# THE AGRICULTURAL ENGINEER

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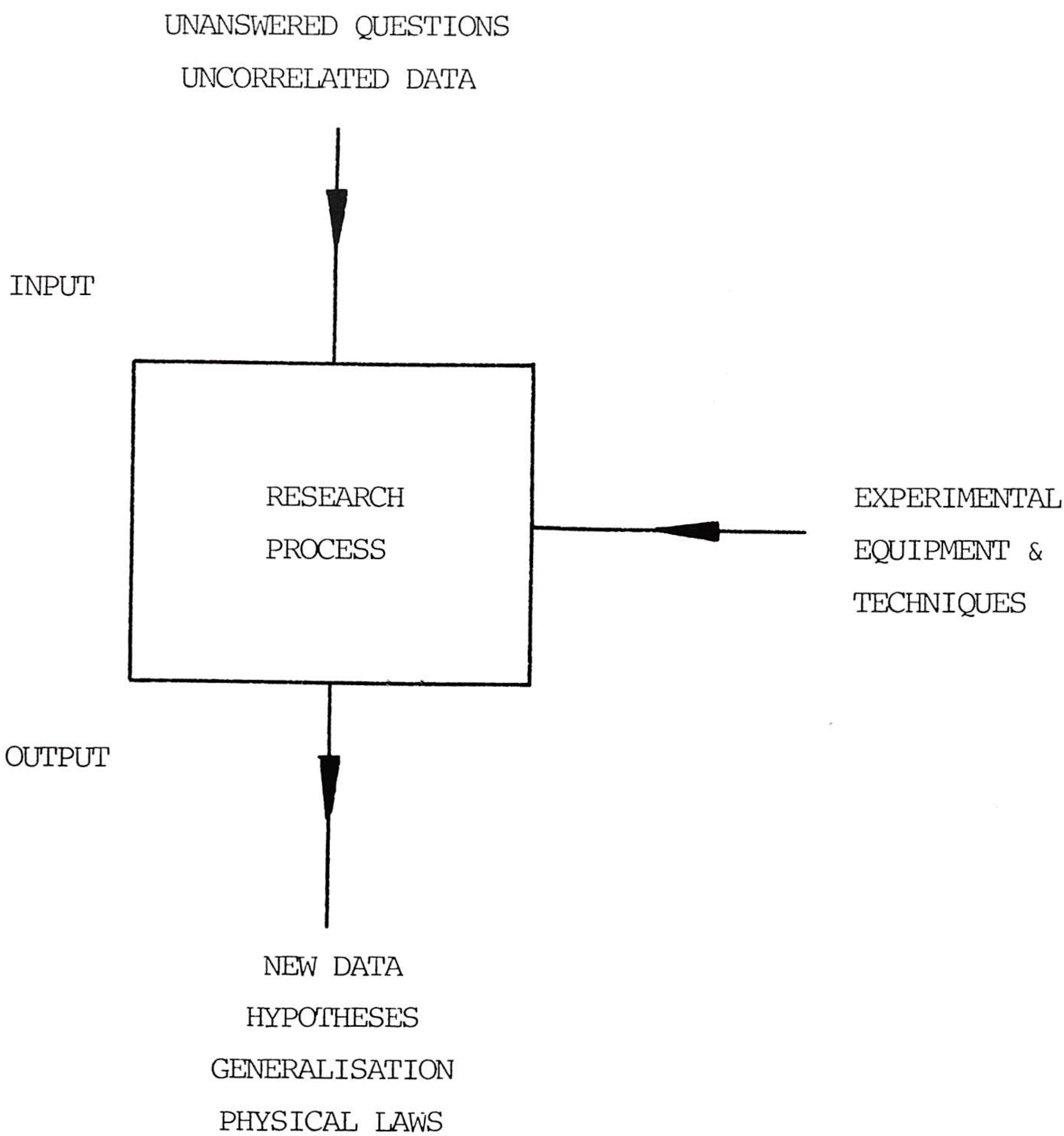

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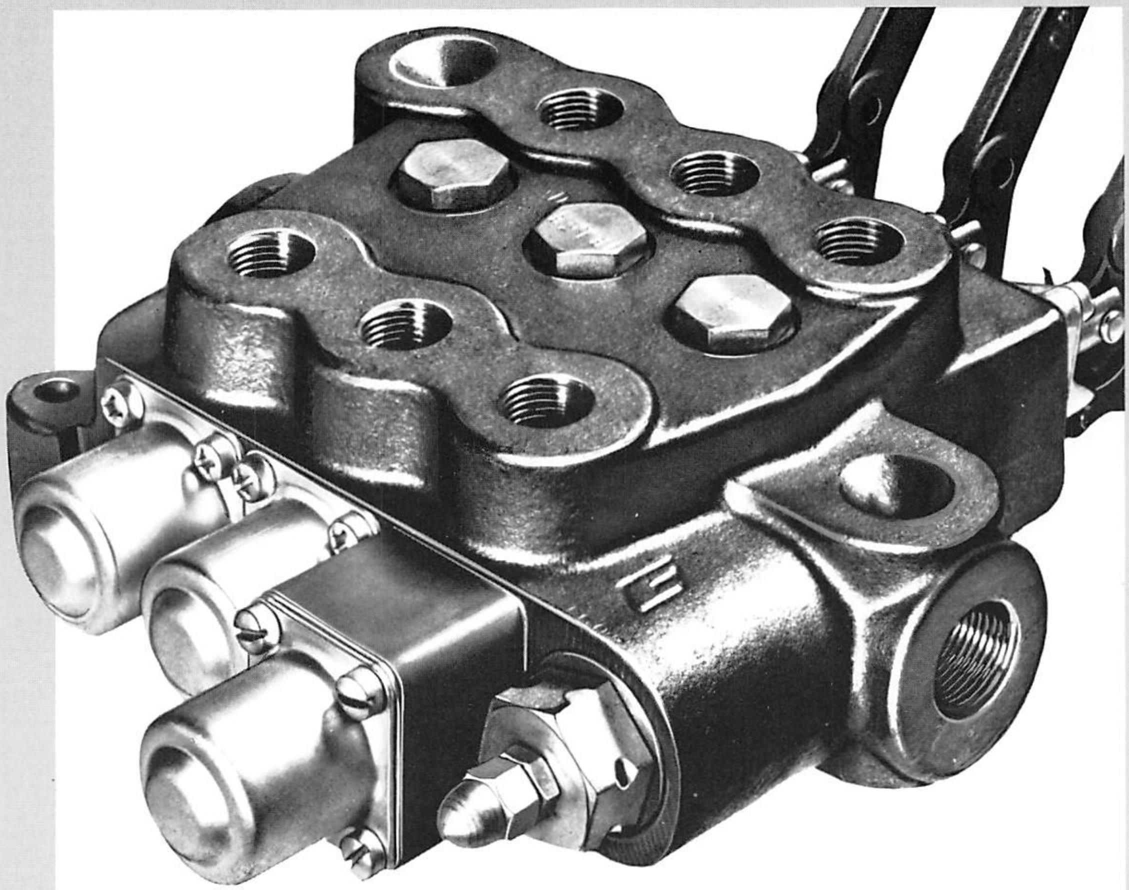

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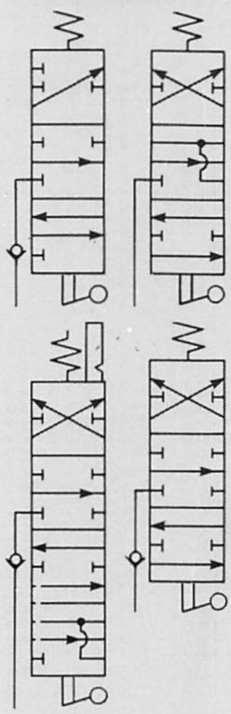

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*Three categories of paper appear in the Journal:—*

*a) Papers submitted to the Honorary Editor and subsequently refereed.*

*b) Conference papers not generally refereed but which may be if the authors so request and if the refereeing process can be completed before the Conference Report is due to be published.*

*c) Mechanisation and review articles not normally appropriate for refereeing.*

*Cover — The research process or transformation —* *see pages 81 — 90.*

# Innovation in agricultural engineering – Its encouragement and utilisation

**D N Scott**

TO THINK only in terms of mechanical devices, which subject is the prime interest of agricultural engineers, is to take a very blinkered view of innovation. The innovation approach is significant on a much broader front.

An innovation approach therefore is *anything* novel, any new idea; the term therefore embraces invention, which has particular reference to mechanical contrivances *and* application and development.

An innovation approach therefore is required not only of the inventor, but also of the developer, and finally, of the end user who must be prepared to alter his system to accept the invention. This innovative turn of mind, the capacity for original thought, is needed for success, be it in the boardroom, on the battlefield or on the drawing board.

Necessity is said to be the mother of invention, and of all human necessities, food has a strong claim to priority. If we look back down the ages and survey the broad spectrum of endeavour and progress, it is clear that in no other field has so much effort been expended on exploiting the forces of nature and on progressing techniques, as in human food production with, paradoxically, the possible exception of that business aimed at man's destruction!

It is not surprising therefore, that agriculture has been a prime target for innovators in the past, and there is no doubt for the future that as long as man requires food from the soil (and perhaps increasingly the conservation of the sun's energy in bio-mass) the agricultural engineer and his innovations, will be more and more in demand.

The purpose of the Conference was to examine, with particular reference to agricultural engineering, certain aspects of innovation, and by so doing, in some measure, to assist agriculture to meet the demands made upon it. The fact that currently, there is at one and the same time, a surplus of food production, and starvation in the world, is not necessarily the fault of the agricultural engineer. But the very existence of this paradox serves to indicate, as little else could, the global dimensions of the scope for innovation.

Let us remember that for any significant innovation to advance to practical and commercial fruition, will frequently require that many other ideas dovetail in with the original innovation. Unfortunately, up to the present, the story in this country has, all too frequently, been one of innovations and inventions that have been admirably conceived, and then, for lack of associated innovatory thinking, left for others to exploit and bring to commercial success. Some of the remarkable concepts left by Leonardo de Vinci in his scrapbook serve as examples of isolated ideas which lacked the associated innovations and developmental thrust needed for complete success.

This point is further illustrated by the experience of Jethro Tull. In 1701 he invented the seed drill, and it is for this that his name is remembered. Yet his real claim to fame was the innovation of sowing crops in such a way that the weeds could be mechanically destroyed by horse-drawn tillage equipment. It was this innovation that pointed to the necessity for some complementary device, in fact, a seed drill, to make his new idea for controlling weeds practicable. Like most good ideas it was simple. It was based on a wheelbarrow, and its design and construction, once Tull knew what he wanted, did not stretch current technology. By 1731, he was sufficiently satisfied with his innovation, and its implementation, that he published his famous work *Horse Hoeing Husbandry*.

Even today, two hundred years later, one of our greatest concerns is the development of methods and machines for the better production of weed-free crops. Looking back at the work of Jethro Tull, and bearing in mind its significance, one would have expected his innovation to have found rapid and widespread acceptance. But not so. In 1804, one hundred and three years after Tull had invented the drill, and almost three quarters of a century after publication, Arthur Young, that failed farmer who prospered on his perceptive pen, wrote of a journey through Hertfordshire "I passed through near 100 miles in the county inquiring for drilled crops, but neither seeing nor hearing of any". Jethro Tull's innovation, since acknowledged to be the basis of successful husbandry techniques in the ensuring centuries, had failed to find general acceptance. The path of the pioneer and innovator does not always attract the followers it deserves.

The reasons for slow, or even non-acceptance of an innovation are beyond the scope of this introduction, but they serve to underline that the many facets of any new idea, on which the sum of man's knowledge may impinge, are such that no one person is likely to be able to manage them all. Failure to exercise an innovatory approach in any one of the disciplines concerned, can deny man progress which is otherwise within his grasp.

Some portions of our discussion will be concerned with managing inventors and inventions, others will be more specific and personal and will examine each individual, *You*, as an innovator. Almost by definition the true innovator is something of a revolutionary. It is interesting to speculate therefore whether, if they were job hunting today, da Vinci, Tull or even Barnes Wallis, McCormick or Harry Ferguson would be selected by present-day personnel departments, and be placed in environments where they could exercise their creativity to the full.

Finally, the Conference will not have been a complete success if it has not caused each member of the audience to stop and think about his own spirit of creativity.

Some of the speakers make it clear that innovation was not just an "Act of God" and that one could do much to stimulate innovation and create a climate favourable to its utilisation.

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*D N Scott BSc FIQ is a Director of J F Scott and Son Ltd, agricultural contractors, Womersley, Yorkshire.*

# Innovations the farmer awaits

## J M Botting

THE farming community is a strange mixture. Whilst being good at taking on sound new ideas, it is, in addition, innately conservative. Nature does not change very readily, or rapidly, and she and the weather represent over-riding disciplines. Fashions change in farming, but the farming community has a habit of reverting.

Consider early man, 6-8000 years ago he discovered that if he scratched the ground, dropped in some seed and scraped the soil over it, he had a better chance of getting his food supply under control. Today it is called direct drilling and harrowing. and people get medals for thinking up the ideas. An over-simplification of course, but the message is there. The basic processes in farming barely change. The farm machinery industry has provided the means to take the drudgery out of the occupation and has allowed mankind the opportunity to pursue goals additional to the mere production of food for survival. Agricultural engineers have allowed man the time to write books, paint pictures, compose music ... and to make atom bombs. The cynical view would be that if man had been confined to spades, forks and hoes, he would not have had the time to "progress" to such mischief.

### Arable farming

THIS side of the industry has become ever larger in scale, and is likely to continue to do so if the inventor and developer of machinery can provide the means.

Since the end of the 1939-45 war, average yields of cereals and root crops have allowed economic survival at the least. The picture has now changed dramatically. To survive, agriculturalists in this country must achieve very high yields indeed. Thanks to our politicians, even higher yields than our European partners/competitors.

It emerges from trial after trial that, above all else, these very high yields require timelines of operation, coupled with attention to detail. Farmers can supply the latter, but due to the economics of the situation only engineers can provide the means to achieve the former.

Operations must be completed still more rapidly than at present possible, remembering that many fields are not big enough to turn a 222 kW (800 hp) tractor round in, let alone to work in.

More work is required on a really effective and fast working, single-pass machine to produce a seed-bed of the required depth. As simple as possible, and less ungainly than most of those at present advocated. If wide, it must be simple to fold, and simple to maintain.

To follow seed-bed preparation, drills will be needed that will sow evenly at speeds up to 24 km/h (15 miles/h) ideally "Precision", and in rows 5 cm (2 in) apart. Difficult, expensive, but capable of 67 ha (150 acres) of drilling in an average day. The speaker will need to drill his 900 ha (2000 + acres) of Autumn cereals by the end of September, with one man.

Having drilled the 67-90 ha (150-200 acres) a day, the means are needed to top-dress and spray the crops many times a year under almost any weather condition. Timing is usually critical to within 48 hours or so if 8-10 tonnes per hectare are to be achieved.

Although great steps have been taken in both these fields over the last 20 years and a great deal of work is being done by members of this Institution, improvements are still needed. We need large machines for top-dressing (and at present for spraying as well) capable of operating when ground conditions are poor with minimal wheel damage to crops or soil. They need to have simply operated, electronic control of application. An integrating flow-meter to measure the amount of spray used in each field would be a useful addition to enable accurate field records to be maintained.

The economics of farming no longer allow odd men about a farm to cart water or fertiliser, and thus efforts must be redoubled to make "Ultra Low Volume" spraying the rule.

The economics of combine-harvesters present the farming and farm machinery industries with enormous problems. Farmers tie up huge chunks of capital in a piece of machinery which works for four weeks a year. The engineering industry invests in development, and in laying down production lines, the finances of which must make the farmers problems pale into insignificance.

The large sums of money involved make major progress in the design and construction of harvesting machinery very slow. Few farmers are prepared to risk new ideas in such a vital and expensive piece of machinery. Similarly manufacturers, having laid out millions in development, are presumably very reluctant to see major changes. Both industries must steel themselves and their bank managers to search for better and quicker ways of collecting and separating grain.

Fairly extensive work has been carried out on whole crop harvesting in Scandinavia, and some in this country. This may well be practical on the smaller farm, but it is unlikely to be applicable on larger farms with low labour forces where this system must require a vast amount of transport for such a bulky commodity as straw, grain and chaff.

Would it not be possible to reduce combine size and cost if it merely had to separate straw from the crop, and left the barn machinery to sort the grain from the chaff and small debris? Admittedly this would pose interesting problems for the designers of wet grain pits and elevators, but larger and more efficient grain cleaners and dressers will be required if British farmers are to sell their grain to advantage under EEC regulations.

Grain loss monitors are becoming more and more accurate. To make maximum use of the combine, why not use the grain loss monitor coupled with shaft speed sensors to control the combine's forward speed? Most combines tend to be driven too slowly anyway, particularly the large ones.

Dealing with waste straw is the next outstanding problem. Straw burning generates a great deal of energy, the majority of which only helps glider pilots to soar to great heights at harvest time. This waste of energy enrages conservationists and housewives alike.

Surely with the aid of the chemist, someone can produce a machine that will turn the straw into conveniently sized bricks, and spit them into a silage trailer. A fortune awaits him. In these days of soaring domestic fuel bills there would be no shortage of market for the end product.

It has been evident for some years that raising plants such as sugar beet in a controlled environment, early in the Spring, and transplanting them into the field when more temperate conditions prevail, can give rise to enormous increases in yield.

The technique opens up a fascinating field for automatic planting, watering and rearing inside, followed by automated delivery for transport to the field, followed by mechanical planting. This must also have applications for other crops such as maize for silage or grain, and one could imagine it being used for crops not as yet grown in this country on account of the short summers.

### Livestock

A relatively small number of dairy and other "cattle" men have made spectacular progress and are a very long way ahead of the field in terms of sophisticated equipment. The speaker keeps sheep, but is not otherwise currently involved with livestock, he will therefore simply encourage his audience to contribute their ideas, to spell out what they still need from the agricultural engineer.

For the cow keeper it would be difficult to say which area of development has been the most important, the spectacular

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variety of building configurations, the electronics of identification, rationing and measurement, or the handling equipment.

Plant breeders have provided outstanding uniformity of genetic make-up, but this is not yet the case in the bovine world. To a degree one has to feed, milk and otherwise handle each cow as an individual. The old-style cowman did this through experience and hard work. Now the engineer is progressively de-skilling these operations *and* making the tasks easier. Both these developments are probably needed by progressively smaller units, although long-term the smallest economic unit will probably be determined by the investment required for this category of equipment.

As electronic diagnostics and telemetry progress in human medicine, so agriculture can utilise much of the spin-off. Indicators will signal disease and the reproductive cycle and the need for ration changes, or could even effect the changes automatically.

Should the engineers concentrate on:
- Lightening the tasks
- De-skilling
- Making the tasks more pleasant
- Total automation?

Finally, will mechanisation/-automation be complete before another group of engineers (and chemists) renders the cow redundant by perfecting the milk analogues for all but specialist and luxury markets?

Pigs and poultry are now semi-industrialised enterprises and, at least in the west, there seems no chance of a return to smaller units. Accepting this, perhaps the audience would again volunteer the priorities for the engineer under the above four headings. As the units get larger, more sophisticated in control systems *and* easier to run on a routine basis, so the fear of breakdown or disease grows. It is theoretically possible to de-skill the whole "factory" to a very high degree, but in proportion the vulnerability to electronic or electrical failure grows. The investment in a large system is such that it will pay to instrument it more and more like an aircraft with "fail safe" and/or standby systems substituted for the stockman noticing that "something is wrong".

