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PREFACE

This is the proceedings from the symposium on "COMPUTERS, ELECTRONICS AND CONTROL ENGINEERING IN AGRICULTURE" hold in Sweden 1986. There were participants from all countries in Scandinavia. There were also invited speakers from The Netherlands, United Kingdom and West Germany.

Computers, electronics and control engineering have become more and more powerful tools not only for agricultural engineering research activities but also for a better efficiency in agricultural and horticultural production processes.

The symposium was needed for making researchers, university teachers and research students in agricultural engineering in the Scandinavian countries aware of the research frontier within the subject.

With the subject is meant not only applications within agriculture but also connected areas such as biotechnology, microbiology, meteorology, ergonomics and so on.

The purpose of the symposium was:

- to state the present research frontier in different parts of the research field

- to identify needs for further research and development

- to find a suitable way for future Scandinavian research and development within the subject area

The symposium consisted of six sections. Sections I-III delt with the agricultural production processes. Each of these sections was discussed by speakers from two different viewpoints, namely:

- to throw light on the biological demands for, needs for and cinditions of applications of electronics, computers and control engineering

- to throw light on the present possibilities to solve the existing problems of applications of computers, electronics and control engineering, state the research frontier and discuss the most probable directions of further research and product development.

The fourth section discussed different ergonomical viewpoints connected to the use of electronic equipment in agriculture, while the fifth section concerned about the impact on the management on the farm firm. Both these sections also discussed the need for further research.

The sixth section of the symposium was a general discussion.

This report has been edited by the undersigned Bruno Nilsson who also was responsible for the organisation of the symposium.

The symposium was sponsored by funds from the Council of Ministers in the Nordic Countries.

Bruno Nilsson

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INTRODUCTION

Bruno Nilsson, dept of agr. engng, Uppsala, Sweden

During the last three decades agriculture has gone through a very extensive process of mechanization. Economically this process has been very profitable for both producers and consumers. In Sweden the total machinery costs today are 7 billion crowns per annum. Calculations have proved that if we hadn't mechanized agriculture the increased labour cost for producing the same amount of food had been about 70 billion crowns.

But now in the mid eighties we are in a transition phase. We cannot to the same extent as before go on with traditional mechanization for several reasons. Many people express hard criticism on the production technique we are using. Among others there are objections to the ways we are breeding our animals, the heavy input of chemicals and fertilizers.

Much due to the slowing down of the rate of mechanization the increase of the over all productivity in agriculture is very small.

Against this background farmers, agricultural engineers and agricultural scientists have to review their partnership for developing agriculture in the future. The challenge is to maintain levels of food production and satisfy a wide range of needs under conditions of complex and often unpredictable change. I also think that the challenge includes seeking ways of developing the handling of both fresh and processed agricultural products beyond the farm gate.

Agriculture is nowadays a science-based industry. Science is making substantial contributions to the success of the industry through work in plant breeding and genetics, crop nutrition and protection, soil physics and chemistry and by increasing the understanding of biochemical and physiological process of growth and development in plants. In the case of livestock, the agricultural scientists is making important contributions in animal breeding, nutrition, disease control and production.

The agricultural engineer has to make full use of this knowledge produced by the biologists. Perhaps the most urgent requirements on him will be to develop methods and machinery for reduced input costs while maintaining existing levels of output. The agricultural engineer, in close cooperation with the biologists, has much to contribute to the farmer in this area. For example through machines and equipment which will give more efficient weed and pest control, more accurate fertilizer placement, reduced cultivations and lower energy requirements. The agricultural engineer has to make full use of the results from animal behavioural and physiological studies. This means developing systems that provide individual care and feed with the assistance of animal identification electronics and gives attention to the control of dust, gases, temperature, air movement and humidity, in the interest of livestock comfort and freedom from disease.

Agricultural engineers have to make significant contributions to environmental needs. Very important areas are for example controlled application of chemicals, manure, municipal and industrial wastes and fertilizers.

The agricultural engineers also have to consider the environmental needs of the farm worker not only by developing machinery that will reduce the physical load, but also by giving the worker the significant information on the production process at the right moment and in the right way.

In addition to working with agricultural scientists the agricultural engineer has to adopt concepts and ideas from other branches of science. One major input to agriculture is the climate, which also has a significant influence on the machinery.

Remote sensing, using satellite imagery is being applied. The application of a wide range of physical and chemical sensors in agricultural systems is a high priority and expanding field. Robotics has potential in for example materials handling systems. Cybernetics, the interlinking of control, measurement and communication has important future prospects.

Well this was a subset of items we have to discuss the next few days.

We are a highly qualified group of scientists from the biological, engineering and economic disciplines. Now we have two alternatives.

The first one is, as sometimes happens when a group like this come together, to start fighting each other. Then you can go home on Wednesday afternoon and blame the organizer for a badly planned seminar.

The other one is to aggregate our total knowledge and to help each other in the discussions to fulfill one of the main objectives of this seminar: to identify areas that are of mutual interest and importance and there our knowledge is limited and thus further research are needed. In that case you can congratulate yourself to a well carried through seminar.

Alternative two is the challenge for this seminar and I do hope that the sessions and discussions will be very informal and successful.

Let me finish by saying welcome to you all, and a special welcome to our friends from Germany, the Netherlands and Great Britain.

S E C T I O N   1

NJF Symposium on Computers, Electronics
and Control Engineering in Agriculture.
Åre, Sweden, 1986-02-03--05.

APPLICATION OF COMPUTERS, ELECTRONICS AND CONTROL ENGINNERING IN SOIL TILLAGE AND SOWING - DEMANDS AND CONDITIONS

By Göran Kritz and Inge Håkansson, Dept. of Soil Sciences, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden.

In soil tillage and sowing, applications of new computer, electronics and control engineering techniques are of interest on one hand for improved characterization of the soil state (primarily in research work), and on the other for improved control of the performance of tillage implements and seed drills (primarily in practical farming).

Characterization of the soil state

For characterizing the soil from a tillage point of view, the following qualities are of prime importance: Bulk density and degree of compactness, soil structure (aggregate size distribution) and strength, moisture and air content, tillage depth, and amount of trash or other obstacles to tillage. Both the average situation (mostly in superficial layers with a sharp gradient) and the heterogeneity are significant, as well as changes with time (over days, weeks, months or years).

