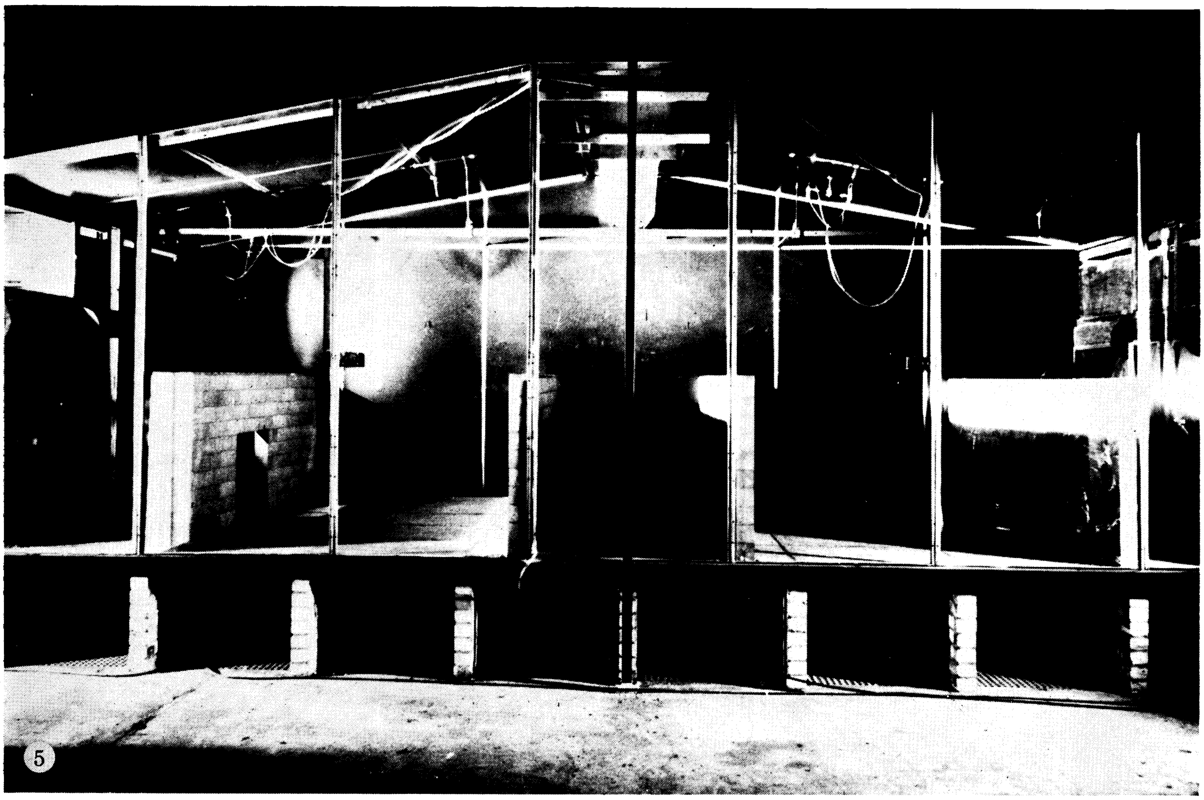
FIGURE 3. Improvement is urgently necessary in the ride characteristics of tractors both to avoid the risk of spinal injuries to tractor drivers and to make it possible for them to work efficiently throughout a long working day.

FIGURE 4. Soft fruit, such as blackcurrants, can be picked by special-purpose machines which replace large numbers of casual workers. Each machine for picking a kind of soft fruit will, however, be specially designed and developed for one crop because of the different habits of growth, etc. of soft fruit crops. (Courtesy Luddington E.H.S.)