Turning to sheep (the speaker runs 2000 ewes) apart from the use of drugs and fencing, this is an aspect of the farming industry that has changed little in thousands of years. The economics of sheep farming are now forcing farmers to increase the density of grazing animals and increasingly to house their flocks for all, or part of the Winter. This even applies in upland areas, but is particularly true in the lowlands. This must be an area where the inventor has scope to mechanise the feeding and handling of these animals indoors. One must remember, however, that the economics of sheep husbandry do not at present allow vast capital sums to be spent on them, unless major savings in labour or feed costs can be made.

## Grass conservation

Agricultural engineers have made enormous strides in conservation machinery over the last 20 years. However, most farmers would like still more. Again, as in cereals, the reduction in the farm labour force focuses attention on speed of operation both in hay-making machinery which is not violent, and in silage making and handling. Whilst the very expensive large-farm and contractors' machinery must continue to have a place, the small family farmer, who is by nature independent, will need his own small tackle increasingly as the worsening economic climate forces him back on to his own resources. But, please, not small, cheap and nasty! The small farmer is, in practice, at least as much in need of reliability and durability as is the large-scale operator.

## Grain store and barn

This aspect of the farm is possibly the most unpopular with the staff and certainly the most difficult for which to find adequate labour to suit the work with any degree of reliability. On the speaker's farm, which is not so big, the drier operator is responsible for the treatment and storage of grain worth over £500,000 every year.

This must surely be one part of the farm where complete automation is possible using true, unattended robots for some of the jobs. One looks forward to the day when all these operations will be fully automated at harvest time.

Other tasks where the true robots will have an application, are in the handling, packing and stacking of vegetables and potatoes, provided that an enterprise is large enough to support the initial investment.

## Dangerous and unpleasant jobs, education and safety

Into this category fall the handling of all dusty materials, slurry and chemicals. Efforts in all these areas to remove all contact with the material in question must be to the farmers' advantage, and bring reward to the inventors.

Safety is, unfortunately, not a popular concept with those occupied in agriculture. The industry has a bad record where safety is concerned, and whilst most manufacturers take the safety of their machines seriously, it is still very obvious that for some, guards are hung on as an afterthought and not considered as an integral part of a design.

Forestry, though not strictly agriculture, still impinges on most farmers lives to some degree. The speaker manages 202 ha (500 acres) of woodland. Whilst true, large-scale forestry machinery is good, and probably as safe as can be expected, there is quite a lot of room for smaller scale machines, adapted for attachment to farm tractors.

Training, whilst perhaps peripheral to the present discussion, still has a considerable effect on the performance and safety of machinery. Everything else being equal, most farmers would buy from a manufacturer who goes to the trouble of supplying adequate training for operators. Too often fitters who visit farms to install new machines and to instruct the operators, turn out to be clueless themselves.

Active support for, and canvassing of, the ATB farmers training groups might well help in this direction.

## Tractor design and operator fatigue

Even bearing in mind the need for low labour inputs and the importance of timeliness and field size, the very big tractors of today are unlikely to get much larger.

The current furore about conservation and the general awareness of the countryside on the part of the general public will stop the removal of many more hedges. Unfortunately the very large, relatively slow-moving tractor, needs very large fields in which to operate efficiently its equally large implements.

What is needed therefore is a tractor that can operate, at much higher forward speeds than is at present possible, with moderately sized implements to cover the acres necessary in a day. This, of course, leads to the question of greater driver fatigue and a potential loss of output. It will be necessary to have tractor cabs sprung in such a way that the operator is not inhibited from maintaining high forward speeds under almost any ground conditions. In addition, trailed machines will have to be equipped with a system of monitors on moving parts with the corresponding instrumentation in front of the driver to obviate the need to turn round to check that all is well. All implement controls should already be hydraulically or electrically operated from within the cab which should of course be pressurised to exclude all dust, chemicals and engine fumes.

## Price and reliability

At a price almost any degree of reliability can be built into a machine and, in addition, in these days of economic squeeze, it is difficult, if not impossible, for dealers to stock all the spare parts that might be needed by the farmer.

However, there is room for a lot of improvement. All too frequently farmers still find themselves buying new machines which do not operate properly, or arrive incorrectly assembled, or with broken parts that can only be provided by the manufacturers after an unacceptable delay.

Over the years the speaker has bought several machines of North American manufacture and, without exception, they have been better built, have been more reliable and spare parts supply has been better than any of European manufacture. They were also somewhat dearer. This does not stretch to American-designed machines built in Europe. By the time the cost accountants have increased tolerances, carved bits off here and there to save money and generally picked them over, they have become less reliable. This is of course a subjective observation, but nonetheless, regrettable.

Reliability is so important from a timeliness point of view that most farmers would pay rather more for the product if they knew that the firm responsible never allowed a "dud" to leave the factory. What is needed is more quality control, more thorough inspection.

## Energy

This aspect of the future is the most worrying. Without putting too fine a point on it, the farm machinery and the chemical industries must overcome the problem of availability and cost of energy if mankind is to continue to make any progress.

The whole of modern agricultural mechanisation is based upon fossil fuel, a finite source of energy. It will probably not run out quite as quickly as the pessimists forecast, but run out it will in the not too distant future and, unless people are prepared to pay significantly more for their food, fossil fuel will be price-barred to us before that time.

Unless agricultural engineers in conjunction with other scientists have provided a reasonably cheap source of *mobile* energy before that day arrives, the former can revert to manufacturing spades, forks and hoes in support of their peasant customers. Therefore, the question must be asked, "What is being done about energy?".

Other forms of energy exist, but they must be at the right price, and truly mobile. At least tentative efforts in that direction should already be under way if there is to be a smooth changeover from diesel to the alternative before the present source runs out.

Manufacturers are already selling their tractors on the basis of fuel consumption in comparison with their competitors. This is a valid point. On the holding which the writer runs the 20% margin claimed by some manufacturers would mean a saving of £5600 in the present financial year, increasing every year.

The farming community requires guidance on the draught of implements and the energy/fuel required to draw them through the soil; optimisation of these factors and tractor speed can lead to significant energy savings.

As an industry, agriculture was, of course, the first to be engaged in the conversion of solar energy into a storeable, useable form. But is the farming industry taking up the latest solar energy collection techniques rapidly enough? Looking at the acres of roof on barns and grain stores makes one realise the potential for energy savings at harvest time, even if it did need topping up on occasions. The economics of the problem need constant review. As an example would it now be economically possible to use a mixture of wind and solar energy for barn hay drying in suitable localities.

Both farmers and machinery manufacturers can see the effects of the energy problem. They should, indeed *must*, do something about it.

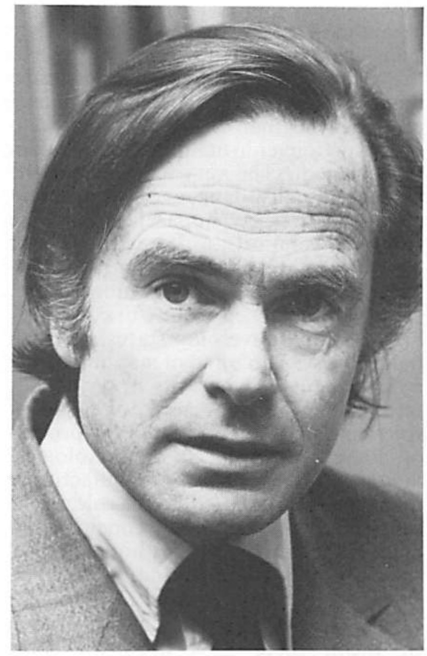
## Conclusion

This look at the farming industry has, of necessity, been superficial and vast areas have been left untouched. The objective was to stimulate thought and discussion, even if there is disagreement over the conclusions.

Should some of the companies represented at the Conference already be in a position to provide the speaker with the answers or equipment he has been asking for, the blame lies with their marketing departments, their publicity should have reached him!

# Productivity and creativity– The link


## Alistair Mant

THIS paper takes the form of an extract from a previous paper, on productivity, prepared for the Department of Industry, together with a commentary. The commentary links the common notion of 'Productivity' with that of another kind of productivity — the productive output of inventors or innovators generally. The argument is that the institutional arrangements which make sense for production lines *also* enhance creativity, despite what many people in Britain are inclined to think.

The excerpt is drawn from *Manufacturing and Management*[1] which also contains an important paper on creativity by Professor Liam Hudson.

### Productivity

ALL the data suggest that British manufacturing in Britain is, on average, less productive than the vast majority of manufacturing operations elsewhere. The pattern in the few foreign-based multinationals (FBMN) we saw is for productivity in their British subsidiaries to be lower than at home but still higher than in comparable British operations. Many of the FBMNS are puzzled about the scale of the differences, given that the 'tempo of work' in Britain appears to be similar to that in comparable, say, Swedish factories. The FBMN conclusion is that crucial differences must occur in management.

This view is reinforced by some of the comparative studies. Pratten for example, found productivity differentials of 50% between North American and United Kingdom firms and differentials of 27% and 15% respectively with Germany and France. He attempted to distinguish whether these differentials were primarily accounted for by economic or behavioural factors. As to the Continental operations he took 'behavioural' factors, especially 'manning and efficiency', to be as important in accounting for the differentials as 'economic' ones. Only in the USA did he regard the size of the market and the length of production run as the prime factor. Notably, differentials in the age of plant and machinery and the incidence of strikes and restrictive practices were not thought to be of paramount importance. Instead, and especially in the Anglo-German comparison, United Kingdom managerial performance and quality, poor systems of production control, lack of attention to methods of production and capital utilisation, slack management controls leading to excessive waiting time, ineffective manning levels, and so on, were cited most often. There appears, in other words, to be a differential commitment and attention to detail in the immediate supporting (management) systems of production, as between British junior management and their overseas counterparts.

*Alistair Mant is an independent consultant.*

On the basis of this study, and the available evidence, we postulate a network of productivity differentials something like this:

| | In UK | Overseas |
|---|---|---|
| Indigenous firms | 1 Low | 2 High |
| UK multinationals | 3 Medium | 4 High |
| Foreign multinationals | 5 High | 6 High** |

*** Box 6 ought perhaps to read very high, relative to boxes 5 and 2 in particular.*

We have insufficient evidence about the performance of the overseas manufacturing operations of British multinational firms. What we do have suggests that they are broadly comparable with competing foreign firms; this implies that, given the 'tempo of work' argument, the crucial factor is to have non-British foreman, supervisors, first-line managers, etc, in the supporting system. Cross-cultural productivity comparisons are notoriously difficult to make due to complexity, except in certain single-product industries such as motors and ship-building, where one can compute the quantities of direct and indirect labour required to produce one ship or one car, or whatever; but the matrix represents the best assessment of available facts.

### Swedish views on British manufacturing

We began the study by talking to a very senior group of managers, all of them with experience of British manufacturing sites and currently in the head offices of Swedish MNCS, for their views of British manufacturing. Some of the themes are summarised below:

(1) *Management versus work* The British manager's self-concept is of being a 'manager' rather than doing a particular kind of work with particular, valued outputs.

(2) *Ambition* In that context, the British manager is found to be more overtly ambitious for higher management rank; the Swede more modest in the expression of aspirations.

(3) *Creativity* British machine development proposals consistently have a speculative 'blue sky' character, vis-a-vis all other countries, though the ideas are frequently very creative.

(4) *Detail* By contrast, British manufacturing managers are seen to abhor detail and to assume, usually incorrectly, that attention to detail may be readily delegated downwards. For example: 'Why don't they keep the factory clean? — it must be connected with productivity!'

(5) *Involvement with work* Further, British manufacturing managers are felt to lack fundamental interest in the technologies they have to manage; they have not the 'hobby' status as with some of their foreign counterparts.

(6) *Human relations and work* Human relations in British subsidiaries is seen therefore to contain an essential 'phoneyness' because of disassociation from the work in the foreground; the technology and the throughput.

(7) *Relationship versus work* The pride of the British managers, production and otherwise, is felt to be in 'profit and relationships' rather than the throughput.

(8) *Sales versus manufacturing* Accordingly, in some cases, the British sales operation was seen as outstanding within European operations. For all the firms, the verdict on British manufacturing operations could be summarised as only 'fair, could do better'.

[1] *"Authority and task in manufacturing operations of multinational firms" by Alistair Mant appears in* Manufacturing and Management. *Reproduced with the permission of the Controller of Her Majesty's Stationery Office.*

These observations are important in the light of the thrust of the productivity comparisons noted above, especially those which point to slackness in the controls exercised by lower levels of British manufacturing management as being the crucial issue. What these observations suggest is that British manufacturing managers, once they achieve 'managerial' rank tend more than their Continental counterparts, to regard themselves as having undergone a change of kind rather than degree. They are, so to speak, no longer in manufacturing, but in management. The very existence of the extensive English-language 'management movement' largely unparalleled on the Continent supports, as Fores and Glover have argued, the idea of a separate, split-off 'generalist' management role, somewhat detached from work itself.

The comparatively low status of British industry as a whole and of manufacturing management and rewards in particular, reflects the apparent need for forms of role legitimation, apart from the process of manufacturing itself. In sociological language, the British manufacturing manager is 'committed' to his role, in the sense of coercion through impersonally-enforced arrangments, but not 'attached' to it (personal choice and self-image). These are not new observations; but for realistic research to be pursued in relation to them, there is a need for some theoretical framework which will provide explanations, and help to make predictions about the outcomes of possible initiatives. This paper adopts an authority framework because the evidence suggests that 'management' status in Britain is commonly associated with the elevation of status, per se; so it is dissociated from the intrinsic authority of task systems themselves.

## The distinction between inter-personal and inter-role relationships

Figure 1 illustrates the difference between relationships between individuals and those between roles in the context of a shared task.

The former model may be characteristic of a relationship based solely on personal power, the latter as based on authority, deriving from roles in relation to a task. A simple illustration is the difference between two people who choose to live together for as long as it suits them, and another two who decide jointly to enter into the institution of marriage and to take up appropriate roles in relation to the institution. The one is essentially dyadic, the other triangular. This is not to suggest that personal power may not be deployed in role, rather the reverse: that an authoriative role provides a sound base for the mobilisation of whatever personal power the individual may happen to have.

## Extrinsic and intrinsic tasks

Plainly the R-T model reflects the formal authority of an organisation, the agreed basis on which work is done. In systems theory, the dominant conversion process of a manufacturing system is the conversion of raw materials, components, etc, into a finished product of requisite quality to generate adequate revenue, after costs, to purchase further raw materials, knowledge, people, capital equipment, etc, in order to sustain the system: to survive. A manufacturing sub-system of a firm has many throughputs; but the product is the dominant one from which, ultimately, all authority is derived. This may be said to be the normal Swedish assumption: irrespective of hierarchical level, the manufacturing task serves as the basis of role relationships, and especially the role relationship between worker and foreman/supervisor/first-line manager.

By contrast, Swedish descriptions of British manufacturing management suggest, at worst, a network of straightforward power relationships, or, possibly, an ambiguous role relationship within which the manager attempts to derive his 'authority' from sources extrinsic to the task: that is, from 'management' status. The extrinsic management task suggested by the Swedish observations of Britain is that of 'getting ahead'; it is almost as if the provision of managerial career opportunities was the dominant task of the British system, and manufacturing simply a constraint upon that.

This is, perhaps, to put the case too baldly. All organisations represent the conjunction of task systems and human aspirations. The balance of these different interests is, however, crucial. The postulated Swedish balance would seem, at the very least, to be a logical one, something which may not be lost on British workers operating under foreign management assumptions. As Nichols has observed of chemical workers, workers may be more concerned with the competence of their management (to pursue the intrinsic task), than the extent to which they pursue 'human relations', 'industrial democracy' and other, doubtless worthwhile, pursuits extrinsic to the central task. Our enquiries in the new towns strongly reinforced this idea.

Seen thus, the current emphasis on human relations in industry may be misconceived, unless it is set in the context of task, role and authority. Good human relations does not ensure good management. However, good management cannot occur except in a setting of appropriate (role) relationships between people. Another way of expressing this is to say that an extrinsic task-assumption will lead to inauthentic interpersonal relationships ('phoney', as the Swedes put it); an intrinsic assumption will lead to limited, but authentic, ones.

## Industrial relations implications of the extrinsic assumption

The hypothesised splitting of British first-line management from the manufacturing task-system may be associated with two familiar phenomena of 'industrial relations'.

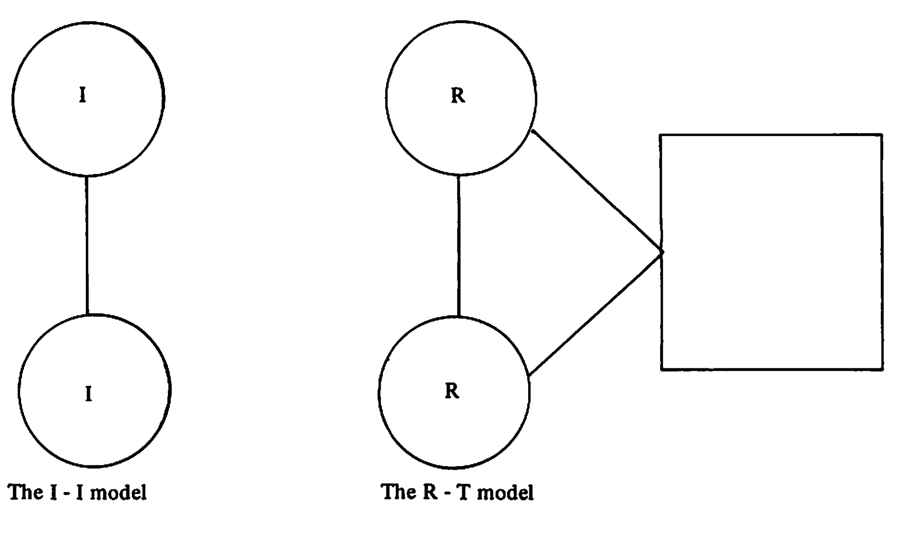
(a) If workers find themselves without leadership in relation to the intrinsic task, it is not illogical for them to seek it elsewhere, on the assumption that everyone requires leadership to some extent. The leadership vacuum is commonly filled by the shop steward, a person who, unlike many members of first-line management, at least appears to be clear in his mind about what he is fighting for. See section on 'Fight' below.

(b) We ought not to be surprised by the prevalence of restrictive practices around workers' demarcation lines, when the pursuit of extrinsic tasks of or 'management' status by managers represents a form of demaraction line between 'management' and work itself. Clearly, the destructive elements in the attitudes of both management and workers in Britain are mutually supporting. It is not, however, commonly recognised the extent to which worker assumptions represent a mirror-image of their bosses' assumptions.

## Task structures and the capacity to fight

An important outcome of the 'intrinsic' assumption noted above is that it provides an agreed, safe structure within which conflict can be confronted and coped with. To quote Rice: 'The problem

*Fig 1*




The I - I model

The R - T model

in industry is not fight itself, but the assurance that the fights will occur between the right people, about the right issues, at the right time.' In a power relationship, or an ambiguous role relationship, Fight is always a threatening thing and its outcomes are frequently destructive. But to fight about important task issues, from within an agreed role, allows the possibility of stepping out of that role into another one with 'no hard feelings'. Clearly, British manufacturing industry is not without fight, but there is abundant evidence that the fighting is often displaced from task-related issue. British 'industrial relations' activity is, to put it bluntly, usually more politicised then elsewhere.

I raise the issue of fight here because, in the course of this study, certain curious similarities began to emerge in the histories of the FBMNS we studied. In almost every case there was a celebrated fight in the company folklore; in each case it was a fight with the super-ordinate overseas system about a task-related issue. Because, in each case the fight was remembered, it appeared to serve as a kind of informal bench-mark — the sticking point for conflict with higher authority. In one case, unsatisfactory profitability was dealt with by the quick deployment of external consultants; in another, slipping production standards, by the sending in of head office 'trainers'. In each of these cases, the superordinate FBMN system defined the presenting problem as a technical one, rather than an 'industrial relations' one.