For instance, when studying soil compaction and loosening processes such as effects of heavy machinery and primary tillage, parameters of importance are depth, bulk density and degree of compactness of the plough layer, including changes throughout the year. When studying seedbed preparation and sowing, harrowing and sowing depth and aggregate size distribution are important parameters, as well as the moisture situation and its changes over short periods of time.

New measuring methods should preferrably be non-destructive, making repeated measurements at the same place possible.

Control of the performance of ploughs

For the mouldboard plough, depth control is now relatively good, but the ploughing quality is often poor. The soil surface is usually left too uneven. Autumn ploughed fields, therefore, are often very rough even after winter, causing too large variations in the depth and moisture content of the seedbed. It is highly desirable to improve the ploughing quality in this respect.

Ploughing also loosenes the soil too much, making recompaction necessary. Development of a primary tillage which leaves the soil in an optimum state of compactness would decrease the need for secondary tillage. This, however, may be impossible unless we give up some other objectives of the ploughing such as soil mixing and weed control.

Control of the performance of implements for seedbed preparation and sowing

When harrowing and sowing, a modern farmer, sitting in a tractor cabin away from the implements, cannot check and control the quality of the work as frequently as the old farmer, walking behind horse-drawn implements. What the old farmer did, using his eyes, feet and hands, however, may now be done with modern control engineering, and hopefully with superior results. As a first step the new techniques might be developped for crops such as sugarbeets or vegetables, having great demands on the seedbed.

In seedbed preparation and sowing an adequate depth control is crucial. However, the optimum harrowing and sowing depth depends on many factors such as the crop and seedbed structure. The most critical factor, however, is the soil moisture situation which may be characterized by the water tension or by the content of plant available water.

The situation encountered in superficial soil layers at the time of spring sowing in Sweden is illustrated in Fig. 1. The normal seedbed depth (=the harrowing depth) is 5 - 6 cm. The variations from point to point and between fields, however, in this factor as well as in the others, are large. According to Håkansson & von Polgár (1984) 6 % plant available water is enough for good crop emergence even in a dry weather situation, provided the seed is covered by a 4 cm thick layer of soil with a fine structure. Therefore, the boundary for this water content is given in the figure. In soils with less than 30 % clay this boundary is found at a shallow depth, especially if the soil has a high silt content.

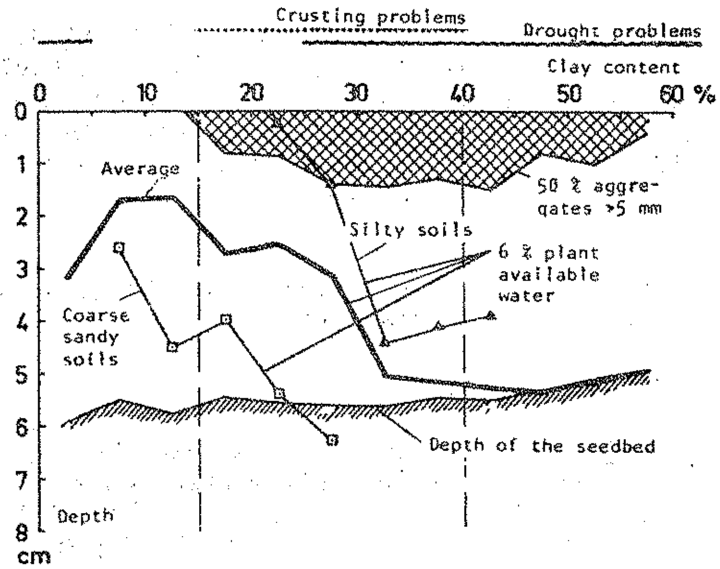

Fig. 1. Results of a seedbed investigation on 300 randomly selected spring sown cereal fields on Swedish farms (after Kritz, 1983). The curves are based on median values for individual clay content classes (class width 5%). The depth of the seedbed is given as well as the lower boundary for soil with more than 50% coarse aggregates (>5 mm) and the upper boundary for soil with more than 6% plant available water. In the last case results for subsamples with silty soils and with coarse sandy soils are given as well. In the upper part of the figure the ranges of soils having emergence problems in dry weather situations and surface crusting problems are indicated.

In soils with more than 30 % clay, 6 % plant available water is usually found at a depth of 5 - 6 cm (the normal harrowing depth). Furthermore, in these soils the superficial layer contains more than 50 % aggregates larger than 5 mm and does not contribute very much to the evaporation control. Therefore, the seed must be placed at a depth of 5 - 6 cm, preferrably on a firm bottom, unless the seedbed has a finer structure and a higher moisture content than usual.

In many fields there is a large variation in soil texture or organic matter content. This means that a considerable part of the variaton illustrated in Fig. 1 may be found within an individual field as well as a large variation in soil mechanical properties. When preparing the seedbed, this leads to large variations in working depth and other seedbed characteristics, if the performance of the implements is not continuously controlled. An improved control system for the implements, therefore, would be very valuable.

In clay soils, to get a good crop emergence, the seed must be placed on, or still better in, a bottom of firm soil. This means that harrowing should not be deeper than sowing. In lighter soils deeper harrowing than sowing only wastes time and energi.

A control system for seedbed preparation and sowing must comprise maximum and minimum depth limits based on properties of the seed and on the climate. Within these limits, harrowing and sowing should be carried out to a depth where the soil has a specified average content of plant available water. This water content should be somewhat higher in a field with an uneven surface and a large variations in the superficial layer than in a more even field. The minimum depth must be increased if the seedbed has a coarse structure and gives a poor protection against evaporation.

A simple model for the choice of sowing depths for cereals on different types of soils in Sweden is presented in Fig. 2. It is primarily based on the normal content of plant available water and aggregate size distribution in the seedbed as reported above, and on the risks of poor emergence because of drought and crust formation.

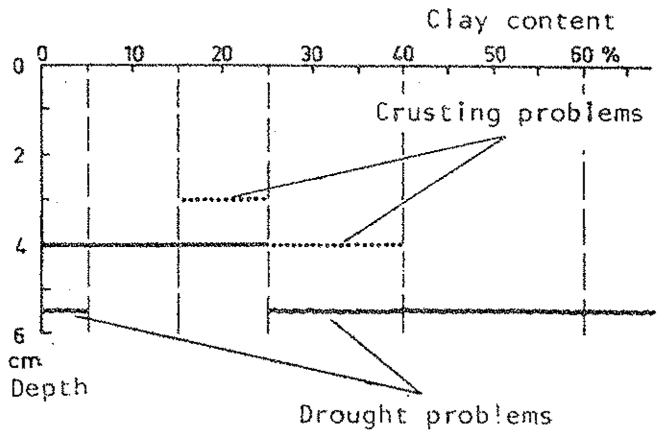

Fig. 2. Suitable sowing depths for spring sown cereals on different types of soils in Sweden. On soils where the risk of poor emergence caused by drought or by surface crusting is low a 4 cm sowing depth should be pursued. On soils where the risk of poor emergence in case of dry weather after sowing is high sowing should be somewhat deeper, and on soils where the risk of poor emergence by surface crusting is high sowing should be somewhat shallower.