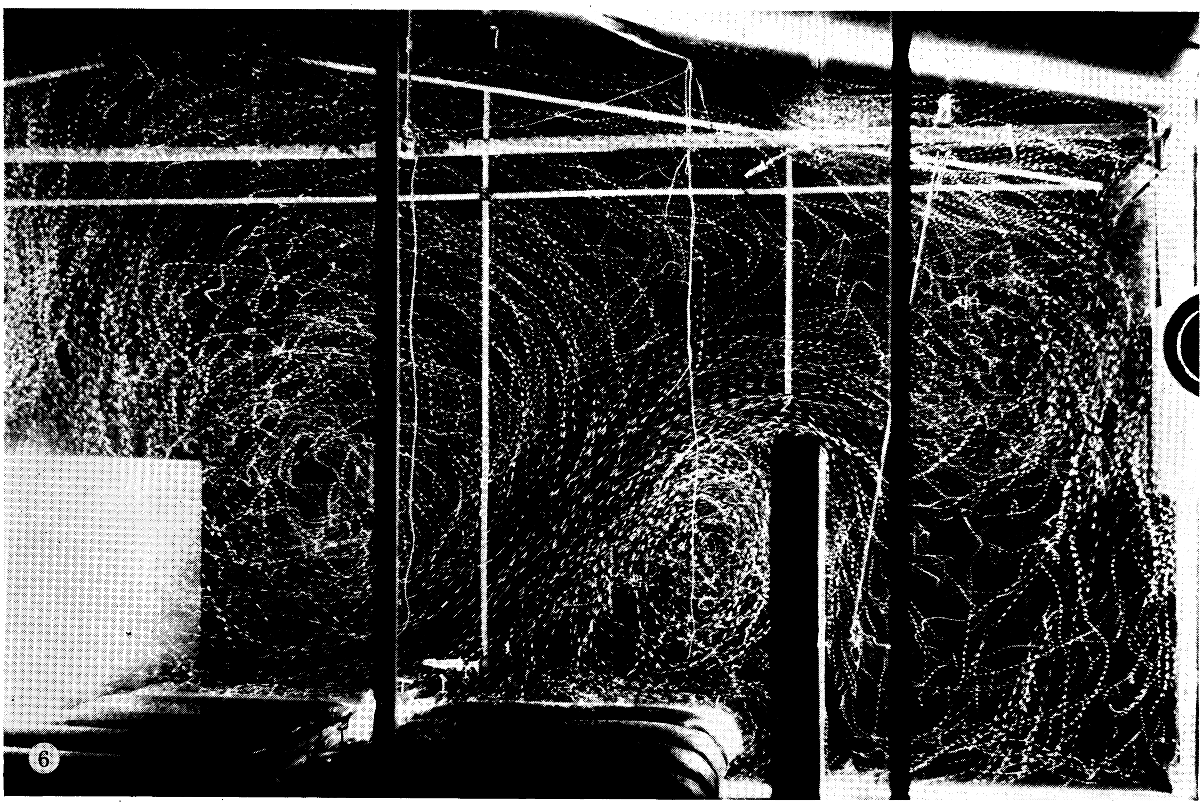


FIGURE 5. This illustrates a model pig house for very necessary research on ventilation. Our present knowledge is rudimentary at the most.

FIGURE 6. Bubbles injected into the model pig house may be photographed and thus the movement of the ventilating air determined. In this photograph cold air is falling on to the backs of model pigs.

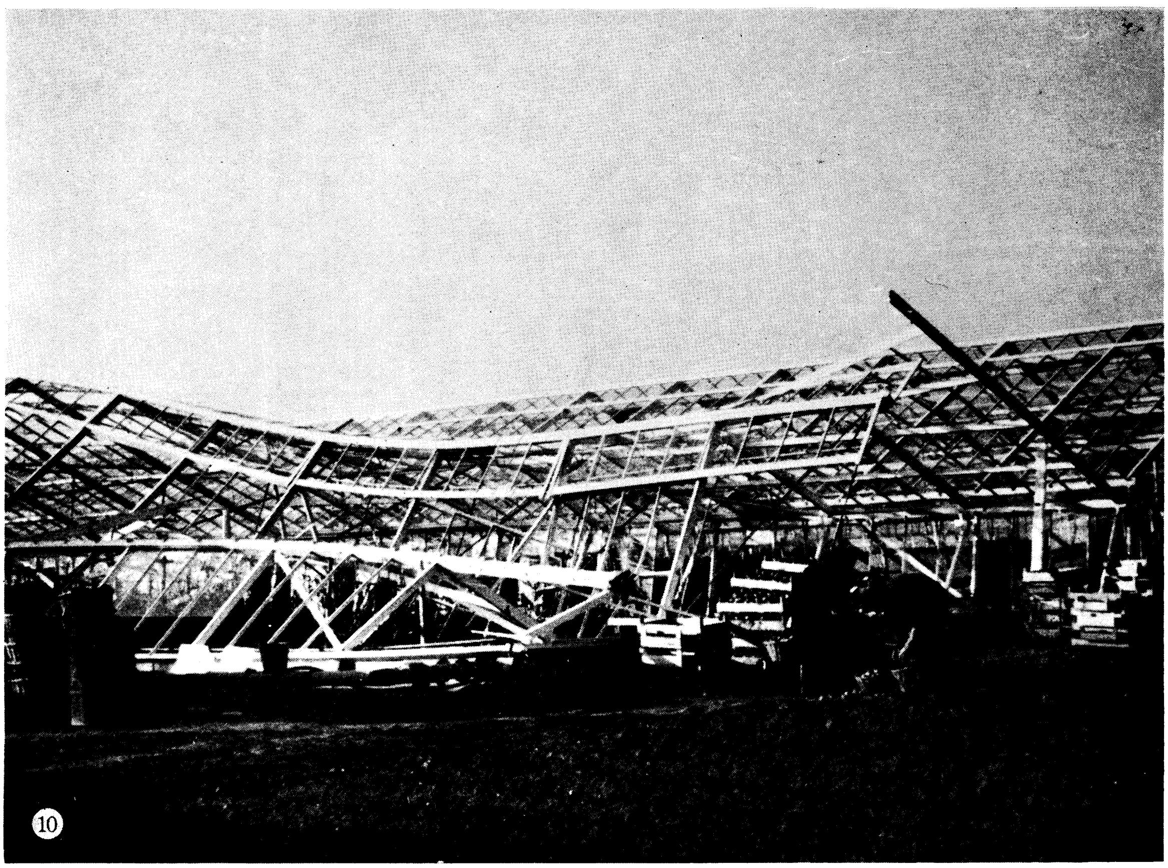


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FIGURE 7. In the 1980s farmers will need reliable methods for dealing with farm wastes and much research will be needed to solve their problems.

FIGURE 10. Lack of knowledge in agriculture as in other industries often results in disasters. For example, we have no sound data on which to base the design of glasshouses and so from time to time gales wreck them completely. A need for the 1980s is much more research to avoid such costly disasters.

driver in a position where he can see his work better than when he was sitting on a tractor towing a harvester. Here the attempt to use the tractor engines and transmissions to power the harvesters has been more promising. This is a rational approach because it avoids the necessity for producing a sugar beet harvester with specially made gearboxes and driving axles; such components made in small quantities are expensive and their use may result in machines beyond the reach of the farmer. What we have still not succeeded in doing is to give the driver a good enough sight of all the operating parts of his machine. This is clearly a difficult problem to solve and one which awaits much more thought and effort.