This provides us with some evidence that the overriding model in the minds of the non-British superior managers was of authority derived from the task system, rather than simply from rank. Neither were they afraid to fight about important issues, because they believe themselves to be so authorised. More correctly, they would be prepared to fight (on technical grounds) but seldom have to do so in reality because the underlying logic of their approach appears to have led, in each case, to harmonious industrial/task relations. To quote one of the Swedish manufacturing managers: "With the British we find it is all right when they have got it that they have to do it!" Moreover, it seems that these fights had historical/symbolic importance. It was as though they represented a threshold beyond which the system had to pass into a mature working relationship, just as children have to determine the sticking point of their parents, their teachers, and so on, in order to establish a workable boundary for their own independence.

A much publicised case, which we were able to look at briefly, is that of a Japanese electronics firm which elected to fight, in the end successfully, over the wearing of overalls by all staff, management included. This is a particularly interesting case because it so clearly represents the importation of alien social ideas to a British manufacturing site. Furthermore, it is an idea from a country which out-performs all others in the productivity leagues. The same firm is markedly more productive than comparable American firms, even in America. Most significantly, the uniform/overall symbolises the shared task: whatever your seniority, your ultimate authority derives from the manufactured products going out the factory door. As in the other cases mentioned, this British factory appears to be settling down to its task-orientation, and its overalls, as if nothing could be more natural. The essential logic of it does not escape British workers, management or otherwise. Additionally, the military model of organisation is not yet dead in British industrial cùlture, although it is presently much discredited. Some aspects of it, such as old fashioned attitudes to the primacy of task-authority and close attention to detail, appear to be more important for success than unsupported creativity.

This Japanese company's decision-making process in establishing a British factory is significant. The key elements were:

(a) The selection of a locally-born factory manager with 'participative' experience in manufacturing management, in fact, the firm's Japenese United Kingdom director is a devotee of socio-technical systems thinking; and the factory manager was carefully chosen from the well-known Glacier-Tavistock network.

(b) A close study of FBMN and British factories with a successful track record in manufacturing. The conclusion was that there was nothing at all wrong with British workers, given good management. As the factory manager now says of his one-time itinerant TV-repairmen: "We had to get them mentally attuned to our standards and flexibility".

It would be wrong to over-generalise about this particular site. Very few members of the management team are over 40, and the predominantly female work-force is drawn from an area of relatively high unemployment. Nontheless, the aspects in common with Swedish management are striking even though Swedish manufacturing represents a distinctly different culture from Japanese:

(a) An unfailing concentration on the output of the task system by all parties. The convener of shop stewards regards his district office as a place to go only in case of 'failure': "I like to keep them out as much as possible".

(b) An 'almost pedantic' approach to standards: "You must get it right the first time, which takes time; and if the set has a tiny scratch on it, it won't go out". Interestingly, the Japanese will not tolerate cumulative target graphs on the factory wall; it is surmised because they divert workers' attention from quality to speed and the possibility of 'pacing'.

(c) The capacity of fight, in role reference the overalls.

*Fight and dependence* To be technical, the issues here are those of psychological Dependence. Elsewhere (Mant, 1977)[2] I have employed the family analogy to suggest that a family unit capable (probably through its breadwinner) of fighting successfully in the environment for its survival, may well have a Dependent structure within. That internal dependence would be a mature dependence if the right people really were able to fight with the right people about the right issues. I contrasted two sorts of families, which are familiar to most social workers:

*Family A*

1. Firm but flexible assumptions about standards of behaviour and performance.
2. High time involvement with the children.
3. Carefully regulated, low-key money allowances.
4. Secure financial base.
5. Mature dependency assumptions.
6. Tested and elaborated authority of family roles related to family norms.

*Family B*

1. Double standards of behaviour and performance.
2. Low and grudging time involvement with the children.
3. Emphasis on spasmodic and lavish gifts and pocket money.
4. Insecure financial base.
5. Immature dependency or Fight/Flight assumptions.
6. Power structure.

Unhappily, the 'problem family' B will do as an archetype for the problem firm in Britain. It is a place where the rhetoric of money has taken over from the more intrinsic, work-related matters. However, it is well known that children from background B are able to adapt fairly readily to the A setting, though not without a fight and not without certain residual identity problems. The British, as we can see, are able to work for foreigners and appear to respond well to their methods.

*Absent leadership* The success of the FBMNS in Britain may, as these accounts suggest, be simply a product of the underlying, and communicable, logic of the task-oriented approach. That is, that if authority derives from task, in the long run, it will not be confused with 'authoritarianism', which I take to be the use, or abuse, of mere positional power. In fact, the FBMNS we looked at are very diverse. As one researcher put it, of three Japanese firms operating in this country: 'One is just like a Japanese company, another just like an American one, and the third seems to everyone there to be English'.

However, since the Second World War Britain has, to a significant extent, as I have argued elsewhere (Mant, 1977), assumed that leadership in the taking of painful industrial decisions must come from elsewhere, notably America. Historically, this had little to do with logic, with the rightness of American methods for British culture, and much to do with a profound disillusionment with the capacity of British managers to cope with the fights that emerge when change is implemented. We have therefore to consider whether the assumption of Absent Leadership is now so deep that it has an independent existence: that is, that irrespective of the underlying logic of management methods, foreigners are automatically assumed by certain types of British employee to be better employers and better managers than British ones. It is plausible that foreigners may be untainted by the negative class projections directed towards British top management. In this reading, the FBMNS may have the capacity to attract some of the ablest and most ambitious people, almost irrespective of the firm's quality, with a consequent long-term impact on productivity".

The excerpt above is drawn from a contribution to the great, and long-running, British productivity debate. At first blush, productivity and creativity are at opposite poles, the one achieved *en masse*, with the maximum of routine the other the outcome, it is assumed, of solitary eccentricity.

Yet there are similarities between the institutional conditions necessary for both high productivity and creativity. The fallacy is to look upon tight constitutional arrangements and creativity as natural adversaries. The Englishman, the Scots are excluded, and others with a good feel for formality, tend to look upon a written and formal structure as next thing to a straight-jacket. His preference is nearly always for informal and inter-personal arrangements, and the maximum of "Freedom" as though the firm were a rural village where the only formal authority required was God's.

The fallacy is obvious to anyone with children. In order to be creative at all the very young child needs *requisite* certainty and structure at the base for exploration. Children reared in no structure at all are usually prey to all manner of uncertainty, guilt and a kind of mental formlessness; in short, they lack discipline of the self-regulating variety. The fortunate child regulates its creative energies *in the context of* some imposed framework though, for all that, a generous and flexible one.

This is not a new idea but, it seems, an eminently forgettable one. Rousseau said as much over 200 years ago.[3] The Swedes, as the DoI report observes, value the untrammelled 'Blue sky' creativity of their English colleagues. They have very little respect for their sloppiness from then on. Yet all the evidence suggests that most winning products are the fruit of the painstaking development of existing ideas, and that is where discipline counts.

What then are the conditions precedent for creativity? The answer seems to be *both* concern for relevance, cost, standards, etc, *together with* the freest of free association. The trick is in the time cycle. Inventors should never be left to their pursuits for months, or years, or until the entire department is disbanded for want of funds. Instead the system needed should be based on fairly frequent oscillation between 'Blue sky' exploration and (very clearly bounded) attention to the nitty-gritty of real life. Workers on production lines respect, and recall with gratitude, the boss who is "Tough but fair". Inventors are people too.

The psychologist Liam Hudson wrote a very fine paper entitled "Making Things" around the life of Nicholas Sprimont, the doyen of Chelsea porcelain manufacturers. Sprimont obeyed all the rules for the classic entrepreneur, that is he was neither English nor a potter. He was a Heugenot silversmith who literally perished in the creation of his greatest works, suffering cruel hardship, bankruptcy and technical frustration on the way. No one turned him loose with a development budget, but pieces of Red Anchor Chelsea remain the pinnacle of beauty, vigour and function in porcelain.

Sprimont worked for himself of course, but he had a great many employees. The inventive employee today requires at least two minimum conditions:

(1) A management closely identified with the *object*, whatever it is, from muckspreader to figurine; experts in finance, "Human relations" and a host of other specialisations are also needed, but they should never call the final shots.

(2) A *constitutional* structure such that no one need feel particularly grateful to a boss, not because gratitude is to be despised, but because the dispensation ought to have been written down in the first place, ought to have been a *right*.

Both of these conditions obey the 3-corner rule set out in the DoI paper. If one succeeds in creating the minimum "Tough but fair" institutional structure, it relieves interpersonal relations of an unfairly heavy burden and frees up the people to be, amongst other things, creative. If the people don't create, one should not look to "Creativity seminars" but to the institutional framework of the organisation. Usually, there are a myriad aggravating rules about small matters, and practically nothing on the policy issues that really affect people. Usually the rule book is plain out-of-date, because no one really takes it seriously.

The comparison with Sweden and Germany is instructive. No one really believes that their people are more creative or innovative than the British. But there, innovation is freed up by the existence of the whole panoply of "Industrial democracy", "Worker participation" and thick rule books. It looks, to the English eye like a paradox but it isn't.

## Conclusions

The conclusion is that a company should, in general, *plan* on generating the new ideas it needs for survival, in-house, and should achieve this by ensuring that innovators on their team know their (innovative) objectives. The innovators should be allowed periods of free-thought (Brain-storming) interspersed with periods when the fruits of the free thought are evaluated and brought to bear on the company's objectives.

Good ideas, irrelevant to the company's objectives may arise in the course of the process — the most extreme form of "Spin-off". If and how these are found a home *outside* the company is a subject which falls outside the scope of this paper.

The speaker would not suggest that ideas generated by the long-haired eccentric working in his garage, or the practical man (user) inventing by accident, should be rejected. However, their availability, when required is, to say the least, uncertain and should only be regarded as a bonus additional to the in-house activity.

In addition injection from outside will almost always need a great deal more re-work before the results can be seen coming out of the factory door.

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# Stimulating creativity in design for production

**Peter M Fowler**

"DESIGN for Production" can be said to be the design or redesign of a product in such a way that its production cost is reduced to the minimum without loss of function or sales appeal.

Many designers would argue that this is already practised, but numerous reports on studies into the decline of certain sectors of British industry, from the Fielden Report (1963)[1] to the more recent Cranfield Report (1979)[2], all conclude that the lack of good detailed design ie "Design for Production", is a major factor in this decline.

In a film on productivity made some ten or eleven years ago, one of the characters made the statement, "The drawing board is the cradle of costs". It is not known whether it originated with the scriptwriter or whether it was an old saying that originated in industry, but it is one that should be fixed in the mind of every Director, Manager, Designer, Draughtsman and Production Engineer. Every line or piece of information put on a detail of an assembly drawing is a decision which commits the company to costs, whether they be for labour, material or overheads, but all too often the tendency is to design a product and leave the problems of putting the design into production to the manufacturing functions. An indication of the frequency of this approach can be seen in many design offices in the form of numerous printed forms headed 'Production Change Request' covering drawing boards and desks. Very few companies seem to analyse the proportion of drawing office time spent on this activity, but it is estimated that some designers and draughtsmen may be spending in excess of 40% of their time improving work done previously. This process is not only costly in drawing office time, wasted time and money in the production areas, but also in the paperwork involved in processing drawing modifications. The aim of every designer should be to issue drawings which are right first time.

## How improvement can be achieved

Every technical product passes through a series of stages during its development from an idea to its manufacture. This process is shown in its simplest form in Figure 1, but it should be noted that this basic procedure can often be repeated throughout the development of a product, not only with the product as a whole but at sub-assembly stages and even at the individual component level.

The two most important ways in which "Design for Production" can be improved are:—

1. By the consideration of the methods of production at the earliest possible stage of the process shown in fig 1, at the concept stage whenever possible. In many cases the concept of the design itself can lead to costly production difficulties, possibly through a requirement for extremely tight tolerances, difficult assembly conditions, or basic forms which can only be achieved at high cost. The consideration of production methods during the design process requires constant and effective collaboration between the departments involved. This not only includes design and production, but also marketing, estimating, buying and any other source of expertise that is needed, whether inside the company or outside. A common failing in the development of many products is the seeking, or providing of essential information at too late a stage. Whilst it is clearly better to have such interaction as a stated part of company policy, it nevertheless remains the designer's responsibility to obtain all the information he requires, in time to achieve a 'First time right' design.
2. Design for economic production demands creative thinking at all levels of the design process, not only to find new concepts, but to find new and simpler solutions at the component or detail design stage. The simplest design of a component is almost always the best design for production, but the simplification process can be very difficult, and an existing functionally effective design, by its very fitness for its purpose, can inhibit the mental processes which lead to production simplification.

To many people the word creativity is synonymous with "Invention" — the production of a completely new principle or the arrangement of known principles in a hitherto unknown way for some new use, but is this true?

It is usually at the speculation or concept stage of the series shown in Fig. 1 that invention occurs, but no invention is of any value unless it can be produced in a marketable form. To achieve this end, ways and means of putting the idea into practice must be conceived, and it is to this process, the process of design, that Thomas Edison was referring when he recalled that his inventions had been "... 1% inspiration and 99% perspiration". Until the design is completed as a drawing, or possibly as a model, with a form and purpose of its own, and seen as something new, it cannot be said to have been created. It can be argued then that it is at the design stage that the truly creative activity is carried out to achieve a fully functional solution to a particular problem, but this by itself is not enough. In the highly competitive markets in which most designers find themselves today, no matter how much creative thought is applied to finding a good functional solution, no design can be considered satisfactory if it cannot be manufactured economically, and without difficulty. What is required is not only

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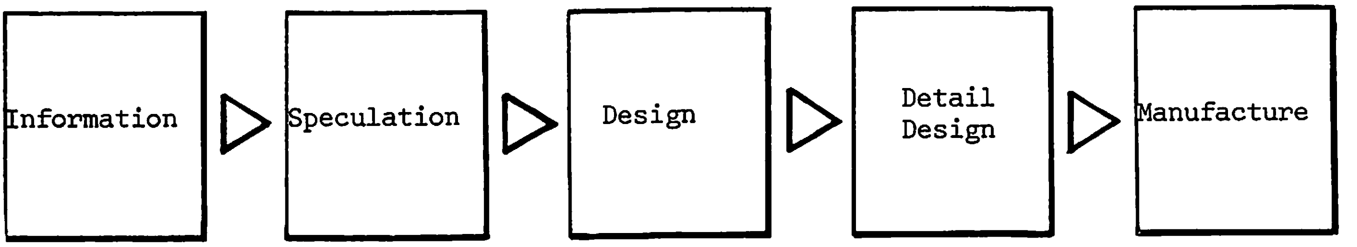



*Fig 1 Essential stages in the development of a product*

excellence in design for function, but also excellence in "Design for Production".

A main aim should be to obtain the maximum number of possible solutions at each phase of the design so that, after taking into account all of the relevant factors such as function, strength, weight, method of manufacture, simplicity, cost, appearance, etc., the best compromise can be achieved. Here also the mental processes can be inhibited, limiting the number of possible solutions which can be retrieved for sound, analytical judgements to be made. Most design problems have dozens, sometimes hundreds of possible solutions, why is it then, that the problem solver is usually confined to producing so few?

## Thinking about thinking

A situation often seen is where one individual is trying, unsuccessfully, to solve a problem, when someone else comes along, and suggests a solution, and immediately it becomes 'Obvious' to the one struggling. Recognition of the solution was instantaneous to the one who was unable to solve the problem, thus indicating that all the information required for the solution was available to him, but for some reason was not used. Why?

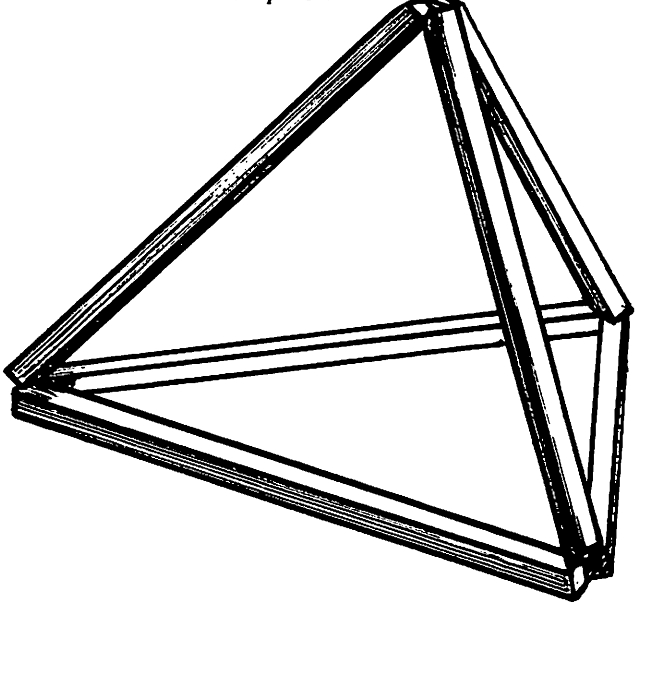
Another example of this human failing which should be of importance to any designer is where, having considered a design problem at some length, a concept is found which appears to offer the best solution and work commences on the design process. Calculations are made, materials selected, detail drawings prepared, when suddenly a much better solution occurs to the designer. What does he do? He can either discard all of the work that has been done or, more likely, he will continue with the design which is almost complete, and eventually launch a product which will be adequate, but which the designer knows can be bettered. Why wasn't the better solution conceived at the earlier stage when it could have been used? Another important question which should be asked at this point is, if it is possible to overlook one 'better' idea at the speculation stage of the design, is it possible that other available information is not being retrieved to produce even better solutions?

The reason for this frequent failure to recall stored information appears to lie in the fact that, whilst that part of the brain which is used for storing information has a tremendous capacity, the part used for the processing of information is extremely limited. Experimental work in the field of psychology has shown that the average person is capable of retaining only six or seven pieces of information simultaneously in the processing or working memory. Since the majority of design problems have more than seven, sometimes many more, parameters to be considered, it is easy to see how individual elements or possible combinations of elements are overlooked.

In attempting to cope with large amounts of information the processing unit tends to organise elements into tentative groups thus having fewer, but larger pieces of information to handle. This possibly accounts for the failure to look for the 'Right' solutions. The organisation of the larger pieces of information has a tendency to determine the retrieval pattern and the direction of the search in the storage unit, often leading into inappropriate areas or resulting in 'Single line' thinking.

An example of how 'Thinking' can be directed to the wrong areas can be demonstrated with a simple matchstick game. Given six matchsticks of equal length, an individual is asked to construct four identical equalateral triangles using all of the matchsticks without breaking or bending them. In the majority of cases the matches will be moved around on a flat surface in a variety of formations and although it quickly becomes clear that it is not possible to achieve the required solution by that approach, many persist in repeating the same formations on the flat surface until they finally leave the problem unsolved. When shown the answer, given in fig 2, it is immediately obvious!

*Fig 2 Solution to "six matchsticks" problem*



If thinking can be restricted in this way when faced with a simple problem such as the one illustrated, it is most unlikely that the brain will perform any better when a typical engineering design problem, having far more parameters, is presented to it. It is not surprising that an individual can 'Overlook' obvious solutions and be limited to producing a few ideas when many more are available. The most important requirement of any designer is the realisation of these limitations in his mental processes so that positive action can be taken to effect improvements at the appropriate times.

Courses such as those organised by the Smallpiece Design for Production Centres concentrate on these aspects of problem solving, and aim at stimulating the thinking processes to provide more creative and simpler solutions to design problems.

## Techniques which can help in design for production

Many and varied are the methodologies aimed at achieving improvement in the design process, and it is impossible to refer to all of them in this paper. The best known techniques[3] are summarised in Appendix 1. Based on observations of post-graduate studies in Engineering Design at the Loughborough Engineering Design Centre[4], doubts have been raised concerning the effectiveness of some design methodologies, particularly those which are more complex and require quantitative judgements.