On soils presenting a relatively low risk of poor emergence because of drought, as well as of crusting, a sowing depth of 4 cm is recommended. At clay contents below 5% the sowing depth should be increased to about 5 cm, if the soil has a coarse-sandy character. On soils having a clay content above 25%, the seed should be placed on the bottom of the harrowed layer. If the risk of crusting is low (soils with low silt content), the harrowing and sowing depth should be 4-6 cm depending on actual moisture content and structure. If the risk of crusting is high (soils of fine sandy or silty character) the harrowing and sowing depth should be decreased by 1-1.5 cm.

It appears that the control system above all must comprise a depth control based on the moisture situation in the soil and on some maximum and minimum depth limits. However, the structure of the seedbed must be considered too. In the traditional tillage system the structure to some extent is controlled by the number of harrowings. When using once-over equipment for combined harrowing and sowing, the control system must also include a control of the structure of the seedbed.

Because of the surface roughness, partly caused by the plough, the tillage tools or seed coulters must be able to move up and down individually. For several reasons an electronic control system for the implement as a whole, and a control of individual tines or coulters based on mechanical principles, seems to be the most reasonable system. The technical possibilities of improving the control of the sowing depth has recently been studied by Jönsson (1985).

In a reduced tillage system without ploughing, the demands and conditions at seedbed preparation and sowing may differ more or less from those mentioned above. The amount of trash in the surface layer and the roughness of the soil surface constitute the most important differences. Sometimes the situaton is simpler, sometimes more complicated. At direct drilling the situation is very differing. A control system must comprise a control of the penetration of the coulters, of the soil cover over the seed and of the trash problem. However, specification of the demands on the system are not yet possible.

Control of implements for other types of tillage

In other types of tillage such as stubble cultivation for weed control or subsoiling, the demands on the control systems are completely different. The stubble cultivation in Sweden mainly aims at control of couch-grass (Agropyron repens). The trash on the soil surface is the major obstacle. The most important objective for a possible control system would be to help solving the trash problem. Control of the intensity of the cultivation with regard to the amount of weeds also may be of interest.

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Computers, electronics and control engineering in agriculture - NJF Symposium 1986-02-03.

Biological demands on sowing and fertilizer application.

Ted Velander, Supra AB

Introduction

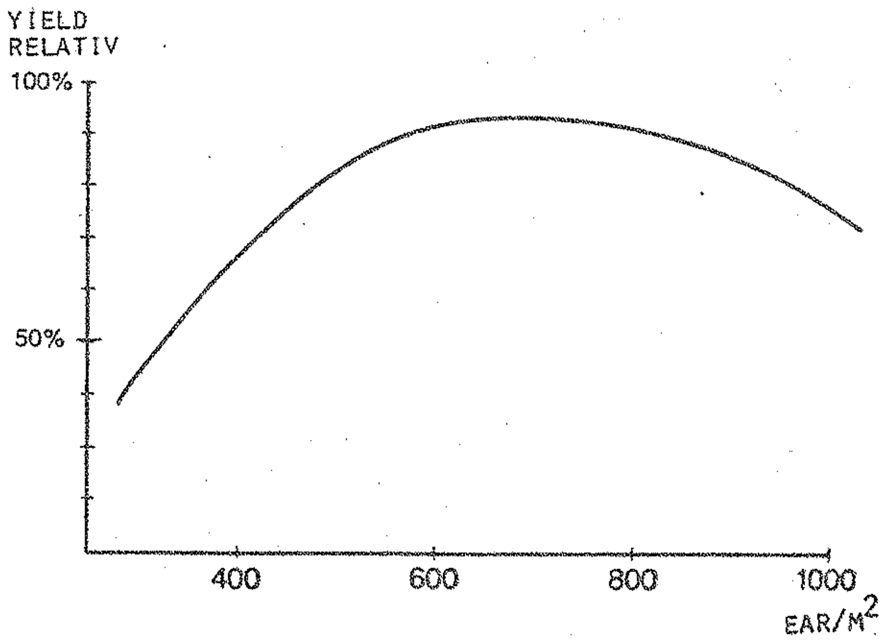
Modern crop production demands a careful sowing operation and fertilizer application in order to manage the crop to an optimal production. The high yields we are aiming at will not be profitable unless the machine operations are exact and reliable.

My experience from agriculture in practice is that machinery which apply granulated materials (fertilizers and seed) are insecure as regards the applied amont.

Sowing

In order to reach the optimum yield is it important to reach the optimum ear-density. For wheat is it 550-650 ears/m^2, rye and oat 500-600, two-row barley 900-1000, six-row barley 650-750.

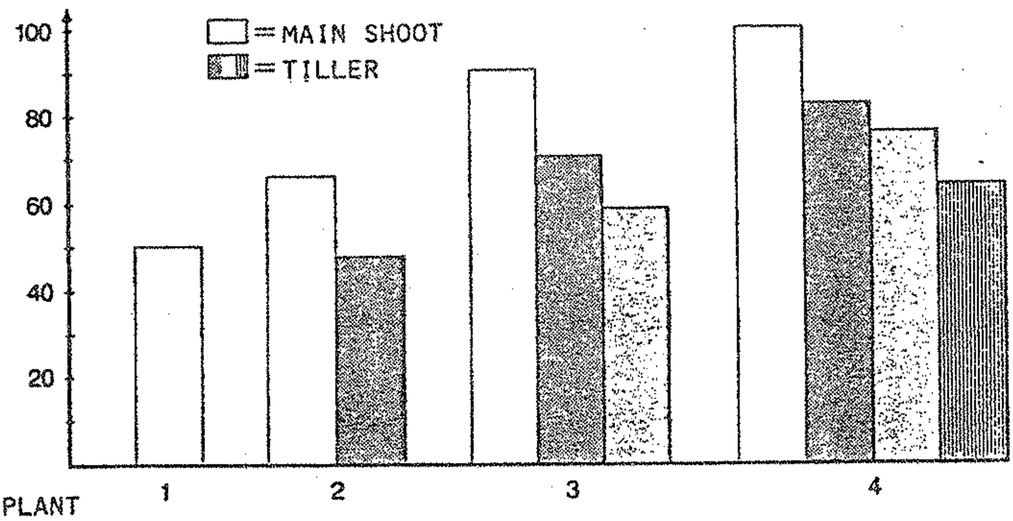
FIGUR 1. WHEAT



Ear density plotted against relativ yield in wheat.