The difficulties for the research engineer in making progress with limited resources for crops produced in large quantities are not negligible, but the problems for those produced in relatively small quantities are much greater. Here it is desirable to consider some of the fruits and vegetables and I must give some figures from my own experience. The blackcurrant crop is important to many farmers and the labour required to harvest it by hand is considerable. With the possible exception of the gooseberry no other commercially produced crop has similar habits of growth and as far as can be seen at present a machine designed for harvesting blackcurrants must be 'special purpose'. However, desirable versatility may be it seems that a harvester will only be valuable if it can replace the very large number of men and women who have hitherto picked the fruit by hand. The knowledge gained in solving the problems may be useful elsewhere and there is a faint possibility that some of the components, for example, of the blackcurrant harvester may be useful in other machines (see figure 4, plate 2).

To develop this machine to reasonable reliability in the field required approximately 5 years' work and an expenditure of £45 000. The inevitable result of this work for the blackcurrant crop has been to create a demand for similar progress for other crops. Other fruit, such as strawberries, have quite different habits of growth from blackcurrants and even a glance will show that we shall need specialized machines to harvest them. With apples we have a crop whose harvesting costs at our present labour rates make progress with mechanization desirable. Needless to say, its problems are quite special and to solve them would require close collaboration between the engineer, botanist and orchard owners. It would probably be optimistic to believe that a machine could be brought to efficiency and reliability in less than 5 years at a cost for research and development of less than £100 000, or that the price to the grower would be less than £10 000 per machine even if the research and development costs are not recovered. All the machines for harvesting fruit are likely to be specialized and the cost of the research and development for any one of them is likely to be high in relation to the number of machines required but probably not high in relation to the potential benefits to the country.

For harvesting cereals, potatoes, sugar beet and carrots the machines already widely used are no less specialized. It is only necessary to recall the effort that has gone into separating stones from potatoes by using X-ray absorption techniques in harvesting machines to appreciate their specialized character. Knowledge and experience in research on any one fruit or vegetable is undoubtedly valuable in approaching the problems of another crop, but it hardly seems probable that the solution to the problems of harvesting is likely to be found in more versatile machines. As in other industries the tools we use on our farms will become more specialized with each year that passes.

It is perhaps worth a further look at the vegetables because in the early 1960s a determined effort was made to develop a versatile vegetable harvester with adaptations to deal with a variety of crops. Unfortunately the effort failed, although the experience gained was invaluable.

Why did it fail? Because insufficient effort was made to produce convincing results in any one crop to show that the machine would be successful commercially? Or because in the effort to obtain versatility the machine was not cheap enough for any one crop? Perhaps because, as has been said earlier, farmers are not attracted to, or equipped to deal with, problems of adapting machines from crop to crop?

However, much was learnt from the attempt to develop the vegetable harvester and it is worth mentioning this briefly. Unlike the fruits, some of the vegetables were already harvested by machine and others were cut by hand quickly. Thus the machine had to compete with men who work quickly in crops which are not as easily damaged as fruit. The lessons are that vegetable harvesting machines must be cheap to compete with hand labour and that machines for various crops should have common components or assemblies in order to reduce the cost of production of the complete machine. Finally, the field trials for proving the various adaptations for different crops must be done thoroughly for each crop and will therefore be comparatively expensive. A rough estimate is that no less than three years of design, research and field trials are necessary to establish a machine as satisfactory for any one vegetable crop. This will require a team of two to four men working in many field and crop conditions and in different weathers and will scarcely be likely to cost less than £50 000 if all costs are taken into account: this is of course very rarely done! Thus for the versatile vegetable harvester to be successful requires a substantial engineering effort and considerable collaboration from horticulturists with comprehensive knowledge of the various crops.

A striking contrast to our vegetable and fruit crops is the scale of livestock farming. Here we have an industry which is producing meat, milk, and eggs to the value of more than £1600M per annum; there are few larger industries in the developed countries of the world, but there has so far been comparatively little engineering research or development done for livestock production. At my Institute where our effort on research of this kind has been increasing in the last few years, we are still spending only about 20 % of our budget on it, and this represents less than one-fiftieth of 1 % of the annual output of the livestock products. Yet it may well prove that, in animal production with its need for labour 7 days a week, the shortage of men will prove more acute by the 1980s than in any part of farming so that in consequence the potential benefits from engineering may be very large indeed.

Work has already started on providing aids to the man in milking and feeding dairy cows because we know that as herd sizes increase so does the stress to which he is subjected. If memorizing milk yields and feeding requirements of individual cows can be taken off the milker then he should have more time for stockmanship. There is a wide measure of agreement that this is desirable and the control engineer should be able to solve this problem. Much of the unpleasant, arduous and time-consuming work of treating and disposing of animal wastes will be eliminated and the ventilation and temperature control of the buildings housing livestock will be very considerably improved. Better equipment will become available in the near future for weighing and feeding pigs and that for weighing cattle will follow soon after if, as we believe, there is sufficient demand for it. (See figures 5, 6 and 7, plates 3 and 4.) Finally, great efforts are necessary to reduce the work of transporting and metering food to animals. Work has started on these problems in a number of countries, but the scale of the research effort in the United Kingdom is small in relation to the annual wages bill for such work, to the value of the products, and to the possible benefits, however they may be estimated. Perhaps we must console ourselves that in recent years the attack on some of these challenging problems has started and that it seems highly probable that a determined effort by engineers with many different kinds of trainings and skills could do much to reduce the expensive, arduous and dirty work of men in livestock production.

Ideal solutions to problems are seldom practicable for the engineer. Usually he has to compromise over the various problems he has to solve and he also has to compromise because the machine he designs must be within the financial reach of the buyer. Design is and will remain the highest expression of engineering; it requires both technical knowledge and creative ability; it is part science and part art and is very much influenced by economic considerations. Despite recent technical advances it has not yet been possible to solve all the problems of harvesting of field crops, but considerable progress has been made and much more will be achieved by 1980 by a systematic application of our knowledge of the properties of crops and of the possibilities of using power to replace the muscles of men and of control engineering and automation to supplement the eyes and the brains of men. In livestock production the attack on the engineering problems of this enormous industry has only just started, but good progress may be expected in the next decade. Progress would be much faster were it possible to increase the research effort for this vast part of our industry.