The concern here however, is directed towards those techniques which can be easily applied by the average designer to improve his own performance in problem solving by overcoming the inhibiting mechanisms described previously ie 'Single line' thinking, mental blockage and failure to recall available information. Some of the more useful methods particularly aimed at improving "Design for Production" are discussed below.

## Brainstorming

The purpose of this group technique is to produce a large number of ideas quickly. The group is best limited to four or five people of mixed disciplines, and relies on association of ideas generated between the members of the group, and helps to overcome mental blockages in individual members. An essential feature of this technique is that early criticism of ideas must be avoided, so a strong chairman is required. An atmosphere conducive to unrestrained thinking is important, and length of session should be limited to about thirty minutes.

## Brainwriting

This recent technique[5] similar to brainstorming, but overcomes the problems which extrovert or introvert members of a brainstorming team engender. Members of the team write down their ideas on separate papers during a fixed period of time, then change papers. Ideas can then be added, or existing ones reformed. The changing of papers continues until the end of a pre-arranged time. Sifting of the ideas generated can be carried out subsequently, without the group.

## Lateral thinking

"Lateral Thinking"[6] is a method of freeing the mind from thought habits and conventional assumptions. It can be used to find new starting points for the solution of design problems.

## Functional listing

By breaking a problem down into sub-problems or functions and looking for ways of solving each function separately. Lists of solutions are generated under each function heading, and only when no more are forthcoming is the problem as a whole considered. Combinations of ideas from different lists generate new ideas giving far more starting points for the main problem then the usual six or seven described earlier.

## Value analysis

This technique demands a formal procedure to ensure that each stage is properly carried out, and involves an inter-disciplinary attack on the main characteristics of a product to achieve cost reductions. An essential step in the process is the use of the function listing technique to find alternative and more economical ways of achieving the same functions. The technique is mostly used to look at existing products which have been in existence for some time, where it is useful to reappraise the design, taking into account new production techniques and/or materials to reduce the existing production costs.

## Value engineering

This technique follows the same principles as Value Analysis except that it is carried out at the design stage ie its aim is cost prevention rather than cost saving.

## Functional cost analysis

Although it cannot be used as an aid to creativity, it is worth mentioning this technique[7] where traditional cost analysis is combined with a functional analysis to enable the value of a product to be judged. It can be used at the design stage to locate areas of high cost. Its main attributes are that information on costs is given in an understandable manner to mixed discipline groups and, if applied at an early stage of design, it enables the designer to judge whether any of the costs are disproportionate. Corrective action can thus be taken at an early stage.

Most of the techniques discussed are group activities and some, like Value Analysis and Value Engineering require a degree of organisation, but others, particularly the Functional Listing technique can be done on an individual basis.

The most important thing to remember is that, as with all techniques, the results will improve with practice, until with sufficient practice the basic techniques, such as Functional Listing, become no longer techniques, but an improved way of thinking.

## Conclusions

Today there is a greater need than ever before to produce well designed products that are competitive in international markets, but good functional design alone is not enough. The design must facilitate manufacture, and be economical to produce. This demands not only design for function, but also design for production. With even more demands on the designers' mental processes, help may be required to overcome some of the limitations imposed by the restricted capacity of the "Processing" part of the brain. Since these limitations are quite normal, training is often necessary to make the individual designer aware of such shortcomings, and show how, by using techniques which stimulate creativity, he has a better chance of producing, not only more solutions to design problems, but more solutions which are both novel and economical.

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## Appendix I

| *Technique* | *Description* | *Typical uses* | *Comments* |
|---|---|---|---|
| *Analysis of interconnected decisions areas (AIDA)* | A technique for analysing complex problems requiring a number of related decisions | Can be used for small or large projects to assess trade-offs and best solutions. Has been used for civil and mechanical projects | |
| *Attribute listing* | Examines each individual facet of a complex process or product | Development of new engineering products | The procedure relies on intuitive synthesis |
| *Bionics* | Takes biological analogy to produce new engineering ideas | Producing new mechanisms or novel ways of doing things | Useful to have a biologist in the team |
| *Brainstorming* | Produces large numbers of ideas quickly which have then to be critically examined | Improvement of existing products, and processes | Atmosphere all important Avoid early criticism Each session 30 minutes |
| *Charts* | T-charts to determine good and bad points of a design | To reduce cost of an existing product | Powerful when used with value analysis |
| *Check lists* | To avoid overlooking any parameter | For design reviews or critiques or aid to tendering | Such lists are built up from past experience |
| *Decision matrices* | Apportioning numerical values to each possible alternative | To record decisions taken as well as assess their values | Skewed matrix can be used to highlight certain aspects |
| *Decision trees* | Graphically describes the design process with branches showing alternative possible sub-problems | In planning design work and showing where development may be required | |
| *Fundamental design method (Matchett)* | Designers are encouraged to develop thinking in parallel planes. Concepts, basic elements, planned thinking, and making the familiar different | To stimulate creativity | Many variations have been developed for special applications |
| *Lateral thinking (de Bono)* | Method of freeing the mind from thought habits and conventional assumptions | To find new ways of tackling design problems | Can be used for training purposes |
| *Meta cards (Crickmay and Jones)* | These cards are aids to design action and help a designer to get going and keeping going at his design | Useful where mental blocks have occurred in the design process. Aid to simplifying a design problem | |
| *Morphological analysis* | Sub-divides form problems into discrete characteristics. From alternatives for each characteristic new combinations may be obtained | Used to design complex machinery, novel aerospace designs and other transport systems | Lengthy process. May need a computer to set down solutions for evaluation |
| *Synectics* | A system of group behaviour for generating new insights and resolving conflicts | Used to produce new designs and has a wide range of application | Sensitive to team member attitudes. Needs a mixed group of engineers and non-engineers. May require 1½ hours to complete each session |
| *Value engineering and value analysis* | Inter-disciplinary attack on main characteristic of a product to achieve cost reductions | Applied during the design process and later after design is released and production under-way | |

*The author wishes to thank B T Turner BSc MSc MICE MIProdE AFRAeS MBIM MATM Fellow, for allowing him to reproduce the above table.*

# Patents for home and export markets - Advice to the small inventor

**D Bryn Jones**

THIS address is directed to the small inventor who can be defined as a person who does not have the resources of a large company behind him, but who is, nevertheless, seriously intending to exploit his invention by himself, or with others.

A few definitions of the terms used in the patents business may help.

*An invention* is simply an idea which has been clothed in reality in some way.

*A patent* is a Government grant of a legal monopoly to exploit an invention for a period of time, and to prevent others from making, using or selling that invention during that period. The invention must be:

(a) New
(b) Contain an inventive step
(c) Be capable of industrial application.

The patent gives protection for a period of up to twenty years and usually is renewable every year of that period.

A patent is enforceable only in the country in which it is granted.

A *patent search* is an examination of already printed patent documents to seek out the printed patent which comes closest to the subject of the invention or lays claim to the subject.

The *prior art* is the whole body of known technology in all its forms.

The *"Convention"* is an international treaty signed by nearly all countries of the world under which a member country will accord national treatment to foreigners. Its full name is the International Convention for the Protection of Industrial Property and under it an Englishman making a French patent application may be given the date of filing of an earlier English application provided there is less than one year between the English and French filing dates. This is called the "Convention Year".

The *European Patent Convention* (EPC) is a convention under which a bundle of national patents may be obtained by making a single application which is followed by a single search and examination.

The *Patent Cooperation Treaty* (PCT) enables a single common application and a single common search for a number of countries. This reduces searching time as compared with several National applications.

## Progress from an idea

Now let us see what can happen to an idea.

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Practical inventions as a rule stem from problems, and in particular, technical problems.

If the solution to the problem appears novel, the person who is confronted with the problem may think "I have made an Invention — I can get a patent for it". Maybe — but at this point he should quietly sit back and think about a few more things. This inventor's Invention will be spelled throughout with a capital "I".

Is his Invention solving a problem that confronts the whole of the agricultural industry or just a small part of it? Is it going to satisfy a need? Is he going to be able to charge a high price for it? Is it going to cost very little to manufacture? Are the materials he needs to build it readily available? Can the workforce make and assemble it easily and quickly? Is it usable in foreign countries?

Is it of such a nature that the competition will go to great lengths to possess it and if they fail will they design an alternative?

Is it going to require very little maintenance once installed or will it need a steady flow of parts? These and similar search questions should be introspectively asked.

Away from the fireside's glow he will concede that the answers do not confirm the rosy picture he probably first had.

The first thing he has to do is to check carefully whether the Invention:—

(a) fills a need
(b) is feasible ie can be built, and is likely to work properly
(c) is viable ie can make or contribute to a profit.

## Searching

When satisfied as to these points he should find out if it is novel. He cannot go around asking all and sundry whether it is novel because he would thereby be destroying whatever novelty might exist. He has to find out if it is novel by means which maintain its secrecy. He can make a search in a technical library himself or employ someone else who is obliged to keep a confidence, namely a patent agent. On the industrial side of patent work we are tending to make searches before we make a patent application, the principal objective being to find out if the Invention is novel thereby saving further time and money if it is not.

A further item is to find out whether the Invention, if put into hardware form, is likely to infringe another patent. This is done by carrying out an infringement search.

It is worth devoting a few minutes to this question of searching.

The history of technology is recorded all over the world in technical libraries.

There are facilities at these libraries for searching patent and non-patent literature, but as a patent in the main deals with a single subject whereas a journal will refer to several, it is easier to classify, file and recover a patent. Thus because of its recoverability searches are conducted through patent collections.

Two kinds of searches can be performed.

The first kind, known as a "novelty search", is carried out to find out if the Invention is indeed new. A novelty search involves a searcher in making a decision on what subject class it falls into and thereafter manually inspecting the patents in that class. The manual inspection consists of looking initially at the drawings of the patents and thereafter reading a part of the whole of the text. Professional searches carry out these duties, and they exercise a great degree of skill in proving the absence of the idea for which they are looking. The word "Absence" is used deliberately here because it is the speed with which a searcher can reject irrelevant patents that cuts down the time and cost of a search. The searcher will usually be instructed to inspect United Kingdom patents, but he can search the patents of other countries if so instructed.

The second kind of search is an "infringement clearance search". This is a much more difficult search than the novelty search because in theory the searcher has to read the claims of the patent, and if they are likely to be infringed by a machine which incorporates the Invention he must bring the patent to the clients attention. This kind of searching involves far more responsibility and is more painstaking, slower and expensive. However since the life of a patent is limited, there is no need to examine patents which have expired for infringement. Infringement clearance searches can be made if a machine is to be introduced without there being any intention of seeking a patent for it.

It is possible to have both of these searches performed concurrently. The results will show, bar mishap.

(a) whether the Invention is novel, and

(b) whether a machine placed on the market and incorporating the Invention will infringe a patent owned by someone else.

If the Invention is novel, the way is clear for the inventor to apply for a patent.

If the Invention is not novel no patent can be obtained.

If the search shows that no patent will be infringed the way is clear for the machine to be built and sold and used.

If the search shows that a patent will be infringed the inventor must proceed with caution and assume for the moment that he will not be able to build his machine. The situation may not be as black as it first seems. He may find, on conducting a further search, that the patent is invalid or that the patentee is prepared to grant a licence on reasonable terms.

His patent agent will assist him over these hurdles.

The novelty search rarely anticipates the exact Invention, and it is often the case that a study of the search results will pinpoint the exact novelty in the Invention, so that the text and drawings for the forthcoming patent application are focused properly.

The infringement clearance search may turn up a patent that is *nearly* infringed by the machine that the inventor intends to build. He is thus made aware of the need to change the design away from infringement if change is needed.

Thus the results of both searches may provoke the inventor into changing his design and in doing this he will take the opportunity of improving it. This process of avoiding patents by improving is seen as one of the overall benefits of the patent system — one of the spurs to invention.

Figure 1 gives a picture of an appropriate schedule.

## The application

Having come this far and being very clear in his own mind that he now has a patentable Invention, the inventor should instruct his Patent Agent to file a patent application, having first found out how much it is likely to cost. The Patent Agent will give an estimate and will explain the options open. It is possible these days to

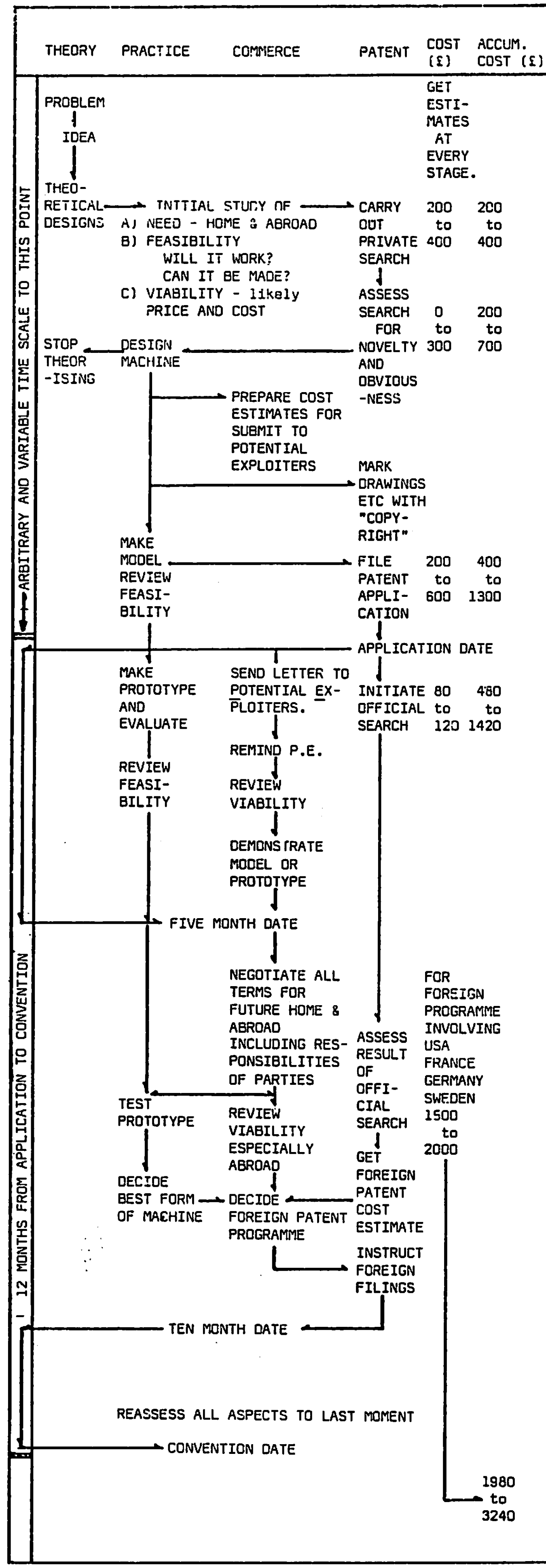

*Fig 1*

take one of three courses with regard to the first filing of a patent application. They are:—

1. File a national application at the British Patent Office — this is the traditional method.
2. File a European application at one of the European patent office receiving centres.
3. File a PCT application.

The choice depends on a number of factors, for instance the potential value of the Invention, the chances of being able to get a patent, the availability of funds at this stage, and the intended patent territories.

Small inventors presumably must have regard to funds and there is such a call on his funds at that stage that it is probably wisest to take the traditional route and file one patent application at the British Patent Office.

The other two routes can offer considerable savings if the territorial programme consists of more than six countries, but as it is possible to take these routes later, there is no necessity for instant decision.

In carrying out a careful, considered approach to the first filing of a patent application it should be borne in mind that it is always a possibility that someone else will come up with the same invention, and get to the Patent Office first. If the circumstances are such that others may have the opportunity to solve a problem at the same time as the inventor, he should act more quickly. For instance if a chemical company develops an anti-parasite chemical which calls for the accurate placing of a porous bag of the stuff at five foot spacings with precisely one inch buried and three inches protruding, an inventor would be most unwise not to rush off and patent his solution to this problem because others will realise the problem and come up with solutions very quickly. If in doubt on this question the patent agent should be consulted at once and all the circumstances of the situation laid before him.

It should be borne in mind that a patent application once filed starts a clock running which can be difficult to stop.

Once the inventor has started this clock running he must turn very energetically to the engineering, manufacturing and commercial side of the invention especially if he has been forced by circumstance into filing quickly. He now has precisely one year the "Convention Year" in which to decide if he is going to try and obtain foreign patents and where. In the same way that he tried to find out about the likelihood of getting a patent before he filed it, so he must now carry out intensive work to find out if the Invention is going to be a feasible and viable proposition, and where the markets will be.

## Engineering

If it is his intention to exploit abroad he should take care that his drawings and all ancilliary data is marked at least with his name or the name of his Company, and that they carry a copyright notice which is preferably in two parts, eg:

© J. Smith & Co. Ltd, 1981
and All right reserved.

The value of marking in this way is that a citizen of the United Kingdom, will be accorded the same rights in another country of the Universal Copyright Convention as a national of that country. These rights may not amount to much in some countries, but at least they establish ownership.

The principal objective under this heading is to get together a model, or a full-scale prototype which will satisfy the inventor, who should remain self critical, and potential exploiters, that the Invention will work. Often agricultural engineers have to cater for a wide variety of operating conditions and this should be taken into account. Any difficulties on the question of reliability or replaceability of parts should be addressed. If any sophisticated manufacturing techniques or materials are involved in realising the Invention these may prevent exploitation in certain countries so this may limit the ability to grant a useful licence.

## Commercial considerations

Where should one exploit? The inventor can probably start quite quickly by eliminating large number of countries where the invention is not usable.

Others can be eliminated for economic reasons, and yet others for political reasons.

It may be found that in some countries any earnings from the sale of a patented product may not be allowed out of the country. In some countries patents are rarely enforced by the courts so it is pointless to seek them.

A further consideration to be kept in mind in choosing countries for exploitation is the activity of competitors in that country.

The inventor should consult every source of information available to him. The Department of Trade and Industry runs a Small Firms Service[1] with offices in the regional centres where he can get information and counselling on business matters. The British Overseas Trade Board[2] provides a similar series for potential importers. Government Bookshops[3] of HMSO are also located in regional centres. The Institute of Patentees and Inventors[4] is a further source. The Chartered Institute of Patent Agents[5] will aid in finding a patent agent.

If the inventor does not have the resources to exploit the Invention himself, he must work with the utmost energy, and with a discipline that he must attempt to impose on others. First of all, no offer should be made to any potential exploiter until the patent application has been filed. When it is offered, the chance of success will be markedly increased if a scale model, or a prototype which has actually performed, is available.

It does not matter what kind of a lash-up the prototype looks like. If it shows that the Invention actually works, worthy potential exploiters will recognise it.

A range of prospective exploiters should be investigated. A short list, based on their qualifications, should be made, and they should be asked in writing for an expression of their interest by a date no more than two weeks later. Foreign parties or companies, especially those where there is a foreign exploitation potential, should be circulated.

A standard letter to a range of prospective exploiters might contain the following:

(a) Advice that a patent application has been filed (title, date and applicant)
(b) A photograph of a model or prototype — marked with a copyright notice
(c) Drawings of all or parts of the machine — marked with a copyright notice
(d) A short description of the operation of the machine
(e) An estimate of the costs if it is a simple machine, or a financial analysis if it is more complex
(f) A request for a substantive response by a date two or three weeks later
(g) A list of the enclosures which should be returned uncopied.

The subsequent correspondence should be conducted with a view to having two or three potential exploiters or backers firmly interested at a date five months after the patent application date.