FIGUR 2.

RELATIV
YIELD/EAR



EAR/PLANT

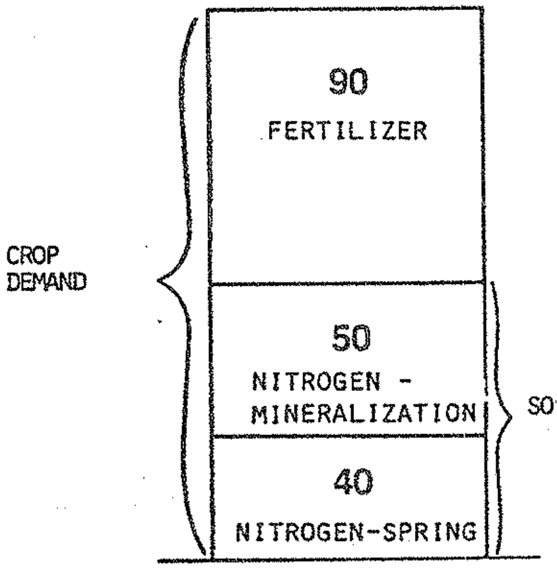
The optimum density could be reached in different ways. German trials have shown that for cereals is it better to reach the optimum from a low plant density than from a high. I.e. it is better with few plants with many tillers than many plants with few tillers.

In order to grow plants that have a good production of tillers there are certain demands on the sowing operation. It should be an early sowing and the seed should be placed on 2-4 cm depth. This depth should not vary depending on different soil density. The optimum would be a precision seeding in all directions. If this is not possible in practice, a row-width <8 cm and an even distribution in the row should be aimed at. It is also important that the right amount of seed (grains/m^2) is applied by the machine.

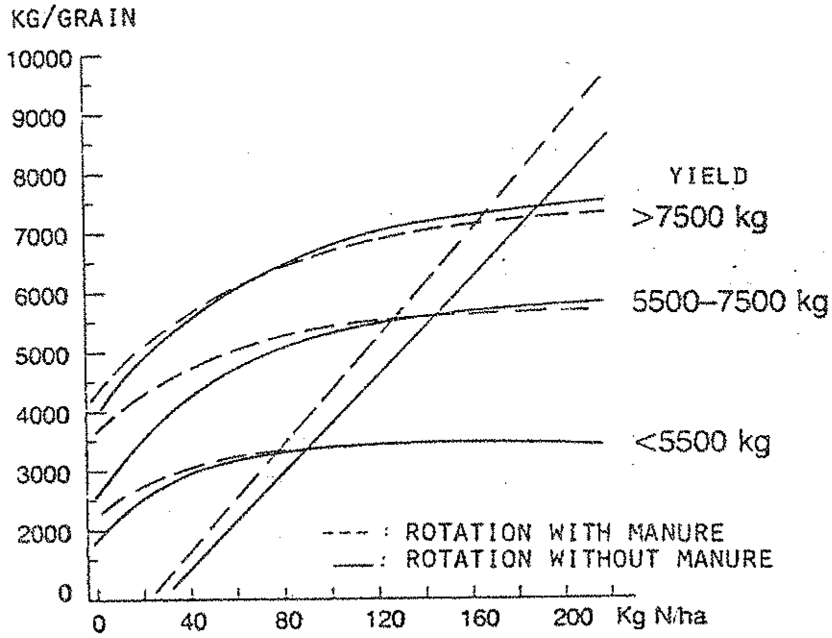
Fertilizer

When applying fertilizer there are two main questions: The total amount and the distribution in time. When deciding the total amount two factors to consider are the soil reserves and the soil mineralisation during the growing period. A rapid and secure method, specially for nitrogen, is desirable for those measurements. The third important factor is a good forecast of the yield. The last time for this, in cereals, is at ear emergence.

FIGUR 3. NITROGEN SOURCES TO CEREAL AN EXAMPLE



FIGUR 4. SOIL- AND HARVEST RELATED FERTILIZING
IN WINTER WHEAT.

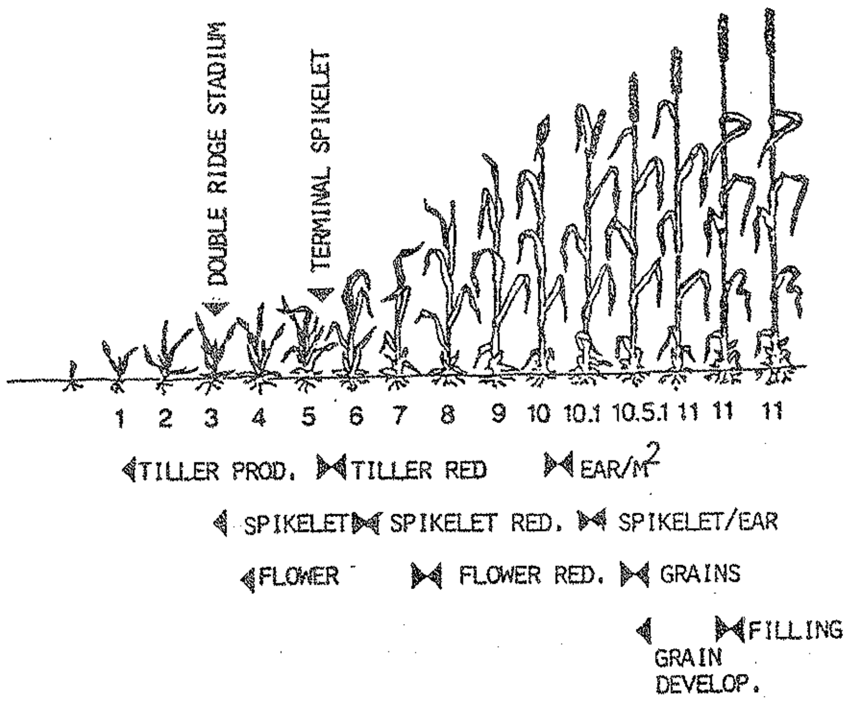


Figur 5. Optimum amount of nitrogen to winter wheat.