However, there is one aspect of engineering for agriculture which is already clear; the elaborate exchanging of parts of machines with the progress of the harvest of various crops on a farm will enjoy little success. Perhaps if farms were large enough to have well run engineering workshops with well organized stores for spare parts, or alternative assemblies of parts, then this would be a possible road for advance. It remains a pipedream at present and specialization in harvesting is likely to be the rule rather than the exception in the next decade. When the farmer starts to harvest sugar-beet in wet autumns he needs to give the management of such work his full attention and he has neither the time nor the training to make elaborate adaptations of his machines. Rather he needs high output and reliability and as labour becomes more scarce and more expensive these needs will increase and thus his need for specialized harvesting machines will increase rather than diminish.

However, this is not the end of the matter. For machines to work on our farms to a high standard of performance and reliability requires expensive programmes of field trials; every engineer is conscious of the uncertainties in producing a new design. Our work for farming must at present be on a modest scale but that should not obscure the point that every new machine must go through a relatively expensive programme of field trials. This programme can be simplified a little if well-proven assemblies such as diesel engines, gearboxes and driving axles can be used. Furthermore, the use of such assemblies will appreciably reduce the cost of manufacturing and field trials and an important part of the skill of the engineer must be in producing machines at a cost which the organization of farming in the decade ahead will make acceptable. Thus for sugar-beet harvesting it is no doubt possible to design a self-propelled machine with the driver carried in a suspended cab isolating him from jolting and vibration but from which he can control the steering and yet see all the operating parts of the harvester without difficulty. This would certainly require a major effort in design followed by extensive trials and then the design, manufacturing and tooling of production plant. This would cost a substantial sum of money which would have to be recovered in the cost of the machines sold to farmers at the rate of only a few hundred a year. It is practically certain that such radical new designs would not be less than 50 % more expensive than the most expensive of the present harvesters. Presumably such a hurdle was overcome when self-propelled cereal harvesters were introduced but whether or not they would be surmounted for other harvesters would depend on a complex of factors which must be studied by a potential manufacturer in each case.

What at present is largely a field for study by the research worker is the extent to which we can use the experience of other industries in reducing the effort of the man by supplanting or replacing his eye and brain by electronic equipment; it is likely that this process will continue and that the possibilities of first aiding and then replacing the man in farm work will increase very considerably in the next decade or so (see figures 8 and 9). Hence the problems which seemed likely to be uneconomic even 5 years ago begin to look much more attractive. Furthermore, research to apply automation to farm work will itself take several years to bring to fruition.

Before this work is done, however, it is imperative that we be clear about our goals and about the conditions prevailing in the operation or non-operation of our machines. It is not

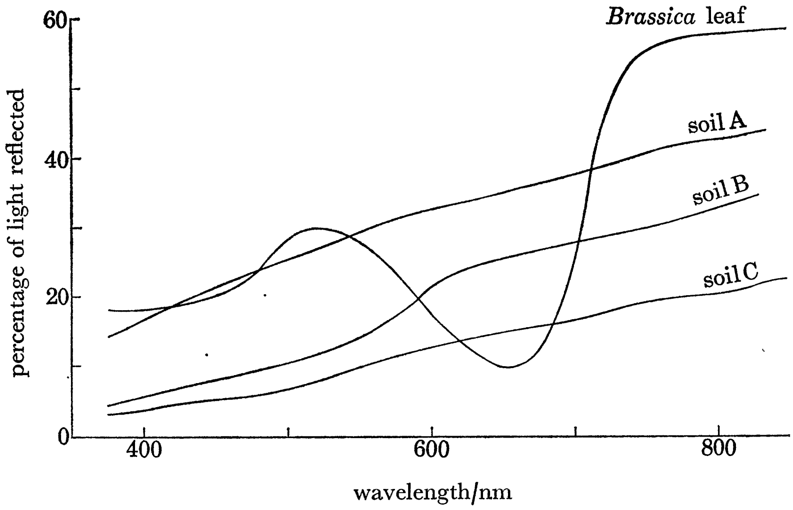

FIGURE 8. The green leaves of plants reflect varying percentages of light according to wavelength and in this respect their behaviour is very different from that of soils. (Courtesy N.I.A.E. Scottish Station.)

enough to talk of applying automation to, for example, sugar-beet harvesters, until we know which of the operations of the harvester are most likely to repay the effort. We need to know if the machines should be steered from signals picked up from the rows of beet extending before the harvester or if the numerous troubles for which the driver constantly turns backwards and tries his best to observe, are likely to be eliminated by suitable control equipment. At first sight it seems that the blockages and breakages of the machine itself are too random and unpredictable to respond to treatment of this kind, but closer study is clearly necessary and perhaps in the meantime more consideration should be given to steering the tractor along the line of beet, because steering problems are common to much of the other work on the farm. In considering such problems it is well to be guarded because, although electronic control equipment has achieved astonishing results in some industries, each new role for it sets formidable technical problems and ours are not the least difficult the control engineer will encounter.