The obvious parties to write to are companies, however these are not the only ones. The National Research Development Corporation[6] is in the position of being able to help inventors. In addition there are organisations willing to provide venture capital. As a valuable incidental they will provide expertise in a number of fields for the primary purpose of protecting their investment, but this will also benefit the inventor. A list of venture capital organisations is to be found in financial directories such as the City Directory[7]. Most reference libraries carry such directories.

The response may contain an offer to purchase an option. The inventor should be very clear about what this means. Usually, under the option, the inventor will undertake to refrain from dealing with other potential exploiters in return for payment of a fee. The inventor should understand that if the option is not taken up, the option period will have robbed him of precious time during the Convention Year. He should therefore be very parsimonious with any option time given, and be paid accordingly. The option fee is not refundable of course.

## The "Five Month" decision

It is desirable that the inventor should be in a position, at a date five months after filing the patent application, where he has a clear idea as to how and where he is going to exploit the Invention, and how he intends to finance the foreign patent applications. In particular he will have to have decided upon the following objectives which must be realistic in the light of the circumstances then obtaining:

The number of foreign countries

Who is going to own the foreign patents and who is going to pay for them (the patent agent will give an estimate of costs for a given programme of foreign countries)

Who the practical collaborators are likely to be

What form the collaboration is likely to take

What particular form of the Invention is likely to be a success.

The next five months must be devoted to reaching those objectives, principally by negotiation with the parties who are prepared to assist in exploiting the Invention. This must be done with just as much energy as the previous five months — if not more — because the chances are that the collaborator will be relatively slothful.

By ten months from filing the first patent application, the patent agent must be instructed where to file abroad, and about the current hardware form of the Invention.

The patent agent can obtain patent protection abroad with the aid of PCT or EPC and the relative merits of each route, including its costs, should be fully discussed. In particular the ongoing costs for keeping the patents in force for their full terms in the selected countries should be appreciated. The costs shown in fig 1 are to give a broad indication of the finances which will be needed.

Turning back to the original patent application, this could have been made as a British Application *or* a European Application *or* a PCT Application. Provision is made under all three systems for an official search. European and PCT searches would involve examination of the patents to be found in all the high technology countries and the British search would, at the present time, be through British and some United States patents. Accordingly it is possible to arrange for the results of one of these official searches to be to hand by the tenth month.

These searches are more international in character, and are official. They may throw up prior foreign patents which affect the novelty of the Invention, and they may show that a foreign patent may be infringed by a machine incorporating the Invention. This is very important for the inventor to know because it will influence his collaborators' attitude, and his own, especially if the patent exists in a country where they were hoping for substantial sales. If no relevant patents are discovered by the official search the inventor's position is significantly strengthened. The result of the search should be shown to the collaborators, but only after the impact on the case has been fully appreciated.

## The "Ten Month" decision

Thus, at the ten-month stage, the inventor will hold the results of a private search and an official one and therefore can assess the chances of getting good patent cover. He will know who his collaborator(s) is (are) and the arrangements with him (them) for the commercial, engineering and financial aspects. He will be in a good position to instruct his Patent Agent where to file foreign patent applications. This allows the Patent Agent sufficient time to prepare drawings and forms, and to get the latter signed, arranged translations, prepare the revisions necessary to the patent specification and anticipate the vagaries of several postal systems before the end of the twelve-month period which the Convention allows for filing in a foreign country.

The patent applications are subject in some countries to an examination in which the Patent Office examiner is empowered to reject the application because he thinks that, whilst the Invention may be novel, it is obvious. Hence nasty shocks may yet lie in wait for the inventor.

The patents will be granted, barring problems, in a sporadic manner over the following few years.

A patent applicant cannot sue for patent infringement until he has received grant of his patent but as it may take one or two years to bring the Invention into production the timing may be such that he receives grant at just the time when the competition is becoming interested in the Invention.

The inventor may relax for a few minutes soon after the filing of the foreign applications, then he must be up and making sure that his collaborators are moving things along with proper urgency. In particular he must keep a sharp lookout for the next technical problem — which is approximately where I came in.

## References


1 Small Firm Services, Department of Trade and Industry, Offices at Regional Centres, Freephone Service on 2444 is available.

2 The British Overseas Trade Board, Department of Trade, Export House, 50 Ludgate Hill, London EC4M 7EU.

3 H M Stationery Office publish through Government Bookshops as follows:

49 High Holborn, London WC1V 6HB.
13a Castle Street, Edinburgh EH2 3AR.
41 The Hayes, Cardiff CF1 1JW.
Brazennose Street, Manchester M60 8AS.
Southey House, Wine Street, Bristol BS1 3DE.
258 Broad Street, Bimingham B1 2HE.
80 Chichester Street, Belfast BT1 4IY.

4 The Institute of Patentees and Inventors, Staple Inn Buildings, London WC1V 7PZ.

5 The Chartered Institute of Patent Agents, Staple Inn Buildings, London WC1V 7PZ.

6 National Research Development Corporation, PO Box 236, Kingsgate House, 66-74 Victoria Street, London SW1E 6SL.

7 City Directory.

# It's novel ~ But is it better?

## R F Norman

THE search for novel solutions to problems is often seen as the sole objective of the research and development effort of an organisation, be it industrial, State or academic. But such an approach does not recognize the vital fact that for any solution to be utilizable, no matter how technically brilliant it may be, it must be an economic solution. It can be argued that there are areas of research which do not have an economic measure and, therefore, research can be, in essence, research for its own sake. Whilst this might just be true in certain medical work, it is generally unrealistic, for everything, ultimately, has an economic value and it has to be funded from somewhere.

It is against this background that, in the broadest context, research may be seen as finding an economic solution to an unsolved problem. It used to be fashionable to quote "Putting a man on the moon" as the classifical research problem. Alternatively finding a more economic or technically superior solution to a problem, that has already been solved, is equally research — or, in some companies, might perhaps be seen more as a development role. Thus, in the agricultural context, a more accurate system for bout marking in connection with fertiliser spreading and spraying activities might be seen as a current research/development problem. Thus, no matter how defined, the term 'Economic solution' must enter into the research and development equation.

For many, this creates concern and, indeed, often alarm on the basis that any attempt to pre-judge the economic requirement will limit the research activity. It is thus desirable to review the economic assessment of research and development activities.

TURNING back to the classical problem of putting a man on the moon, in this case, the market was the US public and the economic solution had to be related to what the Americans would pay to win the space race. Although this was primarily a political situation, it nevertheless had an economic base. Fortunately, in industry we are usually dealing with more factual and less emotional-cum-political decisions. Most problems can be related to a financial base, and hence a particular level of investment in research and development can be equated with the value of the solution. Put in more simple terms, the questions always asked relate to: what is the market, where is it, what will it accept, and how is the organisation concerned related to that market? In terms of research and development management, it is not so much a question of "Is it novel or is it better?" but rather, for a specific market, can a better solution or product be provided that will not only repay the investment in research and development, but also provide a reasonable return on the investment.

Defining the market is in itself an essential part of any research activity. This is not the place to describe market research, attitude surveys, and other techniques which can be used to determine market requirements. It may, however, be appropriate to remind all concerned that a relatively small amount spent on market research may save an expensive and/or abortive research programme. Most products, be they a piece of agricultural machinery, a new chemical, or a new control mechanism on

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a machine, will result from research and development within a company, either because of the expertise of the company concerned, or as a result of a market analysis. Whichever it is, any such proposal must be subjected to an assessment of "Will it fulfil a market need?". That does not mean simply obtaining the views of a few salesmen, or a few directors of the company; what it does mean is getting down to assessing the reactions of customers, distributors and perhaps component and/or machine manufacturers. It can often be argued that such attempts to assess the market must represent a security risk, revealing the company research programmes and, therefore, alerting competitors and perhaps prejudicing the ultimate success of the development. Skilful market research using external agencies will almost certainly avoid this problem.

Having concluded that a market does exist, and that an investment is desirable, the question then arises as to which solution, of a number put forward, should be pursued. Here, one of the most difficult tasks of research and development management comes to the fore, viz. the ability to be flexible, to adapt the programme as it is proceeding, and above all, kill off those areas which are clearly seen to be less acceptable. There is perhaps no more difficult decision than to cancel a research project since there will always be the view that "Maybe it will come right tomorrow". Techniques for assessing the likely viability of research and development projects vary, and clearly must be related to the individual company's approach. Basic techniques are taught in many business schools, but they should not be rigorously applied to each and every situation, but rather modified to meet individual cases.

Once the research and development project has proceeded to the stage where a marketable product is in the offing, then it is essential that the research, development and marketing staff operate as a team to introduce the product into the market place. By such means the expertise derived by the development team will be available for the marketing of the product. Equally, there should be immediate and accurate feed-back from the field concerning any problems which have not become apparent during the development phase.

In considering the overall management of any research and development activity, then clearly the prime requirement is to establish the objective and, in particular, to relate that objective to a specific market situation. In the early days of research, the objective may be very broad but, as the project progresses, it should be capable of being narrowed and integrated into the company's activity. But there are always situations which emerge where, as a result of research and development activity, a product or technique may arise which does not fit in with that particular company's expertise. Many alternatives are then available, but in essence, they fall between the two extremes: either to kill the project or to continue the work and adapt the company structure to be able to handle this new situation. The latter may well prove extremely difficult since, for example, an agricultural engineering company may find itself in consumer products, a totally different market.

Another approach to the "Alien innovation" would be to license it to a party better equipped to develop and market it. Such a licence must reflect the market potential, and provide a sufficient incentive for the licensee to invest in the project. Such projects usually require much greater management effort since there is always a reluctance to accept research and development projects derived outside the organisation, the "NIH (not invented here) syndrome".

Returning to the original question "It's novel, but is it better?" requires careful consideration of what is meant by better. History is littered with novelties which barely progressed beyond the product launch, in fact it was once calculated that eight out of ten new products fail. It is perfectly possible for a novel and even patentable solution to an existing problem to be inferior to other solutions or products already on the market. Even the inclusion of a technological breakthrough is no guarantee of economic success. The "Better" mousetrap should only be selected for introduction if it fulfils a need in the market place.

# Innovation in agricultural engineering – Its encouragement and utilisation

## Edited summary of discussion

**Mr C Brutey** (NFU) thought there was difficulty in translating farmer ideas into a commercial form. The NRDC did not seem to quite fit the role in this case, and do we need a National Development Station to help with these ideas.

**Mr J M Botting** said in reply that in his experience redesigning of a prototype machine was not always successful because the production model seemed to become unreliable.

**Mr P M Fowler** added that redesigning must include all the original functions and sales appeal. Most prototypes concentrated on function only.

**Mr T C D Manby** (NIAE) added that regarding the risk of cost reduction measures interfering with the performance of the machine he agreed with Mr Botting and Mr Fowler that there will be many occasions when changes introduced between the prototype or pre-production stage and final production model led to problems. These were usually because of a change in the way the machine interfaced with the crop or working media so that practical operational problems occurred. There was, however, a different aspect to the application of the principle of value engineering during the development of a new product. He referred to the difficult, but important, task of learning about and understanding the loading and stressing of components so that economic designs which had the desired fatigue life would result, with maximum advantage taken of the possibilities of cost and weight reductions. This could only be achieved if there were facilities to enable the service load data for various types of machines to be measured and for test equipment to be available to help finalise the design process. These facilities would in future be available at NIAE with help from the DoI under the scheme whereby UK manufacturers could be offered help with prototype development and testing.

**Mr H J Carnall** (Bonser Engineering) asked whether dating of drawings was of importance when making patent applications.

**Mr Bryn Jones** replied that dates were not necessary on patent application drawings, but were important for the purpose of copyright, especially if drawings were to be published.

**Mr Jeffes** (Farmer) said that he had during his career produced a number of innovations and inventions and commented on the time it took for them to be taken up by manufacturers. He asked if there was any possibility of using the waste engine heat from the combine for drying and if straw could be bonded with an adhesive to use for fuel.

**The panel** thought there was no future for utilising combine waste heat because of the short time the grain spent in the combine. No one offered an opinion on the gluing of straw.

**Mr F Moore** (Howard Rotavator) asked the speakers to look 50 years into the future and suggest what the developments there may be in agriculture.

**Mr Botting** thought that tractors would be going faster, up to 40 miles/h. Mr Jones thought that farming the sea would be important. Mr Fowler hoped for something to pick up mud deposited on roads by tractor wheels. Mr Mant thought intravenous conference attendance would be beneficial, and Mr Norman thought remote control of seed bed operations would be used. Mr Moore himself, hoped that the wheel might be eliminated from agricultural operations.

**Mr T Sherwen** commented that any innovation should meet a need, have a specification and the potential market must be estimated. Mr Jeffes wanted to set up a panel to help inventors to achieve Mr Sherwen's objectives.

**Mr Norman** thought that the Agricultural Secretariat should be able to help, but his advice was always to see a patent agent first.

**Mr J Matthews** (NIAE) asked what size of step developers should take in innovation. Mr Botting in reply said that someone should be taking big steps with national financial support, whereas commercial firms should take much smaller steps.

**Mr Jones** said that history was littered with inventions that were before their time and strongly advised studying market potential before proceeding.

**Mr Fowler** said that large firms ought to be looking at least ten years ahead. Mr Mant commented that companies seem to oscillate between the sophisticated, making rapid progress, and no progress.

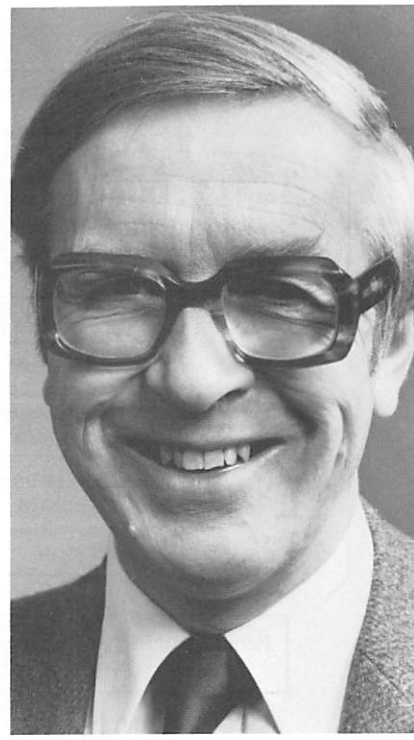
**Mr Norman** observed that agriculture was not as conservative as it may seem to be.

**Mr J M Bunting** (Inveco) said that many overseas customers did not know what they wanted and manufacturers needed to read between the lines and make suggestions. Mr Norman in reply said that it was always best to go and see for oneself but in many cases specifications were made deliberately vague so that the manufacturer would work on these, and then the customer would use this document with which to go out to tender.

**Mr Fowler** said that it might be better for the designer to specify since in many cases the overseas customer was not the ultimate user.

# Modelling for engineering research and development

**M J O'Dogherty**




## Summary

THE principal uses of models in engineering are discussed in the context of the design process. The advantages and disadvantages of models in research, design and development are outlined. The attributes and fields of application of iconic, analogue and mathematical models are given. Four examples of the use of models in agricultural engineering are discussed in detail. These show how complex problems in the provision of an optimum environment for livestock and in the design of orchard sprayers can be aided by the use of laboratory analogue models. The use of mathematical models is illustrated by a discussion of a simulation of the dynamics of tractor overturning and by a study of the dynamics of the shaker mechanisms employed on a blackcurrant harvester for fruit removal. A number of other examples of the use of iconic, analogue and mathematical models in agricultural engineering is given, covering many different types of problem.


## Introduction

THE objective of this paper is to outline the techniques of modelling which are available and to indicate how they can be of value in design, research and development[1]. The use of the word "model" will have a varying connotation for different individuals; for many people it will mean a reduced scale model of a structure or machine. Such models have been widely used for a variety of purposes and will be discussed, but there are many other forms of model which can be employed for specific ends. The essential feature of a model is that it is a simplification of the real situation, which is generally too complex to permit analysis and prediction of its behaviour. The model has to incorporate certain idealisations and abstractions of nature which allow the problem to be approached without the plethora of complexities which surround it in the real world[2]. It is important that the purpose of the model and its limitations are clearly defined. Where the economics of the solution and the resources available make it justifiable, a complex model may be appropriate; in some cases, however, a very simple model may be the only acceptable approach. It is important with any model that it is meaningful and this must be tested by a process of validation against the real situation. It should always be remembered that the model is a simplification and that it should not be applied to situations which contravene the underlying assumptions and constraints which are implicit within it.

Models have been extensively used both in science and in technology. In general, scientific models are of value in understanding and describing natural phenomena, whereas in engineering the model is used as an aid in the design process. The distinction is not always clear cut, however, and there is a considerable overlapping of the roles of the scientist and engineer. A well known example of a model in physical science is the model of the structure of the atom, first proposed in simple form by Rutherford[3], which provided the basis of the understanding of many physical and chemical phenomena at the atomic level. In engineering, the subject of the mechanics of materials is an example in which models enable practical problems to be solved; in general, the mathematical theory of elasticity does not provide solutions to the stability, internal stress and deformation of structural and machine elements[4]. The subject uses models of the behaviour of elements such as beams, shafts and plates, which are based on well defined assumptions and allow the engineer to obtain design solutions to a wide range of situations.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## Design, research and development

Modelling is only one aspect of the overall design process and it is of value to consider the stages which take place in an engineering design project to see where the use of models fits into the overall scheme. A number of attempts have been made at describing the various steps in design and other thought processes[5]. A useful summary of the essential components of a design project has been given by Johnson[6] (fig 1) which corresponds in its essentials to the procedure given by Shigley[7] who defines the six stages of (1) recognition of need (2) definition of problem (3) synthesis (4) analysis and optimisation (5) evaluation and (6) presentation. The component disciplines of design are listed in table I[5].