Yield Kg grain/ha	Not manure	Manure-rotation
3500- 4500	90	80
4500- 5500	115	100
5500- 6500	140	125
6500- 7500	165	150
7500- 8500	190	170
8500- 9500	215	180
9500-10500	240	190

Timing of fertilizer is depending of development stage. The best way to determine this is a dissection and examination of apexstadium. This could also be calculated according to the temperature sum. A good forecast for rain is also of importance.

FIGUR 6. CEREAL DEVELOPMENT



At last are there demands on the applicator. It should be possible to drive in a growing crop (tramlines) and it should give an even distribution and the desired amount of fertilizer.

Further research and development.

* Machinery that could put the seed in the soil with good physical precision (amount and in X-Y-Z direction).

* Rapid and secure method for nitrogen content in soil (NO_3 and NH_4) and other important plantnutriens.

* Method for estimating the mineralization of nitrogen during the growing period.

* Method for estimating the yield.

* Cheap apparatus for showing the temperature sum and the incoming light.

* Machinery that give an even distribution of fertilizer and continuosly show the driver the given amount of fertilizer per hectar.

PAPER FOR "COMPUTERS, ELECTRONICS AND CONTROL ENGINEERING IN AGRICULTURE" SYMPOSIUM, 3rd-5th FEBRUARY 1986, SWEDEN

ELECTRONIC MONITORING AND CONTROL IN CROP ESTABLISHMENT AND NUTRITION

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1. INTRODUCTION

The purpose of the Symposium is to review possibilities and develop strategies for the introduction of further systems of electronic monitoring or control to the mechanised processes of agriculture and horticulture. This paper therefore omits more than a brief mention of electronic monitors or controls which are already commercially available except where they are discussed as a starting point for further more sophisticated or effective devices. The ideas within the paper vary in economic and practical attractiveness from those which might, as a result of development already in progress or beginning very soon, be available on the market in the short term, to those where the economics or the problems of technical development are such that introduction can really only be anticipated within the period ten or more years from now. The economic cases have not been included in this paper except in qualitative terms. In some cases work has been carried out to explore the economic advantages; in other cases this has to be done.

Principal elements of monitoring or automatic control systems[1] are sensors either singly or in combination to give a derived measure from more than one quantity, display elements for the operator during the process or for subsequent appraisal by management, actuators to alter the elements of the equipment involved and the intermediate controlling systems which will normally incorporate digital computer processing of input signal to derive the optimum output based on a knowledge of the process algorithm and hence the desired control algorithm. Of these it would appear to the author that the development of suitable sensors is the principal key to further progress. These are normally not required to be of high accuracy but require robustness to deal with the agricultural environment and must be designed so that their cost is generally relatively low. A great deal of work is in progress already and much has been completed on process algorithms from which optimum design systems will be able to be evolved.

The section of arable agriculture to be dealt with by this paper is divided into three sections, tillage, planting and crop nutrition. There is some reference to horticulture but in addition many of the ideas proposed for arable crops in agriculture can also be applied to vegetable growing.

TILLAGE - PRIMARY PROCESSES

High power demand of the tillage practice[2] implies an economic importance attached to the efficient use of tractor power which requires that the engine is used at a speed and torque to best suit its economic employment of fuels and in addition the power is developed in traction or through the power take-off in the most efficient manner[3]. Much work has been carried out to investigate the use of instrumentation to indicate to the driver how he can improve energy efficiency by altering gear ratios[4]. The natural evolution of this work, already the subject of some research, is the incorporation of automatically controlled transmissions based on either fuel economy monitoring through fuel flow and engine power measurement or alternatively on the measurement of draught or pto power together with forward speed so that the transmission can be adjusted according to the known performance model of the vehicle. In general, the cost of fuel is still relatively low compared with the economic advantage of work timeliness resulting in improved yield or the cost of labour. This however is likely to change in the direction of increased importance in fuel cost and such measures as are outlined here will increasingly become important and be adopted.

The optimisation of traction initially requires the correct match of tractor and implement characteristics together with an optimum choice of ground drive, including tyre size and number of driven wheels, together with inflation pressure. Some work has been reported[5] on automatic control of tyre inflation pressures in relation to draught with the view of minimising the soil compacting effects and maximising tractor efficiency whilst avoiding damage to tyres in ensuring that the pressure is high enough to avoid buckling. Beyond this, however, the existing type of implement control system and improved versions which may be evolved from it, have much importance. Hydromechanical systems and the electronic types which largely copy the action of the earlier designs show limitations in effective performance at high operating speeds; this may be overcome by the employment of more sophisticated algorithms. Another feature which may be included is the sensing of slip of the traction wheels to enable the control system to optimise between the maintenance of a suitable implement depth, control of draught by altering this depth and override limitation such that when a predetermined maximum wheel slip is reached, adjustment to the implement depth is given even greater urgency.

The third way in which power and hence fuel efficiency may be maximised is to ensure that the soil processing is the minimum necessary. This will probably apply more to secondary tillage or seedbed preparation and will be dealt with below. In primary tillage, however, the depth of work is a variable which may be altered. The scope for this will depend on the relative needs in the particular field and for the crops to be grown of weed burial, surface soil treatment, subsoil treatment and in particular the removal of any compaction "pan". For cereals there is a great deal of evidence that tillage processes may be carried out to less depth without the sacrifice of yield[6]. A working depth sensor on a mouldboard or chisel plough or on discs which might be employed in primary tillage is a practicability, although more development may be needed in arriving at devices that have the robustness and performance reliability on a wide range of soil types and surface vegetation conditions. Such devices could then be used either as an operator indicator to enable the minimum depth to be set, or as part of a control system for the tractor hydraulic linkage or implement wheels. Another possible implement control system which has recently been introduced in a manual sense is the control of furrow width on a mouldboard plough. Means could be contemplated whereby this could be coupled to an automatic system for the maintenance of furrow straightness. Similar systems may be employed to adjust the operating width of tined implements although in that case straightness may equally easily be achieved by an overlap with work done.

Other derivations of these ideas include the automatic adjustment of furrow spacing to provide better quality ploughing when the depth of work is altered. Such an adjustment could obviously be automatically coupled to depth of working. Such an adjustment could also be seen as part of a tractor draught control system where instead of adjusting implement depth, implement width is altered, so preserving a more uniform depth of work but again optimising tractor performance.