My conclusion, therefore, is that in the 1980s the farmer will be offered a wide range of specialized engineering equipment to reduce his need for men in livestock and crop production, and that the shortage and high cost of manpower will lead to his welcoming such equipment on his farm. The rate at which specialized machines and electronic aids are introduced to our farms depends on a complex of factors of which research in engineering has already been emphasized. Progress in engineering is dependent on expenditure of our national resources in applying hard won scientific knowledge to special conditions, and those in agriculture certainly have their fair share of features which require special consideration. Every such feature needs expenditure on research and field studies and then usually design followed by field trials before their problems can be solved in a technically and economically satisfactory manner. It follows that the rate of progress is roughly proportional to the extent of the resources provided and our resources are not on the scale provided for designing and proving a few prototypes of a supersonic airliner! Our work may not be as glamorous as that in some industries but the difficulties

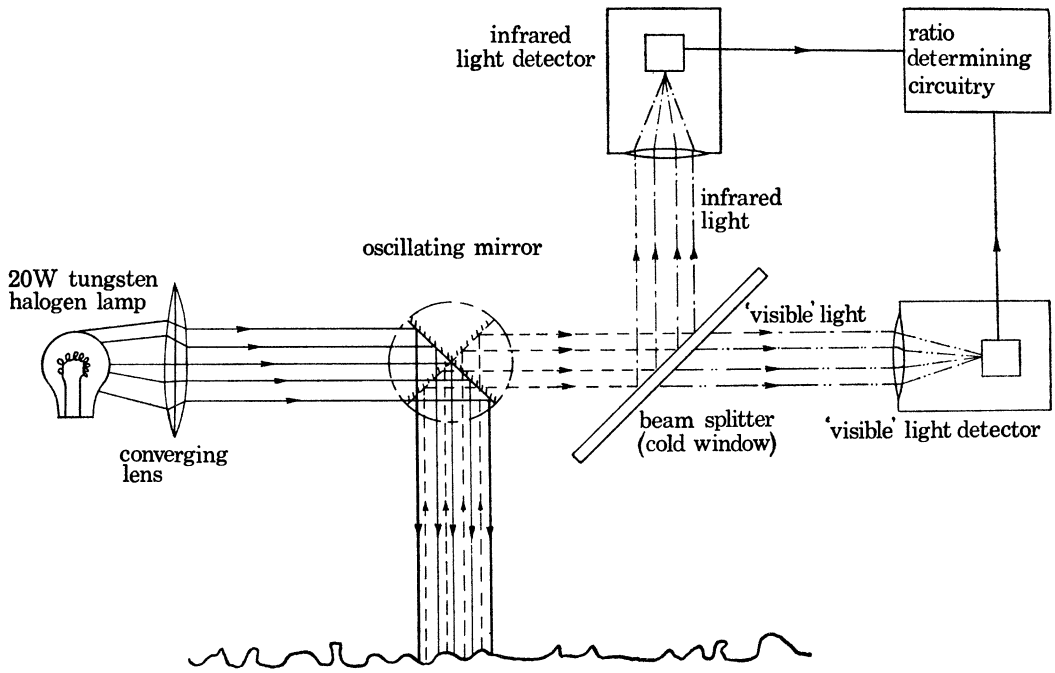

FIGURE 9. This behaviour may be used in future to identify plants in rows and to operate thinning mechanisms. (Courtesy N.I.A.E. Scottish Station.)

in making progress are just as great, and need just the same determined, sustained and intelligent approach. (See figure 10, plate 4.) Inspiration and innovation are of vital importance in agriculture but without systematic research and development and hard incisive assessments of practicability, we shall make little progress in producing our food more cheaply, and that is surely no small matter to all of us.

Finally the replacing of manpower by specialized products of the engineering industry will mean that agriculture must somehow become a more capital intensive industry, that the output of some crops will be restricted to a relatively small number of farms or horticultural holdings, and that even the larger farms may become more specialized in their outputs in the effort to employ their capital equipment efficiently and profitably. Here however, I must end or I shall trespass on the paper which Mr Jenkins will shortly be giving us.

Discussion

J. A. HOWARD (*Howard Rotovators Ltd, West Horndon, Essex*). I listened with much interest to Professor Moss's paper and would first like to thank him for presenting such an excellent paper.

There are comments I would like to make on two specific aspects of his paper; these being the tractor of the future and cultivation machines.

The farm tractor as we know it has changed very little since the time of its conception, except that it has gradually increased in power, has been adapted to carry as well as drag implements, and has now become a mobile source of power on the farm rather than just a draught producing machine.

A very important aspect of the tractor which I feel is not receiving the attention it should is that of the requirement for a tractor to carry tools.

We have heard today that tractors are increasing in size and power, and I am very pleased to hear that along with the increase in power the weight per unit power is reducing and the trend is for more power to be taken from the tractor by way of the power-take-off.

We have also heard that new tillage systems are evolving which make use of the power being transmitted through the power-take-off. However, these new tillage implements are becoming heavy and bulky, and even with the largest tractors available now, the capacity of the rear lift system is not enough to be able to lift this heavy equipment, and the weight that this equipment is imposing on the rear wheels of the tractor is too much and contributes towards the compaction problems which have been mentioned today.

I would like to ask Professor Moss whether he considers that the configuration of tractors, particularly in the larger power range, is likely to change in the next decade to allow tractors to become not only a mobile power source on the farm but also capable of carrying this heavy equipment without it having to be hung on the back of the tractor. For instance, is it likely that we will see tractors arranged so that they can carry big heavy tools between the front and rear axle?

The second point I would like to make, particularly in respect of the general theme of Professor Moss's paper, is the trend towards specialization of farming and farm machinery.

Professor Moss has said that cultivation equipment is being developed which may possibly in the future lead to single pass tillage system. The machinery required for such tillage systems is heavy and bulky, and very often in order to be able to provide a single pass tillage system it is necessary not only to carry the machinery itself, but also to carry considerable quantities of fertilizer, seed, etc.

I would like to hear Professor Moss comment on the possibility of this type of machinery developing in much the same way as the combine developed and are we likely to see self-propelled tillage machinery for the large-scale farmer.