**Table I Component activities appropriate to the design and research transformations**

| |
|---|
| Classification of goals |
| Organisation of existing information |
| Identification of problems |
| Analysis |
| Synthesis |
| Formulation of criteria |
| Design and conduct of experiments |
| Development of hypotheses |
| Testing and revision of hypotheses |
| Development of theories — generalisation and prediction |
| Optimisation |
| Evaluation and decision |
| Testing and performance evaluation |
| Communication |
| Implementation |

The essential feature of the process (sometimes referred to as the "morphology of design") is that it is iterative so that each stage may yield information which leads to a reappraisal of earlier stages. Although the whole process is of interest, our concern is with the use of models which is primarily applicable to the phases of synthesis, analysis and optimisation and evaluation, although they may also be of value during the earlier stages. The

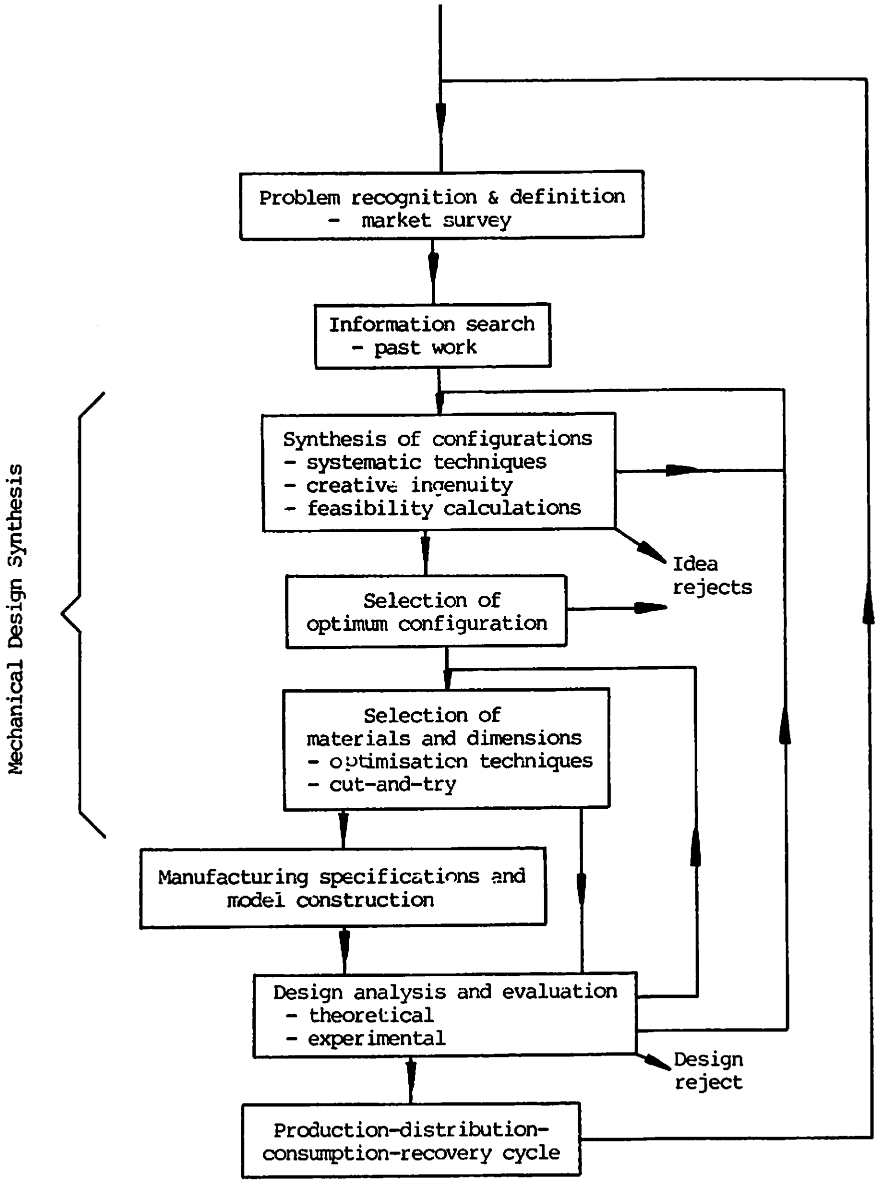



*Fig 1 The mechanical design process showing some typical feedback loops*

synthesis stage of design is the crucial one in that it embodies the creative element and will be a divergent activity in that it will consider as wide a variety of solutions as possible[8]. Many of these will be rejected as impracticable or not satisfying the criteria of a specification which will have emerged from the initial stages of the process. Models may be used in this part of the process, often as an aid in conceptualisation; an example of this is the use of models in the styling of car bodywork. As a result of this process one or more possibilities will be chosen for more detailed examination and at this stage models are often of great importance as a quantitative way of optimising the design criteria to select the configuration which best meets the overall requirements. The evaluation stage of a prototype follows this phase in which the performance of a design can be critically evaluated and the validity of models tested and reassessed; this will form an essential part of the iterative process[9] (fig 2). It should be emphasised that different kinds of model may be used throughout the design process for different purposes. The selection and use of models requires skill, knowledge, judgement and experience on the part of the design team and a clear definition of the objective for which they are to be employed.

It is relevant to distinguish between research and design activities[5 10]. In the research process (fig 3) the output is unknown and the use of experimental equipment and techniques leads to a better understanding of natural phenomena. In design (fig 4) the input requirements and constraints are defined and the desirable and undesirable characteristics of the product are specified; in this case the design process is unknown and is essentially a creative function; it is important to appreciate that a methodology must be employed in design to apply constraints to the creative faculty within known scientific laws. Design is a convergent activity in which all resources are brought to bear on a

*Fig 2 Model evaluation process*

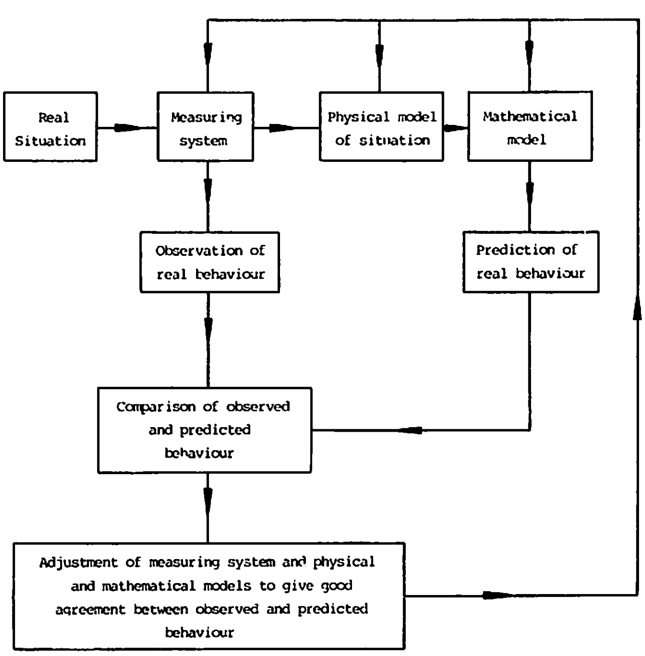
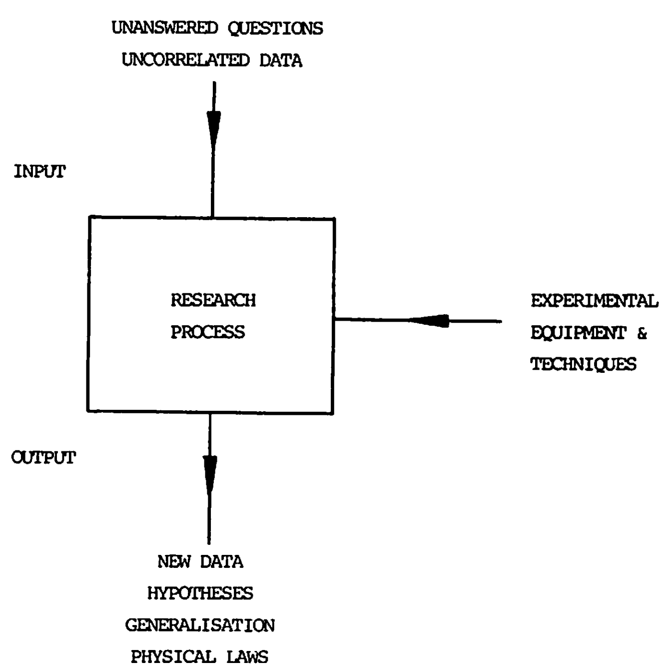



*Fig 3 The research process or transformation*



specific solution, whereas research is divergent and a broad perspective is taken to state and examine the problem in a general way. Development may be regarded as part of the design process. In some cases invention pre-dates development by a considerable time as has often been the case in agricultural engineering[11 12]; in mechanical engineering well known examples are the early steam engines of Savery and Newcomen[13] and the early motor cars. In other cases development is an integral part of the design of an engineering product and forms part of the iterative process. There is, however, an interaction and overlap between these three activities; for example, new scientific knowledge forms an input to design activities, development generates the impetus for research work and design can embrace both research and development within its framework.

Modelling can be of value in many aspects of an engineering project. Its principal uses have been summarised by Woodson[5] as (1) organising and recording development (2) clarification and visualisation (3) analysis and synthesis (4) prediction and (5) communication of ideas to others. The principal attributes of models are summarised in table II[5]. Problem solving can, of course, be approached by the direct method of "cut and try" in which an embodiment of an idea is made and subjected to use and observation. This approach, although appropriate in limited investigations, has serious demerits and can be very wasteful in terms of manpower, equipment and time. It usually does not lead to success in identifying the important parameters of a problem and is inappropriate to any optimisation procedure. In agricultural engineering, as in any other aspect of engineering, it is necessary to examine machine performance in the real situation as broadly as possible, but this should be done in a disciplined way, as part of the design process, which should draw on all the design techniques now available, in which the various modelling approaches play an important role.

As with any engineering technique, models have limitations which must always be borne in mind by the designer[14]. The most important point to be remembered is that any model is an abstraction and is limited in its application by the assumptions which underlie it; the designer must be careful

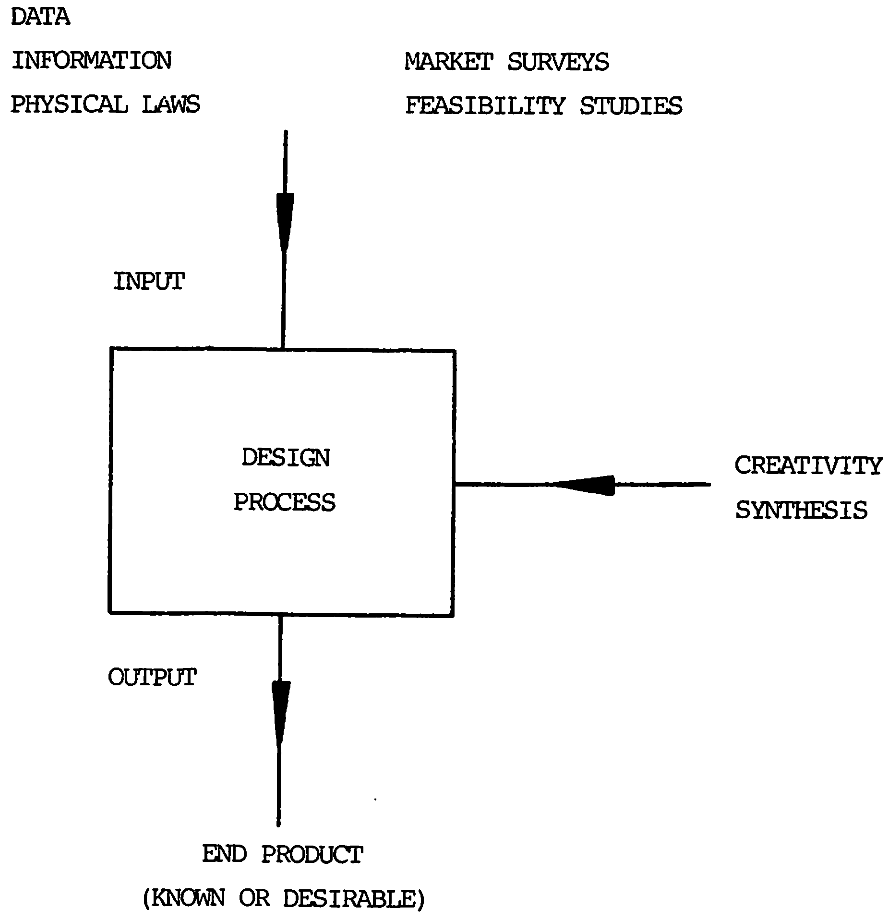



*Fig 4 The design process or transformation*

## Table II Summary of the attributes of models used in problem-solving

**1 Purposes and power**

Iconic

a. Visualise: Enlarge, shrink, emphasise sense of texture and shadow, show aesthetics.

B. Establish relationships: Rank, order, proportion, arrangement. Observe the interactions.

C. Synthesise: Make a whole out of parts.

D. Communicate and record: With self, clients, subordinates.

Analogue

A. Simulate performance: Operate in the desired mode and in real or artificial time.

B. Determine numerical results: Check quantitative interactions.

C. Employ various phenomena: Suggest new areas of investigation.

D. Interchange variables and parameters at will.

E. Use one piece of equipment (analogue or digital computer) to solve many varieties of problems.

Symbolic

A. Use maximum generality in attack on problem.

B. Economise effort: Use symbolic shorthand for attributes and operations.

C. Lead to numerical results, to explicit functional relations.

D. Use methods of mathematics, geometry, and other logical techniques.

E. Solve many problems economically: Use only pencil and paper.

**2. Laws involved**

Iconic

A. Scaling ratios: Lines, areas, volumes.

B. Laws of projection, geometry.

C. Rules of seeing: Limitations both by physiology and by dramatic effect.

Analogue

A. Equivalence of the differential equations, or other equations of behaviour.

B. Dimensional homogeneity.

C. Rules of similitude.

Symbolic

A. Self-consistent axioms and laws of the logic used: Numbers, functions.

**3. Limitations**

Iconic

A. Limited number of variables: 1, 2 or 3 (dimensions).

B. Optimisation generally done visually.

C. Limited by the engineer's conceptualisations.

Analogue

A. Fidelity of assumptions: Simulation increases probability of correct answers.

B. The range of the specific equipments available.

Symbolic

A. The fidelity of assumptions: Answer must be tested.

B. Solving-power and skills of the engineer or mathematician.

not to attempt to use a model for purposes for which it is not intended. There will always be some differences between the predictions of the model and the real situation and it must always be mandatory to validate the model by testing against reality.

## Types of model

There are three basic types of model: (a) iconic, (b) analogue and (c) symbolic or mathematical[1 5 15] the essential attributes of each type are discussed below and particular examples of (a) and (b) are listed in table III.

### Iconic models

A model of this type looks like reality (from the Greek "eikon" an image or likeness); it is a visual geometrical equivalent which may or may not be of the same size as the original[16]. They usually only show the features of the original which are relevant to the purpose of the model. A number of examples are listed in table III. There are two broad types of iconic models: (i) two dimensional or pictorial representations and (ii) three dimensional replicas which may have either a uniform scaling or part of the scaling may be exaggerated, as in the vertical height of a topographical model.

This type of model can be of great value in design for gaining a conceptual appreciation of problems and for communicating ideas; it is often important in the creative phase of a project. Designers often make extensive use of aids such as Meccano and simple mock-ups in wood and cardboard for these purposes[5].

### Analogue models

A model of this type follows the same principles of operation as the original and is only of use when it is in operation. Some well known analogies which have been extensively used in engineering studies are given in table III. Their use is characterised by the fact that they enable quantitative information to be obtained as a result of experiments which are conducted with the model. This enables specific information to be obtained more rapidly and economically than with a prototype; a good example of an analogue is the employment of scaled aircraft and ship models in wind tunnel and ship tank experiments to study a wide range of their performance characteristics[17]. The use of such models requires a good understanding of scale effects and of simulitude requirements[17 18 19]. Another class of analogues which has been extensively used is that where there is a correspondence between phenomena which follow the same laws of behaviour and can be characterised by similar sets of mathematical equations (sometimes known as isomorphisms). Use has been made of the fact that electrical circuit analogies can be found (examples of these are mechanical systems, heat flow and fluid flow network problems) which can then be used to obtain solutions to the basic equations; this principle is that used in the electrical analogue computer[20]. An important type of analogue is that which simulates the performance of complex equipment such as aircraft or space vehicles and which are used for training in a wide range of situations, some of which could not be introduced in real life.

The use of analogue models is as varied as human ingenuity and it is impossible to discuss other than typical examples. Some aspects of design which would previously have been studied by analogues are being approached by the use of techniques now available on digital computers which offer powerful analytical techniques (such as finite element analysis) and visualisation facilities[21]. However, it is still easier to model behaviour physically in many problems and to use the two techniques as complementary.

**Table III Examples of iconic and analogue models**

**Iconic models**
- maps; drawings; charts; photographs; diagrams topographical relief models
- "stick and ball" models (molecular structure)
- frame structure models
- reduced (or enlarged) scale models (architectural, civil and mechanical engineering)
- "mock-up" models (product design).

**Analogue models**
- slide rules; calculators; analogue and digital computers
- ship tanks; hydraulic models (e.g. harbours, estuaries)
- wind tunnels (aircraft, motor cars, building complexes, bridges)
- simulators (aircraft flight, motor car driving, high and low gravity)
- photoelastic; brittle coatings (stress distribution)
- soap film (torsional stresses on non-circular shafts)
- electrical analogies (correspondence with mechanical systems, heat flow, fluid flow, acoustics)
- structural (bridges, towers, dams, vessels, shells)
- soil mechanics (earthquakes, tunnels, pile foundations, vehicle and implement design)
- acoustic (design of auditoria)
- hydroelectric machinery (pumps, turbines)
- loading rigs (simulation of static and dynamic load conditions)
- lunar vehicle
- spread of fire and conflagrations

### Mathematical models

The concept of a mathematical model is familiar to all engineers and scientists. Whenever we use a familiar formula we are, in fact, making use of a mathematical model. We may not always be consciously aware of this fact and may not know the assumptions which underlie the formula and, therefore, define its limits of applicability. The principle of the mathematical or symbolic model is that is represents the characteristics of the original which are important. It represents generality in attacking problems, provides a simplification of complex problems, uses well established techniques of analysis and provides numerical information. Such a model uses sets of mathematical equations which may represent well established basic scientific laws or experimental relationships established for the purpose of the design, possibly on physical or analogue models. The power of such models is that they can explore a wide range of combinations of design parameters and, most importantly, lend themselves to optimisation and prediction procedures. The scope of such models is very wide and can range from simple formulations which can be solved on paper, or with an electronic calculator, to highly complex systems which require the use of a digital computer. The same principles of validation must be applied as for other types of model to ensure that the model represents reality and to define its limits of applicability. The availability of digital computers has made it possible to deal with very complex problems and to solve equations by numerical methods which cannot be solved by analytical means; in addition the computer enables optimisation procedures to be used for problems with many variables[21 22].

The potential of mathematical modelling is so great that the number of examples is limitless. Some examples in the agricultural engineering context will be discussed later.

The use of system simulation using a mathematical model has proved of great value in problems where analytical and numerical techniques are not possible[23]. The use of such a model enables the response of a system to be determined for a wide range of operational variables and design parameters. A simulation can deal with both deterministic and stochastic problems[24 25]. Its value lies in the fact that the model can be used as an experimental tool and very extensive investigations can be conducted. The technique is particularly applicable to the use of digital computing methods.

Mathematical models lend themselves to the use of optimisation techniques which have been extensively developed in recent years and the process should be the basic objective of the engineer. The process of optimising depends on the use of an "objective function" which is a set of criteria which has to be maximised (or possibly minimised). In any design there are conflicting objectives which have to be given appropriate weightings so that any real design will be "optimal" rather than a theoretical optimum. The process is one which may be applied at various levels of complexity from the graphical to complex algorithms.

## Examples of models

There are many examples of models which have been used for design purposes in agricultural engineering as in other engineering fields. The choice is wide and the examples which are given below are taken principally from work carried out at the National Institute of Agricultural Engineering. Four models are chosen for more detailed description, as examples of particular interest in that they illustrate the range of model uses and their ability to tackle complex and diverse problems. A number of other applications of models are then discussed briefly to given an indication of their range of applicability to many different kinds of problem.

The models discussed are of the analogue or mathematical types because they are used to obtain quantitative information and the results of their use are reported in the published literature. Iconic models, however, can play an important part in the design process, as discussed above, but generally lead to information which is qualitative rather than quantitative. Some examples of iconic models in agricultural engineering are given at the end of the paper.

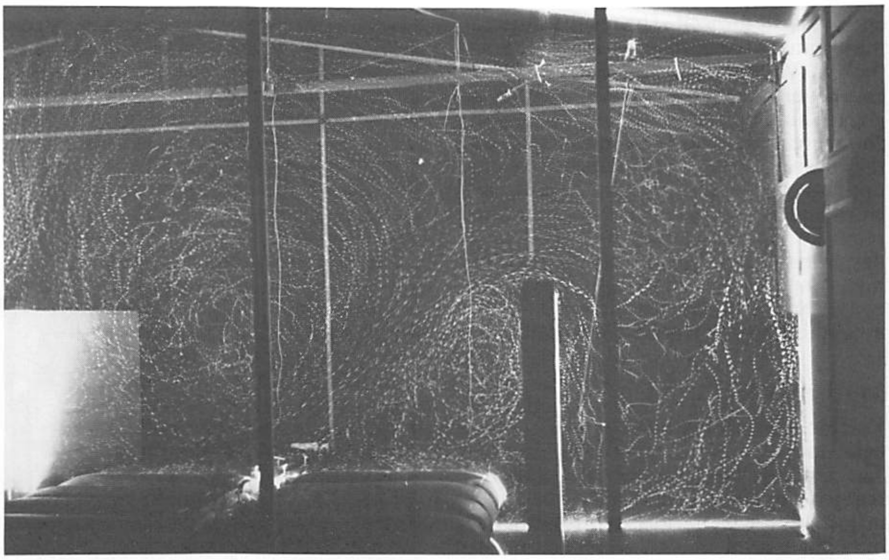


*Fig 5 Visualisation of air flow pattern in full size section of piggery, using simulated pigs*

## Analogue models

### Environment in livestock buildings

The provision of ventilation to provide optimum environment at livestock level is a complex problem. A full scale model has been used to study the airflow patterns for a number of finishing piggery layouts and ventilation systems. The model consisted of a section of a typical building span which was one pen in depth and was fitted with a transparent end wall for observation purposes[26]. It was surrounded by an insulated shell which enabled the exterior temperature and relative humidity to be controlled to simulate a range of ambient conditions. The pen area of the section contained twenty eight simulated pigs which consisted of butyl bags through which warm water was pumped; these were of an appropriate shape, size, surface temperature and rate of heat release so as to provide the requisite convective effects. The complex patterns of air movement within the building section were observed by the use of bubbles which were generated in the building section and whose tracks were photographed by time exposures of light scattered from their surfaces (fig 5)..