TILLAGE - SECONDARY AND SEEDBED PREPARATION

Secondary tillage is carried out to achieve a suitable seedbed for plant growth. The objective is a soil which provides good conditions for the flow of fluids to facilitate nutrient and oxygen transport and has a limited level of mechanical impedance to root extension. Both of these characteristics would seem ultimately to be amenable to electronic sensing which will then allow the action of the implement to be minmised to achieve what is required and no further soil breakdown. Today's visual assessment of a seedbed is based to a large degree on the 'tilth' which is a description of the soil aggregate dimensional characteristics. The possibilities of measuring this tilth objectively appear interestingly challenging. A sensing device could be based on the measurement of the contour irregularity of the surface, and processing of this information to arrive at a correlated measure of surface aggregate dimensions. Surface irregularity might be assessed either by optical ranging from a reference point above the surface[7], effectively being part of an implement moving over it, or alternatively ultrasonic ranging means may be employed. At this stage with the availability of ultrasonic sensors already being used for boom attitude control, this principle may be the most likely[8]. Work needs to be done on the accuracy and reliability of such devices but perhaps the larger challenge is to convert the information on surface irregularity into a meaningful objective criterion for the actual seedbed quality. Mathematically this will imply the conversion of a signal which may be inferred to indicate a histogram of soil aggregate dimensions into a single figure representing what is required in a seedbed. The measurement of soil permeability to fluid flow, be it liquid or gases, is essentially a sensor challenge. Static measurements are already practicable although these normally take a significant time even with electronic instruments. The development of a means of measurement which is both moving and instantaneous is a difficult challenge but, in view of the probable suitability a relatively lower level of accuracy may be attainable within the medium term. One can perhaps most easily envisage a device based on air leakage and hence pressure differential from the tine or share-like element propelled through the soil on the tillage implement. Finally, the mechanical impedance to plant root growth implies again a device being propelled through the soil with measurement of the draught force required. The dimensions and depth of the device must have affinity with the equivalent characteristic of plant roots.

Having made measurements of the soil and related its characteristics to the requirement in the seed bed, we need to address the means of obtaining the correct implement response. The employment of soil state displays on the tractor and manual operator actions is one possibility, but we can also in due course envisage automatic adjustments to the speed of rotation of powered tillers, the oscillation frequency or amplitude of oscillating tillers, or the geometry of the soil engaging elements of draught tillage implements. In the cases of soil driven devices such as turbo-tillers or disc cultivators adjustment to the angular approach of these devices or to the vertical weight applied represent main possibilities.

PLANTING

Control and monitoring applications in seed planting implements divide into those related to the functioning of the planting mechanism or coulter and those concerning measurement of seed quantities either remaining within the hopper or flowing into the ground.

Depth adjustment of coulters may be contemplated to place seed into a position determined by the nature of the moisture profile within the soil surface. Hence in a drier soil seeds would normally be planted more deeply than where the soil has a high moisture content near to the surface. As with the other characteristics of the seedbed described above, the soil moisture profile may be measured statically with instrumentation but this is both sophisticated and requires time for the measurement. For coulter depth control a continuous measurement is required as the implement passes over the soil surface and the data are required instantly. Again, however, the level of accuracy useful is somewhat less than in the case of instrumentation used for field experimentation. Among the principles to be contemplated for this measurement are soil electrical permittivity using capacitance techniques, soil electrical resistance or impedance, microwave absorption or scattering and near infra-red measurements of soil reflectance. Superficially, however, it would appear that the permittivity and impedance methods are most practicable bearing in mind that one is looking for a measurement not only on the surface but to at least a few centimetres below it. Principal problems which would have to be overcome are the variability of soil density which will equally affect any electrical impedance measurement or capacitance measurement, and presence in the soil of chemical ions which will be of varying concentration and again have a major effect on the electrical characteristics. The author is unaware of progress in this area but believes that in the medium-term possibilities do exist. If the moisture data are to be used for automatic coulter depth control one current limitation may be the relatively low sophistication of the dynamics of drill coulters and advance may need to be made in improving coulter frequency response.

The needs in connection with seed quantities are to both assess the amount of seed available on the implement and also to measure the rate at which seeds are being planted. The former is more simple and devices already exist, some of them electronic, to indicate the level of seed material in the hopper. If these data can be produced in sufficiently accurate terms, and this may result from the employment of either mechanical surface sensors coupled to electronic indicators of displacement, or to the employment of direct electrical level monitoring such as capacitance sensors, then the use of signal data may be developed in more sophisticated ways. This will, however, also require a knowledge of the seeding rate and hence the rate at which the material is being consumed. If this can be achieved then simple computational measures can indicate not only seed level but also the operating time remaining before material runs out and perhaps in addition, by recording the time taken for the last working bout in the field, the number of bouts remaining, or whether or not one more may, at any stage, be undertaken without risking the material being used up before the other side of the field is reached.

The measurement of total seeding rate may, at this stage, be most practicable by processing a continuous record or hopper weight. Such weight may be determined by mounting the hopper on strain-gauged beams or rings. The most serious limitations are likely to be the influence of field irregularities and hence implement vibration on the signal and also the cost of strain gauge techniques. The vibration influences are likely to be amenable to removal by signal processing through averaging over an appropriate time. Such a measure cannot indicate the flow of seed to individual coulters and this also will be needed in due course both to ensure an evenness of planting and to indicate blockage in any one coulter. For this measure the options would appear to be the use of electromagnetic coil type flow detectors, the employment of impact force signals where seed is allowed to impact a plate (as in the case of combine harvester discharge meters[9]), or optical devices. Optical devices are already employed to monitor the flow of individual seeds in precision drills but it may be possible to derive a useful correlation between signals from such optical devices where seeds interrupt a light transmission beam and the total quantities of seed in volume.

In vegetable growing, and perhaps in the future with sugar beet, plants may be grown from a seedling transplanting process. In this process the contribution of the electronics engineer is likely to be connected largely to the monitoring of the state of growth and hence health of the individual transplant prior to planting out using perhaps pattern recognition or image analysis techniques.

In this way inadequate transplants may be rejected and corrections made to ensure that satisfactory plants are dispensed at every position. Computational means may also be employed, as was the case with an earlier device for controlling thinning mechanisms[10], to adjust the planting frequency and distances to allow for inadequate plants within the quantity. Depth control or the pressure to "firm" the soil around the plants are other variables which could become electronically controlled in due course.