Professor Moss. Improvements are likely by the 1980s in the capacity and versatility of tractor lift systems but changes to permit carrying tools between front and rear axles a little less likely. More self-propelled equipment will probably be available in the coming decades and on farms with large areas of land to be cultivated there is at least a possibility that we shall find powerful self-propelled cultivating equipment economical; the tractors for general farm work may then be of medium power.

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Figure 1. In future it is hoped that soil cultivation will require less passes over the field. Powerful tractors make it possible to combine operations hitherto done one at a time.

Figure 2. Skilful design should make it possible to cultivate in the 1980s without heavily loaded rear wheels of tractors running in furrow bottoms.

FIGURE 3. Improvement is urgently necessary in the ride characteristics of tractors both to avoid the risk of spinal injuries to tractor drivers and to make it possible for them to work efficiently throughout a long working day.

FIGURE 4. Soft fruit, such as blackcurrants, can be picked by special-purpose machines which replace large numbers of casual workers. Each machine for picking a kind of soft fruit will, however, be specially designed and developed for one crop because of the different habits of growth, etc. of soft fruit crops. (Courtesy Luddington E.H.S.)

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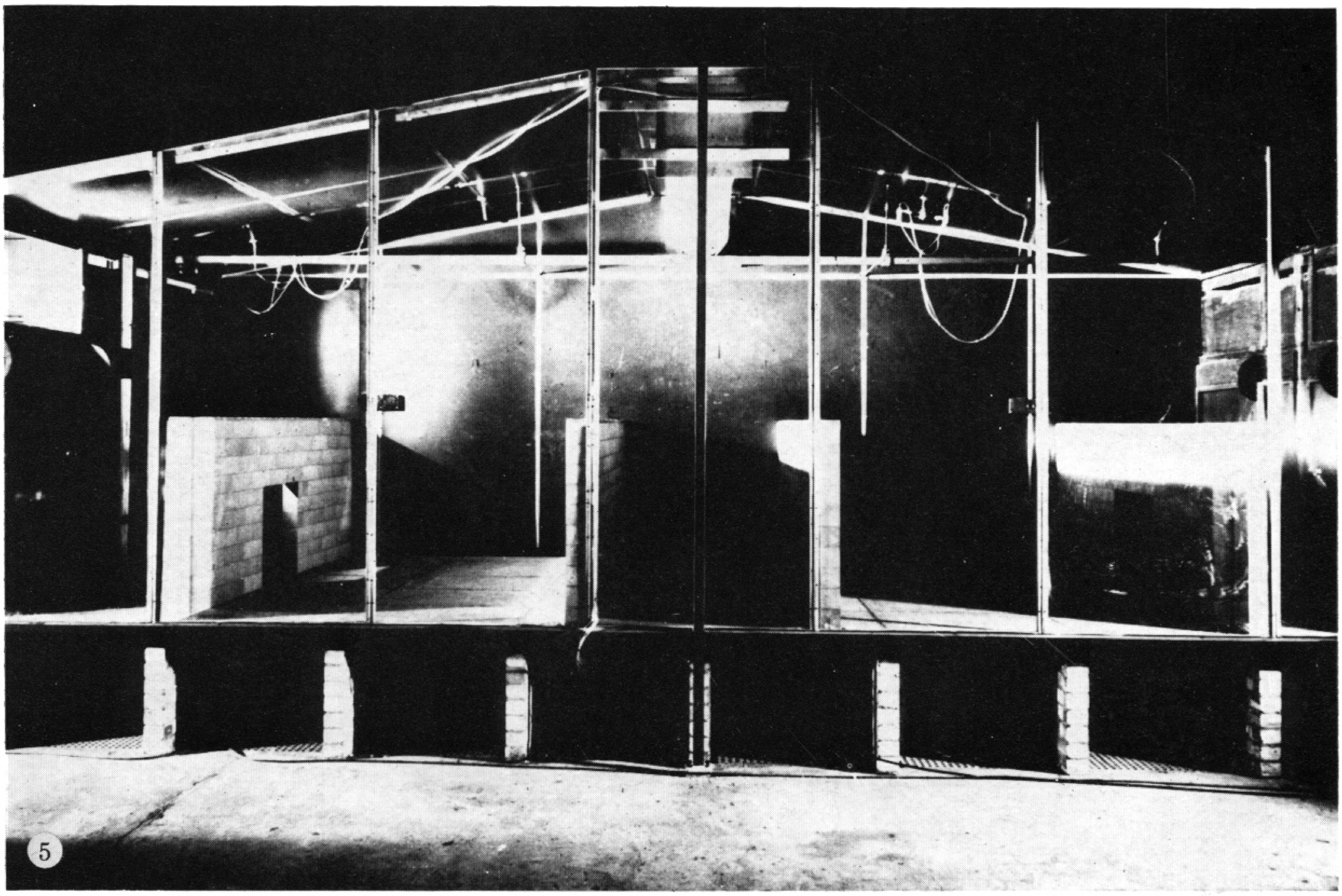