The power of this type of model is that it is an analogue of the real situation which contains the essential factors which produce the inertial and thermal forces which lead to the complex spatial distribution of air movement within the building. It enables a wide range of situations to be investigated which would be impracticable in the real situation. The model enabled an examination of different penning arrangements, ventilation systems and ventilation rates to be made, together with the effects of ambient temperature due to seasonal and diurnal changes. The use of the model has resulted in design criteria for providing a stable and unchanging air flow pattern which is unaffected by outside conditions[27]. It is of interest that the stability of the flow pattern was successfully characterised by the ratio of buoyancy and dynamic pressures (Archimedes number).

The ventilation system must remove the heat produced by the stock. The cooling effect depends on a number of factors and a mathematical model has been used to determine how they influence the lower critical temperature of groups of pigs (the temperature below which they use food to maintain their body temperature)[28]. The model was used to study the distribution of air speed and temperature across the building, for a range of ambient conditions, ventilation rates and penning arrangements, in order to determine whether the cooling effect could be maintained at a constant level[29].

The result of the detailed studies which were conducted with the model building section is design criteria which overcome many of the problems of traditional systems[30]. A system incorporating these findings has been installed in a large commercial piggery and has shown considerable improvements in feed conversion and pig welfare. This work is continuing and a new study is beginning on the ventilation of buildings which house poultry in cages.

### Orchard spray application

An interesting application of a scale model was the use of a model orchard installed in a wind tunnel to obtain information on the design requirements for orchard sprayers. Such machines use an air jet to transport the drops of spray liquid and to obtain penetration of the drops into the tree leaf canopy. The sprayer is travelling at right angles to the direction at which the turbulent jet is emerging from the machine. An analytical approach to the problem presents formidable difficulties and the conduct of field experiments is slow and difficult because of the large number of variables present, some of which cannot be controlled. The model was constructed to obtain information on the correct fan specification and air jet requirements for a range of circumstances which occur in practice.

The model consisted of 1/12th scale model trees, some of which were fitted with scaled leaf trusses, which simulated both a bush orchard and a hedgerow orchard[31 32 33]. The trees were placed in an open jet wind tunnel (of 4 m x 1.8 m cross-sectional area) which has a 0.8 m working

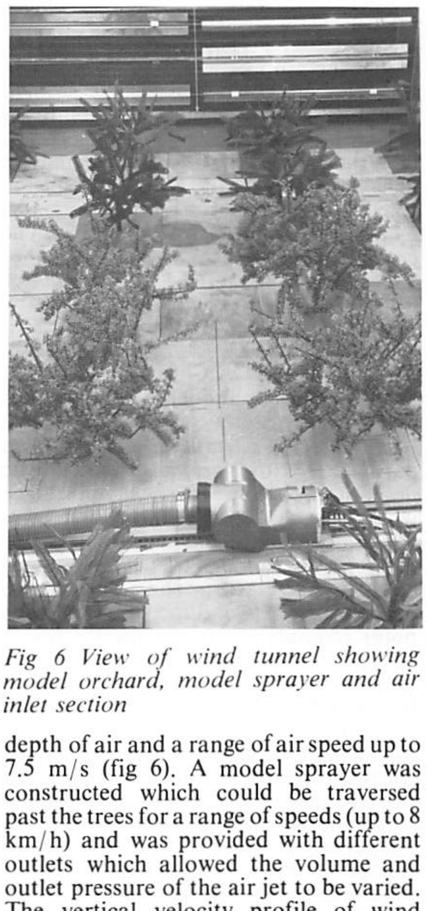


*Fig 6 View of wind tunnel showing model orchard, model sprayer and air inlet section*

depth of air and a range of air speed up to 7.5 m/s (fig 6). A model sprayer was constructed which could be traversed past the trees for a range of speeds (up to 8 km/h) and was provided with different outlets which allowed the volume and outlet pressure of the air jet to be varied. The vertical velocity profile of wind velocity and the degree of turbulence in the air above the plantation were reproduced on the basis of measurments made in orchards. The performance of the air jet was assessed by measuring the air jet velocity and calculating the air horsepower as the model sprayer moved through the orchard; this was done at positions within the tree canopy and between trees. The air jet and wind velocities were kept at actual values as was the sprayer speed.

The model was used to study the effect of wind direction, air volume at constant air horsepower, sprayer speed and the energy of the air jet[34]. The results showed that sprayer performance improved as the air volume was increased, with a consequent reduction in velocity at a given air horsepower. A successful commercial machine was developed on the basis of the work which was an optimal configuration determined by considerations of fan efficiency, size and requisite operating speeds[35]. The new design has been shown to be capable of higher speeds and operating in windier conditions with the maintenance of an acceptable spray deposit distribution.

## Mathematical models

### Tractor overturning and impact behaviour

The aim of work on the dynamics of tractor overturning is to provide information which leads to the provision of a high level of driver protection in overturning accidents. There is a requirement for strength and deformation criteria for roll-over protective structures (a safety cab or frame) which can be used by standards committees, legislators and manufacturers. The dynamic behaviour of an overturning tractor is very complex and there are about 40 parameters which can affect it; these can be divided into (a) those which affect the overturning phase, (b) those which affect the impact behaviour and (c) the parameters of the tractor (eg its inertias and geometry) which affect both (a) and (b). The complexity of the problem is such that experiments on real tractors can only be done to a limited extent because of the restraints of cost, time and reproducibility.

A recent study by Chisholm[36] has used a mathematical model and computer simulation to study overturning down a bank as in a multiple roll, and particularly to provide a realistic description of impact behaviour. The work was based on realistic cases and validated by experimental studies. The mathematical model was based on the equations relating the forces and deflections in two dimensions at each point of contact between the tractor or safety frame and the ground. The solution of these equations enables the forces and accelerations on the rigid part of the tractor to be found which enables the next instantaneous position of the tractor to be predicted. The computer simulation used numerical integration to solve the differential equations of the mathematical model and determine the tractor position and orientation for a series of time intervals.

The model was validated by experiments in which a tractor with an instrumented safety frame was overturned down a 2 m high simulated bank[37] (fig 8). Angular and linear velocities and displacements observed on the tractor showed good agreement with simulation predictions as did the energy absorbed in the safety frame. In view of the complex nature of the problem, the results of full scale tests were such as to give confidence that the model was able to predict the effect of various parameters on the overturning behaviour in this type of accident, which is likely to result in the most severe cab or frame damage. The model has been used by Chisholm to examine impact velocities and inertia, the parameters which affect overturning and the overall effect of tractor mass[38]. An interesting finding was that because the vertical kinetic energy of the tractor was much higher than the roll kinetic energy, excessive deformations were predicted for a protective structure of typical strength for an overturn down a bank more than 3 m high; although such accidents are not common they do have a significant probability of occurrence. Information of this type is of considerable value when considering strength criteria for protective structures for the driver and the model enables a wide range of circumstances to be examined in a short time.

*Fig 7 Tractor overturning down a simulated bank*

### Torsional inertia shaker for a blackcurrant harvester

A good example of a mathematical model developed for studying the design parameters of a mechanism is that of Tuck and Brown[39] who were interested in the development of inertia shakers employed on a harvester for removing fruit from blackcurrant bushes. The design of the shakers used in the early trials of the harvester was evolved empirically and enabled easy adjustment of the amplitude of the oscillating tines mounted on inclined cylinders which engaged with the blackcurrant bush and produced a vibration which detached the fruit[40]. The need for the mathematical model was to establish general design principles which could be employed during the development of commercial prototypes so that proposed design changes could be evaluated rapidly.

The shaker mechanism consisted of two eccentric weights, arranged diametrically about a central drive pulley, so as to rotate in the same sense but 180° out of phase; this arrangement results in an alternating couple which produces a torsional vibration of the fruit shaking mechanism. The model established the equation of motion of the shaker mechanism but it was not possible to obtain a complete solution on an analytical basis. A semi-empirical method of solution was adopted in which the motion of the drive unit was related to that of the eccentric weights from observations taken from an experimental shaker. A simplified design equation was also developed which was adequate for examining the effect of component changes on shaker performance.

The mathematical model was of practical value for design purposes. It was used in the final design specification of the blackcurrant harvester (fig 8) to calculate the increase in eccentric mass required to compensate for major changes in the inertia of the shaking mechanism resulting from an increase in cylinder length and in the number of tines employed. In addition, it was used to establish the optimum form of the eccentric weights used in the shaker mechanism.

## Other examples of models in agricultural engineering

A number of other applications of modelling techniques is given in tables IV and V covering a wide range of problems involving analogue and mathematical models, respectively. There are too many examples to discuss them in detail, but key references are given in the tables.

Analogue models have been used to cover very diverse problems, ranging over studies of mechanism dynamics[45 48 49 50] heat transfer[51], light transmission[52 53] the performance of cultivator implements[54 55], tractor cab acoustic resonance[57], fruit picking[59] and ergonomics[63 64]. Mathematical models have been widely applied to the study of dynamics, because of the attraction of applying classical methods of analysis and the use of computer programs to enable complex problems to be solved. A number of models have been used to study tractor dynamics in relation to draught controls[68-71], lateral stability[72], and ride vibration[77-80]. The dynamics of drivelines has also been modelled[73-76]. The use of finite element methods[88] and

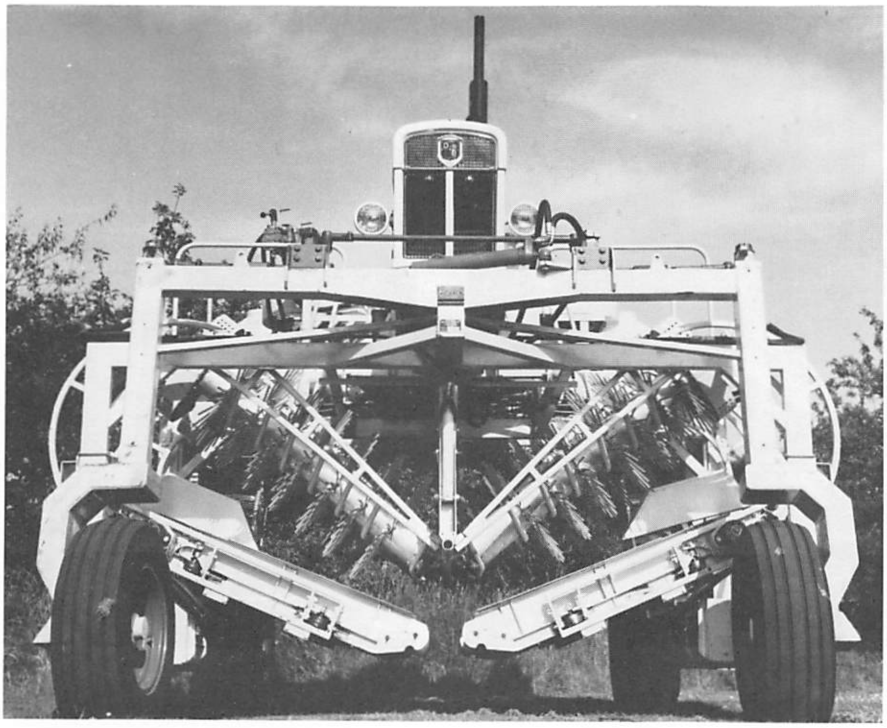


*Fig 8 Blackcurrent harvester showing inertia shakers*

## Table IV Examples of analogue models in agricultural engineering

1. Studies of performance of tractor drive tyres and of tractor front, trailer and implement tyres using single wheel testers[41 42 43 44]
2. Sugar beet topping dynamics using a simulation rig[45]
3. Impaction of spray drops on plant surfaces in a laboratory cabinet[46]
4. Movement of electrically charged spray drops in a wind tunnel[47]
5. Simulation of dynamic response of an electronic selective thinning machine[48]
6. Studies of seed trajectories and impact at the soil during drilling using a soil trough[49 50]
7. Convective cooling of simulated vegetables in pallet-based boxes[51]
8. Transmission of light through model inflated greenhouses[52 53]
9. Study of interaction of cultivation implements with soil using a soil tank[54 55]
10. Use of a treadmill for the evaluation of the performance of model wheels[56]
11. A two-dimensional quarter-scale model of a tractor cab section to study acoustic resonances[57]
12. Analogue computer model to investigate tractor vertical and pitch modes of ride vibration[58]
13. Simulated tree for studies of hand picking of fruit in relation to mechanical aids[59]
14. Laboratory studies of the performance characteristics of threshing drums[60]
15. Laboratory rig for study of brush conditioner configurations for forage crops[61]
16. Studies of semi-automatic quality inspection of fruit using simulated apples[62]
17. Examination of criteria affecting entry and exit using a simulated tractor cab[63]
18. Simulation of tractor tasks and environment[64]
19. Milking parlour simulation[64]
20. Bumpy track simulation of ploughed field and unmetalled road surfaces[65]

## Table V Examples of mathematical models in agricultural engineering

1. Tractor and plough performance using empirical relationships[65]
2. Prediction of rolling resistance of rigid wheels[67]
3. Calculation of forces produced by open lugged wheels[68]
4. Performance of tractor draught controls[1 69 70 71]
5. Lateral stability of tractor and trailer combinations[72]
6. Dynamics of tractor and machine drivelines[73 74 75 76]
7. Tractor ride vibration[77 78 79 80]
8. Pig slurry treatment system[81]
9. Performance of an electronic selective thinning machine[82]
10. Dynamics of sugar beet topping mechanism[83 84]
11. Definition of the practical limits of sugar beet topping accuracy[85]
12. Spacing distribution of seed from a fluid drill[86]
13. Impact cutting of forage crops[87]
14. Application of finite element methods to stress-strain properties of granular materials[88]
15. Heat and mass transfer in crop drying processes[89]

the extensive work which has been conducted on models of heat and mass transfer in crop drying processes[89] are of considerable interest. Mathematical models have also covered a complete system of slurry treatment[81], mechanisms[83 84 87] and simulation of the performance of machines[82 86].

Some projects have made use of a variety of modelling techniques in approaching problems of machine design in order to define optimum criteria. Examples of this are the design of a lightweight sugar beet topper[45] which employed a number of laboratory analogue models (fig 9) as well as mathematical models, which were conducted in parallel with seasonal observations of topper behaviour in crops as part of the iterative process illustrated in fig 2. Other examples which used a similar method of approach are the work carried out on selective thinning machines[48 90] and on seed drills[91]. In such projects, models are used as part of the research and development process and result in the acquisition of new information and in the synthesis and optimisation of improved design concepts.

In conclusion, some typical examples of iconic models are given which have been used for the exploration of design concepts and as a means of communicating ideas. Figure 10 shows a model which was constructed to aid the design stages of an experimental four wheel drive vehicle, with a range of facilities for mounting and dismounting bodies and machinery, which is intended for a study of a new form of agricultural transport[92]. Figure 11 shows a model of a system in a three span glasshouse which has been developed for the mechanisation of crops grown under glass, or film plastics tunnels, which employs a travelling gantry mounted on rails and spanning the crop[93]. Figure 12 shows a model of a rotary unit developed for the preparation of vegetables in the pack shed[94] where each operator is supplied with crop individually and discards the waste as well as preparing the produce. There are many other examples of such models but those given serve to illustrate their value in the design process.

Finally, it is well for the modeller to bear in mind the importance of validation, as summed up in the following quotation written as long ago as the thirteenth century:

"Experimental science does not receive truth from superior sciences: she is the mistress and the other sciences are her servants".

Roger Bacon
*(Opus Tertium)*

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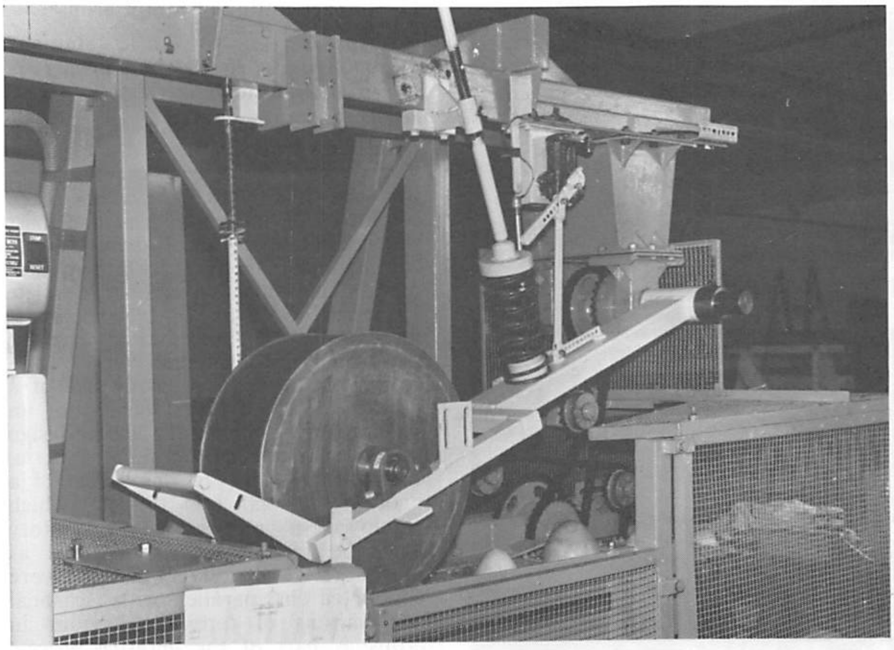
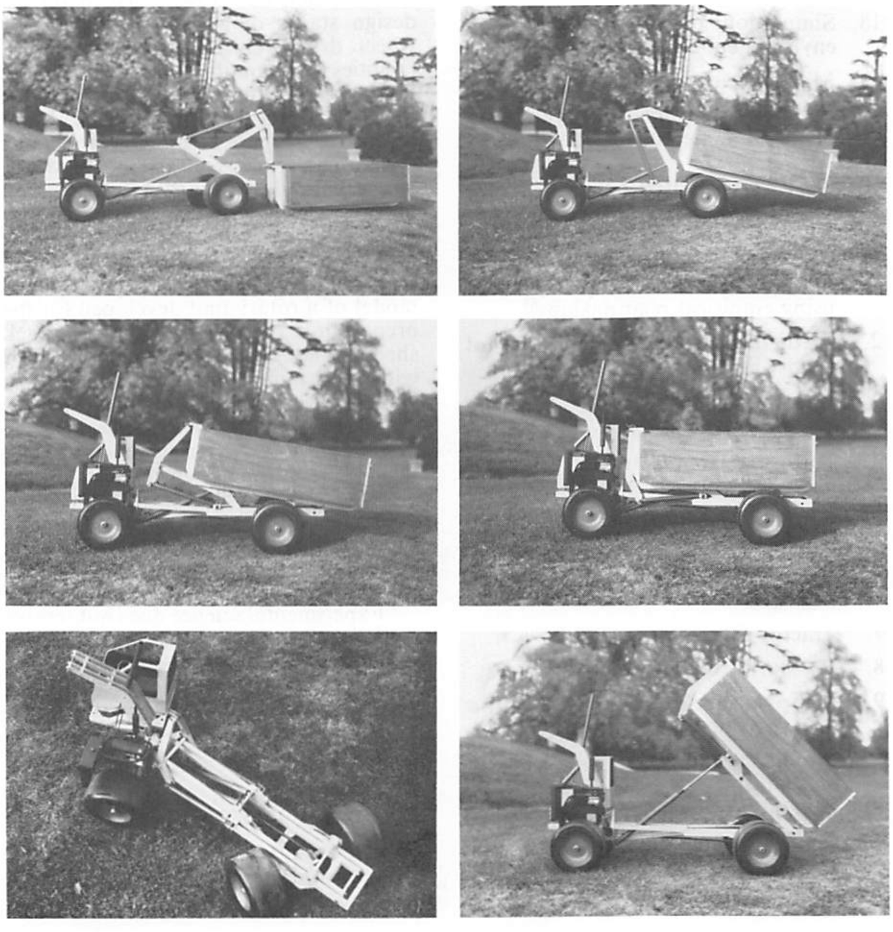