PLANT NUTRITION

The high cost of the fertiliser input to arable agriculture suggests that high priority must be given to concepts such as variable application rates throughout a field to reduce overall quantities and yet ensure that the nutrient status for all individual plants is adequate. The prime problem therefore again becomes one of sensing, that of sensing the level of the principal components of nutrition within the soil either directly or through knowledge of the plant response. In research terms we may be relatively near to sensing soil nutrient status by the employment of, for example, ion selective sensors for at least the nitrogen, potassium and phosphorus ions[11]. It is not possible to envisage the employment of these sensors on a moving implement to give instant readings, however. Alternative means would have to be sought and these might include the burial of appropriate sensors and computational devices at regular intervals throughout the field and their interrogation by a passing machine. Such a possibility would surely only become practicable if sensors, recording and transmitting elements can be produced in the same chip. This possibiity must exist before the end of the century but is hardly likely to yield an early economic solution to the problem.

Earlier indications of localised nutrient status are more likely from measurements on the growing plant where applicable. The most obvious example is the use of colour sensing to indicate the need of cereals for nitrogen fertiliser. Local differences are easily seen but the economic significance of altering quantities of nitrogen added and the timing of application need to be investigated before practical solutions to the measurement and control possibilities are sought. Other measurements on the plants which could indicate their status of growth and hence nutrient requirement, are of stem thickness, ground cover (in terms of proportion of area covered in plan view by the plants), or the employment of visual imaging and pattern analysis to indicate wilting or changes which may be characteristic of either a nutrient deficit or a moisture deficit.

The other needs in fertiliser dispensing are similar to those for seeds, namely indications of hopper fill and of flow rate. With the high cost of fertiliser inputs, the need to monitor and maintain the distribution pattern may be even more economically justifiable than with seed and these two examples seem to make the reasonably accurate but low cost monitoring of particle flow one of the highest sensor priorities.

CONCLUSIONS

This review, which is of only part of the mechanised processes on an arable farm, indicates that there are many important opportunities for the application of electronics which should lead to the better use of the input materials, be they seed, fertiliser or the energy employed in the processes. The reduction of labour input has not been addressed although driverless operation in at least primary tillage could be seen to be justified economically[12]. It would appear, however, that there are other factors which make this at the moment unattractive and principal among these is probably the already low level of manning on Europe's farm. This is surely near to the level necessary to deal with unforeseen problems even where the straightforward and more routine work can be carried out completely automatically.

Overall the need seen by the author is for the development, principally by Government-supported activities of adequate sensors and control algorithms. Further improvements in the robustness and the lowering of cost of actuators is desirable if automatic control is to be used much more routinely, but this is probably better left to industry. Equipment manufacturers will also obviously play a large part in the development of complete systems but the author's analysis would suggest that the ultimate advantage of the employment of the majority of the devices will benefit rather more the farmer and grower or the consumer of his products than there will be benefit accruing to the agricultural engineering industry.

The author hopes that this review will at least generate further discussion which will help to determine the relative priorities of investigating the many opportunities proposed.

-End-

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Symposium "COMPUTERS, ELECTRONICS AND CONTROL ENGINEERING IN AGRICULTURE"

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APPLICATION OF COMPUTERS, ELECTRONICS AND CONTROLS ON AGRICULTURAL MACHINERY WITH SPECIAL EMPHASIS ON THE DISTRIBUTION OF CHEMICALS

Horst Göhlich

Looking at the farmers situation today and trying to forecast the technical needs for agricultural production for the next decade, it becomes quite obvious that the following prerequisites will have priorities:

- Most economical production of high quality products
- Less physical work stress of the human being and more mental threngh
- Stronger considerations on the environment and ecology, including soil + water.

All three requirements need new technological support combined with an enlarged package of new technological knowledge. In order to make progress technological support means in that respect computers, electronics and automation on a broad scale. However, such development programs are only justified through clear benefits for the user.

Agriculture is just doing the first step in that direction, implementing their "production line" with automated steps, containing more intelligence.

It appears to me that the introduction of any kind of electronical means will open undreamed of possibilities in the design of the future machines, but these actions will be a most important tool to achieve the future requirements mentioned before.

Thinking on the surplus production situation and the subsideries given to agriculture on one side and the increasing burden through legislation regulation reflecting the various interests of our society, only most modern operating farmers will survive on a longer term.

Automation even more than mechanisation has the potential to enhance human capabilities. It can do jobs which humans cannot do. It can do better what people can do, and it can take on tasks that are hazardous, monotonous and arduous. Those who adopt automation first and enthusastically with the attitude of making it work for them will be most likely to solve the future problems properly and succesfully in the agricultural business.

Automation offers a new dimension in agricultural mechanisation. Special sensors capable of detecting product and environmental characteristics and monitoring machine parameters are already available or will be developed, that greatly exceed human capabilities. Informations processing units and data memories will be available such a way that they will make decisions ready for managing business as well as for improved machine operations.

For example:

Tillage requirements vary on the field, the amounts of fertilizer and plant protection chemicals varries with the fertility of the soil and the situation of weeds or plant deseases in different field plots. Sensors could detect such characteristies and control and adopt the operation towards the changing conditions.

Carefully controlled conditions of the field as well as of the machine could result in significant increase in productivity both per unit of area and man and machine input. They also may contribute for more safty on the human being and less physical workstress. Another remarkable chance of sensor automated systems is the environmental control of air, soil and water. Soil erosion, drift of chemicals and the purity of the ground water has to be controlled more seriously than before.

Another important field of control is the soil compaction. The disadvantage of our machine development of the last period was the permanent increasing weight of our field machinery. Sensitive soils against compaction have to be controlled in the future. New styles of field operations will have to be considered for particular soil conditions.

Controlled traffic farming is a technique that will reduce soil compaction and may provide substantial impacts in both effiency and yield improvement. As soon as all tractor wheels and implement load bearing wheels operate on specific limited width, that means traffic paths within the crop area, new vehicle controls become necessary. A significant benefit of controlled traffic farming is the feasibility of automatic guidance of vehicles. The efficiency of traction could be raised by lower traction losses of the wheels; even smaller wheels instead of wider could be used because of reduced flotation requirements.

The control of seed planting, the uniformity in depth and spacing is another important field which needs sensorized operations. First steps are already practicised.

Still one other area may be mentioned in which has already made good progress by applying electronics and computers: the automation of animal husbandery. All three requirements, I mentioned at the beginning can be considerable contributed by any kind of control and automation. From here it leads me to the most suitable farm computer and its software. Useful and appropriate software for farm operations is an another important field for scientific developments.