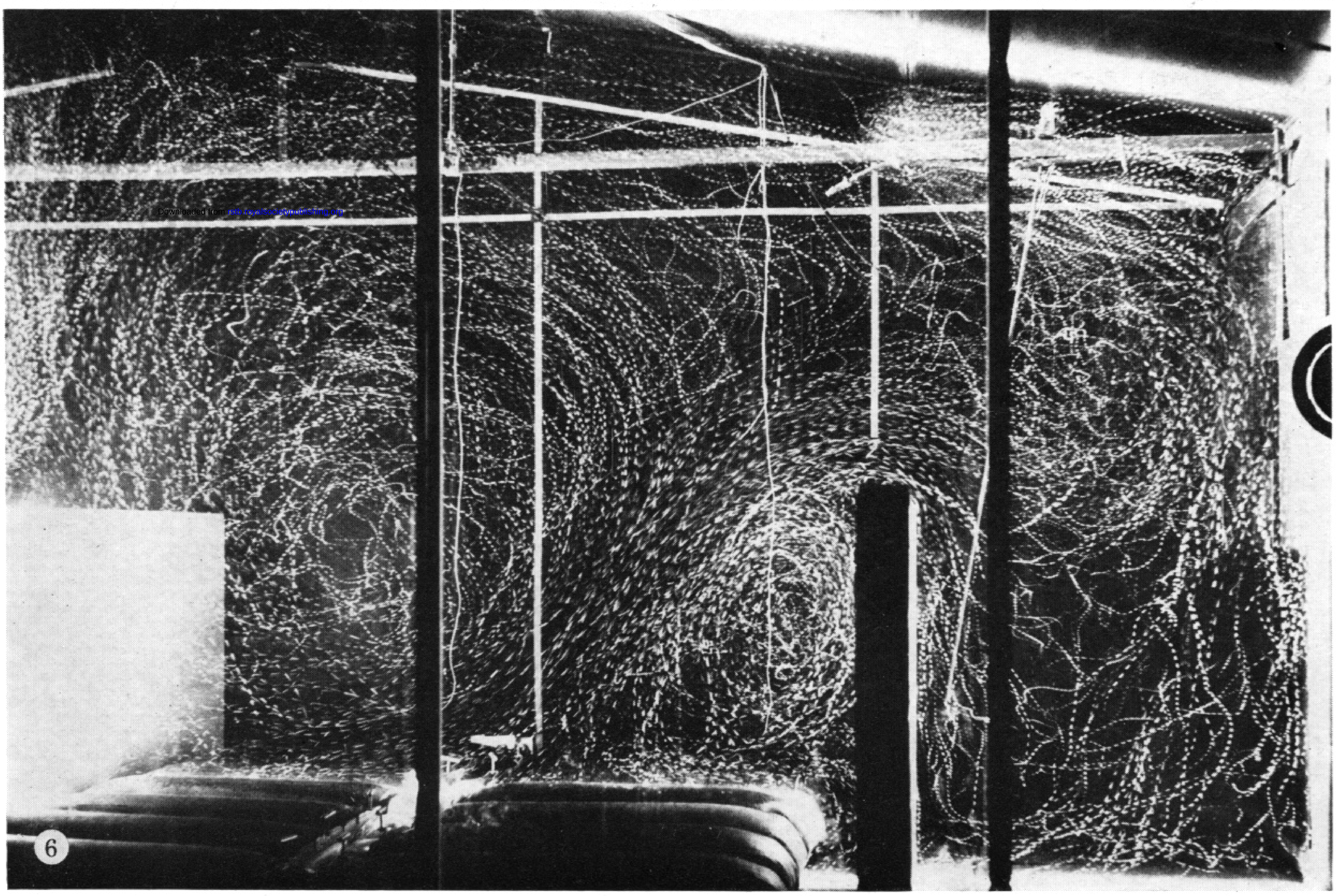

FIGURE 5. This illustrates a model pig house for very necessary research on ventilation. Our present knowledge is rudimentary at the most.

FIGURE 6. Bubbles injected into the model pig house may be photographed and thus the movement of the ventilating air determined. In this photograph cold air is falling on to the backs of model pigs.

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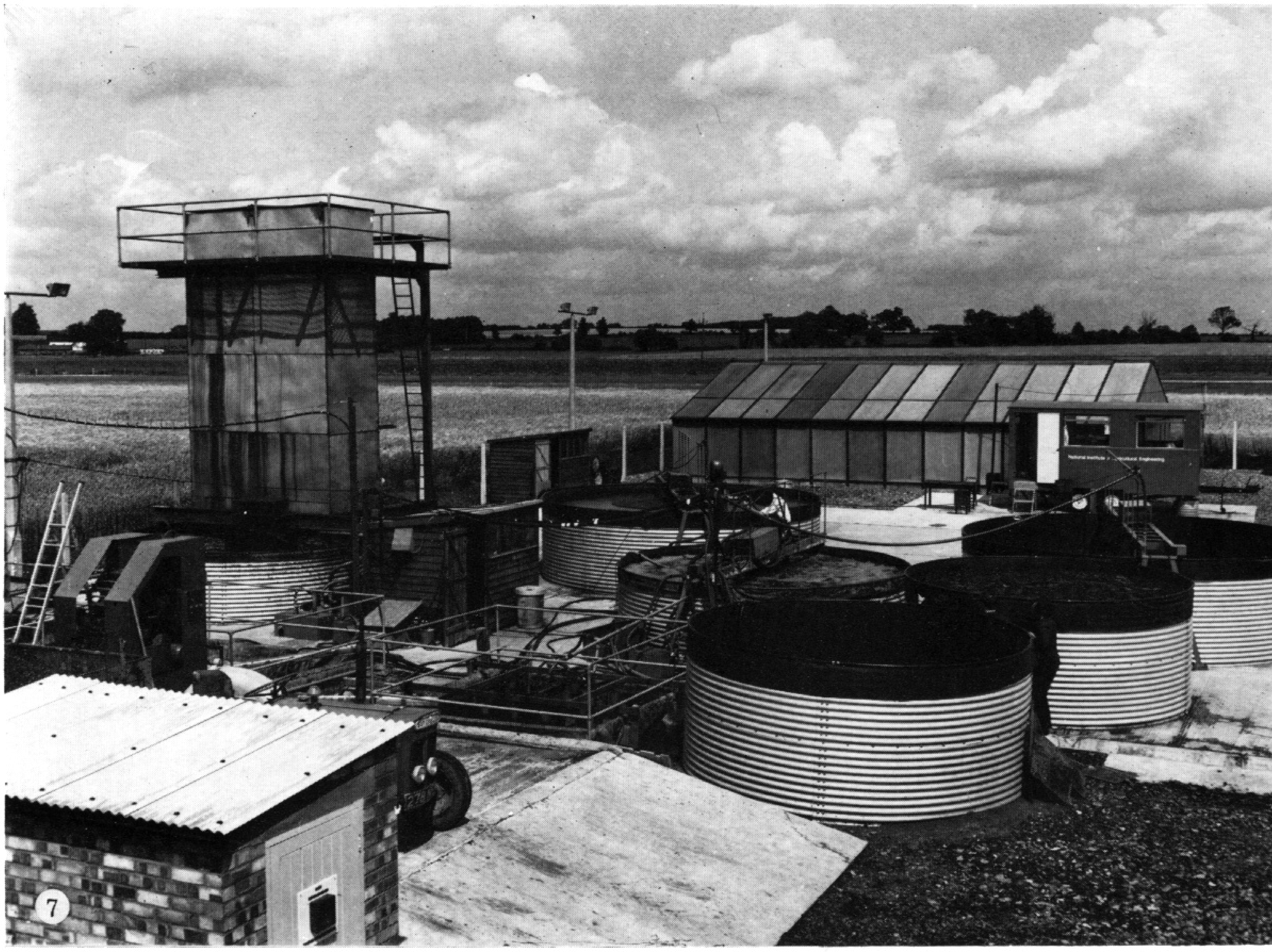