*Fig 9 Laboratory analogue for investigating sugar beet topper dynamics*

*Fig 11 (right) View of model of travelling gantry system in a three-span glasshouse*

*Fig 10 Scale model of novel farm transport vehicle showing pick-up of a container (top, left to centre, right), tipping container (bottom, right) and general layout (bottom, left)*

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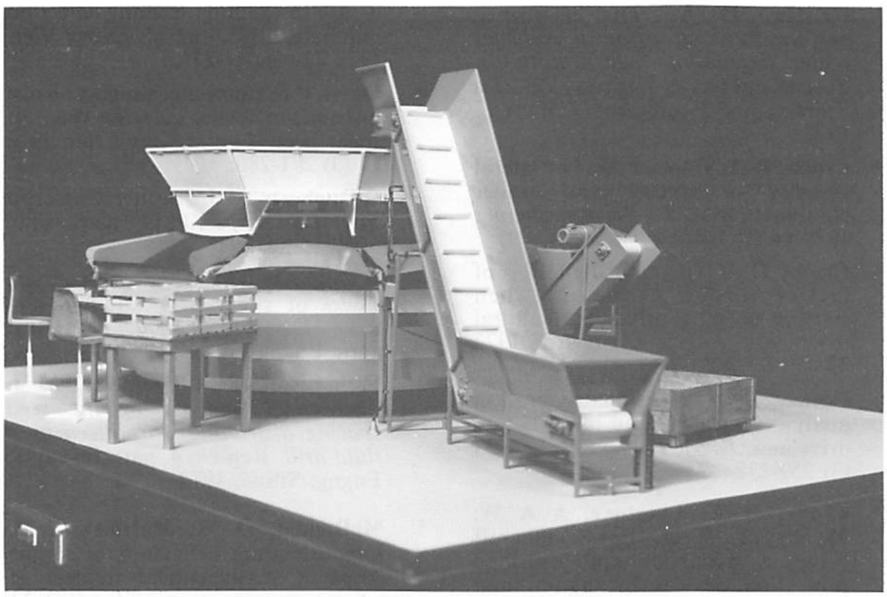

*Fig 12 Model of rotary unit for vegetable preparation in a packhouse*


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# Moisture measurement in agricultural crops

## Crop drying and storage special study group

THE second meeting of the Crop Drying and Storage Group, held at the Farm Electric Centre on 19 February 1981, was attended by more than 30 members and guests.

The difficult and controversial subject of moisture measurement was introduced by means of short talks given by four workers who are closely associated with the problems involved.

*Mr P H Bailey,* of SIAE, Chairman of the Group, began by reminding the meeting that within agricultural materials we were concerned with "bound" moisture and "free" moisture but that there was no clear distinction between the two. The "active" water could, in principle, be determined by some sort of oven method designed just to achieve complete dryness with no attendant chemical degradation of the crop. Experience showed, however, that this was not possible in practice, so that it was necessary for a standard procedure to be adopted with the tacit understanding that it would be very unlikely to reveal the "true" moisture content of the stock.

For forage and other green materials, there were no internationally accepted standards, but the widely used regime of 103°C for 16 hours in a ventilated 'Unitherm' type of oven was found to give consistent results.

For cereals, the ISO Standard No 712, described the reference method against which moisture meters should be calibrated for European acceptance. This standard was based on recommendations made by the French milling industry and regrettably demanded the use of milled samples. However, it was the recognised basis for international agreement and must be respected as such. It involved the use of an oven for 2 hours at 130°C to 133°C. British Standard No 4317 (1980) Part 3 corresponds to the ISO 712 in almost every detail.

Some agricultural engineers had expressed preference for use of the whole grain method recommended by the ASAE (ASAE S352, 1977). This required an oven temperature of 130°C and exposure time of 19 to 20 hours. The advantage here was that, when high moisture grain was under investigation, the two stage method demanded by the ISO standard was avoided.

The adoption of yet a different standard by the brewing industry was reported. Mr Bailey expressed the firm opinion that standards were only of use if all parties used them as the bases of calibrations and negotiations. He reiterated his conviction that ISO 712 should be respected and used.

*Professor T A Oxley,* of Aston University and Protimeter Ltd, speaking as a director of a moisture meter manufacturing company, agreed with Mr Bailey that there was no possibility of our being able to quote "exact" values of moisture content, even when reference methods were employed. The manufacturer, however, was faced with additional problems. In particular, these were "repeatability" of an instrument (sometimes referred to as "precision") and "conformity" (or "accuracy"). Most moisture meters show good repeatability within samples and good accuracy at one or more points on the scale. But it must be appreciated that variability of the basic grain characteristics from season to season is not unknown. An example had arisen with German wheat in 1980; some of the electrical properties, notably the resistivity of the grain, had shown striking abnormalities and no reason for this was apparent.

Another important dilemma of the manufacturer was the abundance of reference methods advanced by the many official bodies. ISO, BS, ASAE and ISTA standards were among these. Which reference standard should the manufacturer adopt?

*Mr G E Bowman,* of NIAE, reported on some of his recent work involving the electrical permittivity of agricultural products. Defining a term called the dielectric loss factor, the speaker explained that this was found to vary with the frequency of the applied voltage in a fashion indicated in fig 1. The various curves express the relationships for the different ways in which water could be retained in a moist material. A frequency of 10 GHz appeared to be suitable for use with agricultural products since this minimised the influence of the otherwise dominant ionic conductivity. At this frequency, the use of appropriate "microwave" techniques and equipment was necessary and a stripline technique had been adopted which had given good response for samples of grain and other powders, and even for leather (see fig 2). For grass, however, the packing density had proved to be problematic, so attention had turned to infra red reflectance measurement for this material.

Water has the ability to absorb,

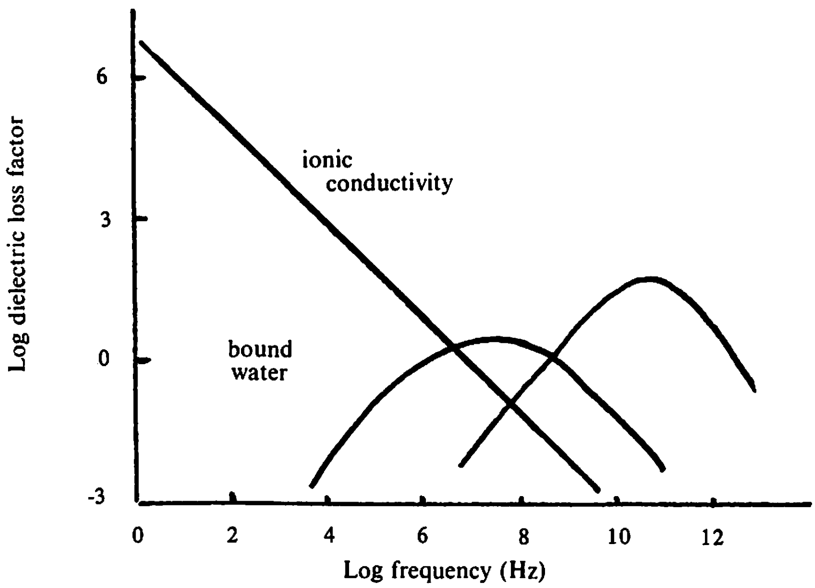
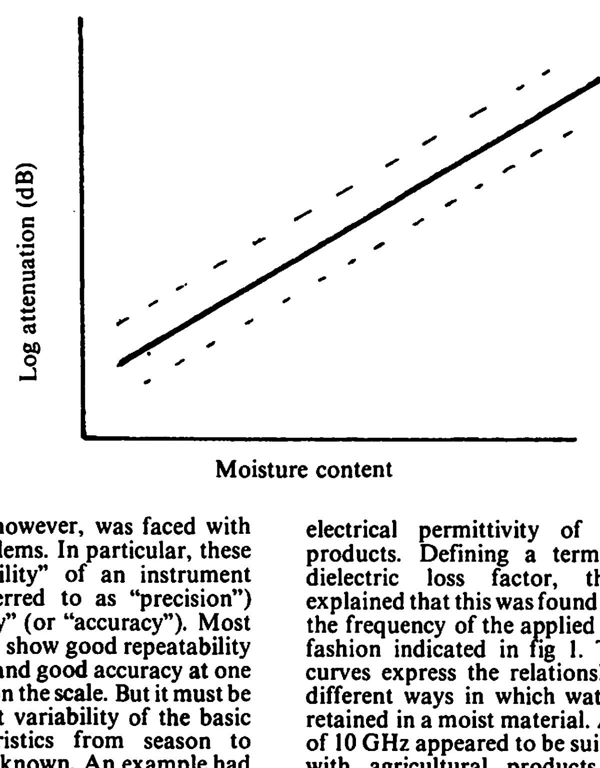



*Fig 1 Dielectric loss factor related to frequency*



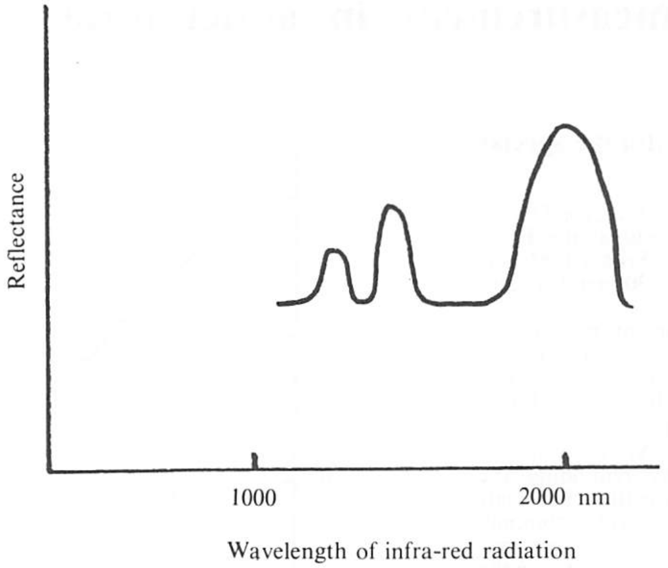
preferentially, certain wavelengths of infra red radiation (see fig 3). If radiation comprising two different wavelengths — one readily absorbed by water and one not — is directed at a moist surface, the relative intensity of the reflected components will depend upon the amount of energy absorbed by the water. Surface effects other than moisture content influence both wavelength components similarly, so comparison of the reflected components yields unambigous results. Although the technique is sensitive only to surface moisture content, it has the important advantages that it does not require physical contact between the sensor and the sample, it is very rapid and it does not require knowledge of the bulk density of the material.

*Miss Betty Dwyer*, Kinsealy Research Centre, summarised some recent investigations of the comparability between oven determinations of moisture content and measurements made on a range of commercial moisture meters. In the feed barley trade in Ireland, a premium is payable on grain which is drier than 20% wb. On the other hand, reduced prices are payable if moisture levels exceed this figure.

The Foss Supermatic instrument was widely used in the Irish grain trade and Miss Dwyer's work had revealed good agreement between this instrument and the 130°C, 1 hour oven reference method for wheat samples. Agreement was less good for barley, deviation from the reference method being, to some extent, seasonal and regional. Other sources of discrepancy were the presence in the tested sample of impurities (weed seed, straw etc), immature grain and shrivelled or poor quality grain. Removal of barley awns also appeared to improve the indicated results.

Other popular commercial instruments which had been tested were the Marconi, Protimeter Grain Mini III, Wile 35 and Kongskilde KM Tester Mk IV. In general, the agreement with the oven method was good in the low ranges of moisture content (17-19%) for spring barley, but deteriorated as moisture levels rose. Seasonal variations in the apparent reliability of instruments were again apparent, and it was pointed out that there is a good case for year-to-year performance checks to be made on the instruments which were discussed.

A lively discussion followed the four short talks and there was general agreement that further major effort was required into moisture measuring techniques (including accurate sampling of bulks of grain) if traders were to be able to reach agreement on the financial value of parcels of grain. When agreement could not be reached, the farmer was left no alternative but to adopt the policy "when in doubt, overdry". *BCS*




# Letter

## Mechanical harvesting of soft fruit

Mr Day's unfamiliarity with the Lincoln Canopy system of growing and harvesting raspberries is no doubt responsible for three inaccuracies in the raspberry section of his paper 'Mechanical harvesting of soft fruit' in the summer issue of *The Agricultural Engineer*. I would be grateful for an opportunity to correct his statements.

The drive to the shaker shafts and finger wheel vibrators on the NZAEI harvester used in conjunction with the canopy system is positive and at any setting the frequency and amplitude do not vary with changes in cane density. This imparts a more consistent and effective shake to the fruiting canes rather than less, as Mr Day states. The inconsistencies of the commonly used inertia shaker used on many berryfruit harvesters are well known.

The considerable reduction in fruiting cane numbers which he mentions as resulting from the adoption of the canopy system is not so in practice (see enclosed photograph). At our specified density of 30 to 40 fruiting canes per metre of canopied row in a well grown crop, there should be little difference in population per unit area between this system and that of the conventional method. As the canes are trained horizontally to both sides of the row to form the canopy, light interception is maximised over a wide area. Every fruiting bud has an equal chance to develop fully with less competition from its neighbours than occurs within upright canes.

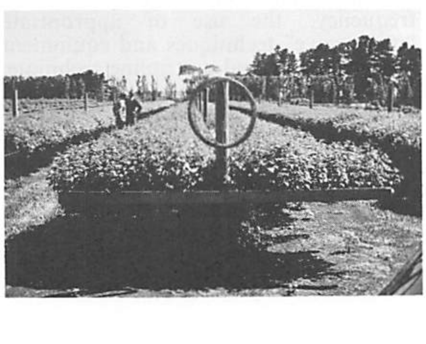
Harvested yield from the Lincoln Canopy has exceeded 12 tonnes/ha. (variety 'Marcy') and the quality has been higher than that of hand picked fruit. The harvester is a better judge of ripe fruit than the human eye and individual berries are not handled.

Mr Day's assertion that the Lincoln Canopy system is wasteful of ground is also not correct. The row spacing is 5.2 m (17 ft) not 4.4 m (14 ft) as stated but of this only 1.8 to 2.1 m (6 to 7 ft) is required for access and 3.0 to 3.4 m (10 to 11 ft) is fruiting width. The ratio of access to fruiting width differs little if at all from that of canes at a 1.8 m (6 ft) row spacing.

The four problems with raspberry harvesting which Mr Day lists no longer exist if the Lincoln Canopy system is allied to good management techniques and the right varieties. This has been proved in New Zealand.

JOHN S DUNN,
*Senior Principal Research Officer, New Zealand Agricultural Engineering Institute, Lincoln College, Canterbury, NZ.*

*Raspberries trained on the Lincoln canopy system — early summer*



# Book

## An introduction to economics for students of agriculture

AS Dr Hill points out in his introduction, this is not a book on the economics of agriculture, but one on general economics, illustrated primarily by examples drawn from farming and the food industry. To a reviewer who is an agricultural engineer with now very dim memories of his student days, the book appears as an exceptionally comprehensive text. It covers basic theory (and assumes no knowledge of the subject) but it also deals in some depth in more advanced matters — Consumer choice theory, price mechanisms, Distribution theory — for example.

In a world where the majority of agricultural degree students must find employment other than directly in farming, the inclusion of material on macro-economics and international trade is admirable. It is this reviewer's often stated opinion that we British are still (relatively speaking) babes-in-arms in international agricultural selling in its broadest sense, compared with many nations. Thus the inclusion of these chapters is more than appropriate.

The author lectures at Wye College, and previously was at the Royal Agricultural College. Thus he must have a clear idea of the sort of textbook which is required. For many students I am sure that this one alone will provide most of what they need, but a useful reading list is provided, covering not only this specific subject, but also a wider field of value to the student with more than the obligatory interest in agricultural economics.

Perhaps the most valuable feature of the book is the very comprehensive set of exercise material which accompanies each chapter. This has been assembled so that a good understanding of the text material is required, before an adequate attempt at answering can be made. (Answers are given for those in doubt!)

To a reviewer without a specialist interest in agricultural economics, this book appears to give a comprehensive introductory course to both agricultural students and those of ancillary subjects. It might also serve those of us who, established in our careers in agricultural engineering in particular, need updating in current economic thinking in general.

*An introduction to economics for students of agriculture, Berkeley Hill BSc PhD, Pergamon Press, 346 pages.*

*JSR*

### Farm Machinery 10th Edition

FARM MACHINERY is already accepted as the standard text book for all concerned with agriculture and its mechanisation in UK and the 10th Edition can do nothing but enhance its reputation.

The book retains the same format as the 9th Edition which was in itself a major advance in both content and presentation over previous editions.

In the latest edition Mr Culpin and his collaborators have concentrated on updating those areas where mechanisation has forged ahead over the past five years, notably in materials handling, harvesting machinery, environmental control and the use of electronics in agriculture.

Other notable features are firstly the careful consideration given to the quality of the photographs, in many cases improved views of the same machines that appeared in the 9th Edition are included, and secondly the very high standard of the line drawings which in these days of safety covers and the enclosure of machines are so necessary to show how they operate.

The author is to be congratulated on the standard the book has reached. It has, like many of the good things of life, matured over a long period and certainly in its present form bears little resemblance to the "Culpin" I had as a student having more than kept pace with the changes in the agricultural industry.

Required reading for every student of agriculture and agricultural engineering.

*Farm Machinery 10th Edition by Claude Culpin, Granada Publishing; Price: hardback £17.50, paperback £9.95*

*JHN*

# INSTITUTION FORTHCOMING NATIONAL CONFERENCES

SOIL MANAGEMENT FOR CEREAL PRODUCTION
Tuesday, 10 November 1981.
St Ivo Centre, St Ives, Cambs.
(In association with the Agricultural Development and Advisory Service (Eastern Region) and South East Midlands Branch of the Institution).

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ENGINEERING FOR MEAT PRODUCTION.
Tuesday, 16 March 1982.
National Agricultural Centre, Stoneleigh.
(In association with West Midlands Branch of the Institution).

ENGINEERING DEVELOPMENTS FOR THE HANDLING AND STORAGE OF CEREALS.
Tuesday, 11 May 1982.
National Agricultural Centre, Stoneleigh.
(Institution Annual Conference).

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STRAW PROCESSING.
Tuesday, 12 October 1982.
Essex; exact venue to be advised.
(In association with South Eastern Branch of the Institution).

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MECHANISATION OF POTATO PRODUCTION.
Tuesday, 15 March 1983.
Scotland, exact venue to be advised.
(In association with Scottish Branch of the Institution).