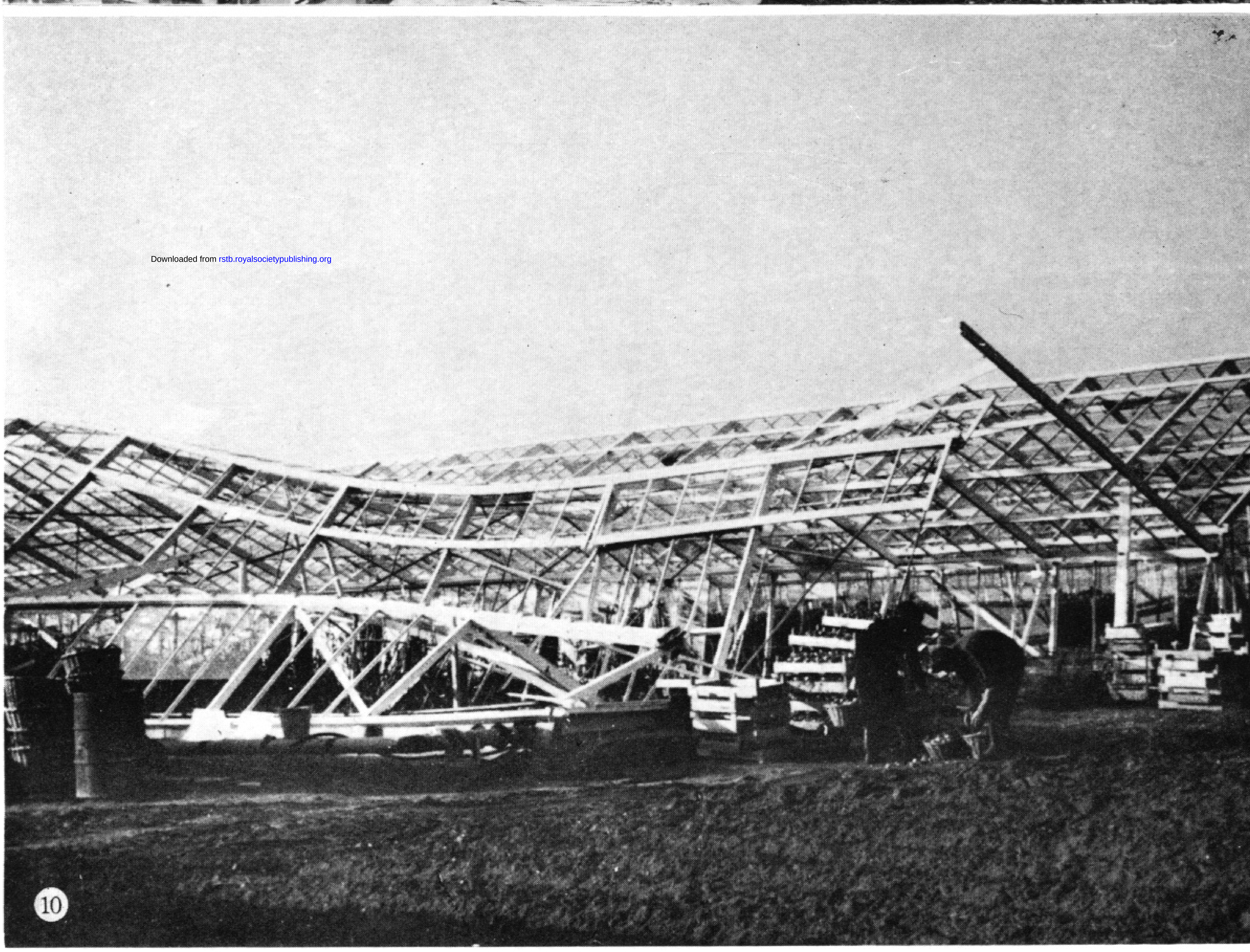

FIGURE 7. In the 1980s farmers will need reliable methods for dealing with farm wastes and much research will be needed to solve their problems.

FIGURE 10. Lack of knowledge in agriculture as in other industries often results in disasters. For example, we have no sound data on which to base the design of glasshouses and so from time to time gales wreck them completely. A need for the 1980s is much more research to avoid such costly disasters.

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