Economical success on one side depends on correct planing and optimal decisions for all farm operations. - Computers do help considerably, supposed they are fed with the correct parameters. - Economical success on the other side depends in the same manner on the always optimized technical procedure.

For example:

- Tillage operations with the highest acreage per time, lowest wear of the tools and burning the lowest amount of fuel by the tractor engine.
- Control of quality and losses during harvest operations are means for securing a higher over all efficiency.
- Driver information systems and automaticly operating transmissions are means to assist the driver during his work as well as automated correct machine settings.
- Increasing the transport speed of the tractor and implement without stressing the driver by controlled steering, suspension of the wheels and the operators place.

More or less automated operations will contribute to the fact that the operator is less stressed physically and achieves more time for thinking on operational tasks.

The dialog of the operator with the control electronic will more and more substitute the direct process control by the conventional operating elements. Sensors provide the informations of the physical occurance of the process to the control computer. Actors receive the information to react and to change physical data of the process.

In the following I like to present some examples of the application of electronics and microcomputers in field operations with tractors and in spraying operations, where we have been envolved in the development during the past years, and which may touch some general futur developments.

Tractor powered field operations:

Aims are to raise the overall efficiency with less stress of the operator and less compaction of the soil. That includes increasing speed for transportation. The overall efficiency means much field work accomplished in a given time with the lowest amount of fuel consumption and the lowest exertion of the driver. To accomplish such a requirement, further advanced optimization of the field operations is needed. Optimization leads to automatisation and improved driver comfort. Fig. 1 shows the steps of automation of the tractor implement system.

Step 1 represents the situation of today. The operator receives some information by direct observation of the tractor and the implement and some others by instruments (f.e.speed, engine r.p.m, and other engine data).

Step 2 leads to advanced information by instruments which exposes already processed data for an easier decission of the driver. One proposed configuration is to give the driver explicit operating advice for the most efficient engine speed and the recommended gear. The signals for the driver could be given by simple indicator lights, by a two dimensional target like indicator that helps the driver to stay between certain set limits or even by a built-in speech synthesizer for an audible advice.

Fig. 2 shows a panel which we have developed for step 2, and Fig. 3 shows a device with two instruments giving the sets for engine speed and gear shift.

Step 3 represents a fully automated system. The computer controls directly the speed of the tractor, supposed there is an automatic shifting transmission available. The computer controls in addition the engine speed and in particular cases also the implement itself, for instance the depth of a plough. Automatic shifting transmissions for tractors will be available in the very near future and consequently after that the automation of the whole operation with field machines will take place.

At our institute, two different systems have been developed and field tested, the system OPTDISP for a 52 Kw tractor, a conventional 16 gear transmission and the system OPTPS for a 125 Kw tractor with a 15 gear power shift transmission. Because of the difference in characteristics and resulting indicator specifications, the two systems were programmed with different optimization algorithms. Fig. 4 gives a short description of the system design.

The futur work will be concentrated only on the full automated system because the practical experience on farms has shown up that the farmers finaly want the full automation instead of concentrating their eyes or ears always to the signals. Fig. 5 shows some results of our field investigations, using a driver information system as explained in step 2. It shows a considerable saving of fuel and an increase in performance as soon as the information system is applied.

Dynamic axle load performance:

Transportation by tractors in agriculture will play further on an important part of the total work of tractors. The maximum speed now in the range of 30 to 35 Km/h is increasing. The first tractor shown at the "Agritechnica" in Frankfurt last November was designed for 50 Km/h. Having experience with non wheel suspended vehicles, it becomes doubleful, whether such a speed can be applied without additional risks on the road. Therefore the suspension, at least of the front axle will be a next step in the futur tractor development. In order to addapt the vibrating system of the tractor and the mounted system to the different load conditions, controlled suspension characteristics such as spring stiffness and damping will be necessary.
Fig. 6 shows the principle design of a suspended front axle which fulfills the various requirements in order to reduce the dynamic loads and to improve the safety on the road as soon as going with higher speeds. The spring system of our design is a hydropneumatic one, which consists out of the Hydraulic cylinders, damping valve and gas accumulator. The suspension can be blocked completely by a lock valve.
Fig. 7 shows a tractor with a front axle suspension developed at our department. The suspension characteristics i.e. spring rate and damping coefficient could be controlled by an electronic device.

Another mean for controlling the axle load could be in cooperation with the electronicly controlled hydraulic three-point hitch. Such a mechanism allows the reduction of pitch vibration which is very effective when driving with heavy loads mounted on the three-point hitch.
Fig. 8 shows the power spectrum of the dynamic front axle loads for the tractor-implement-system with and without the explained damping system.

PTO Torque control:

The power demand of the pto driveline, e.p. when propelling a forage mower or chopper is mainly a function of crop density and ground speed. The chopper performance is generally optimized for one of the standard pto speeds. Assuming the chopper reaches a field spot with increased crop density, the ground speed must be reduced before the implement is run into a stalling condition. If the pto-torque is measured and compared permanently with a present value, and if the tractor transmission allows immediate shifting, the control loop can be closed without operator interference.

Data acquisition:

Most of all control systems need a certain data collection and preparation in order to reduce the data storage size and to feed the microcomputer with the prepared information. Such a preparation of sensor signals, the calculation of data and the determination of indicators can be handled by a data acquisition and control system (MDES). Such a system accomplishes a necessary data acquisition tasks for the field researcher under conditions that would prevent the use of a conventional mini- or microcomputer.
Fig. 9 shows the principle configuration of a MDES. Through the online data reduction process only a limited amount of storage is required.

Electronics in spraying tasks:

The application of chemicals in agriculture is one of the most criticized operations; it is costly, bothers the operator and creates environmental problems. Unfortunately, no way is known or appearing on the horizon, which will avoid spraying in general. Biological approaches make very slow progress and we cannot count on them at least for the near future.

Most important aims in the development of the spraying technique are as follows:

1. The improvement of the chemical distribution such a way that most of the chemical will reach the target and in consequence the reduction of the amount of the chemical, applied per unit area.

2. The reduction of losses by overflow, ground deposition and drift.

3. The protection of the operator against any kind contact of the chemical.

The advanced improvement of the distribution of chemicals as well as of fertilizes and seeds needs all kind of controls and adjustments for any kind of deviations from the optimal point in the overall process. For the example of spraying some necessary controls are as follows:

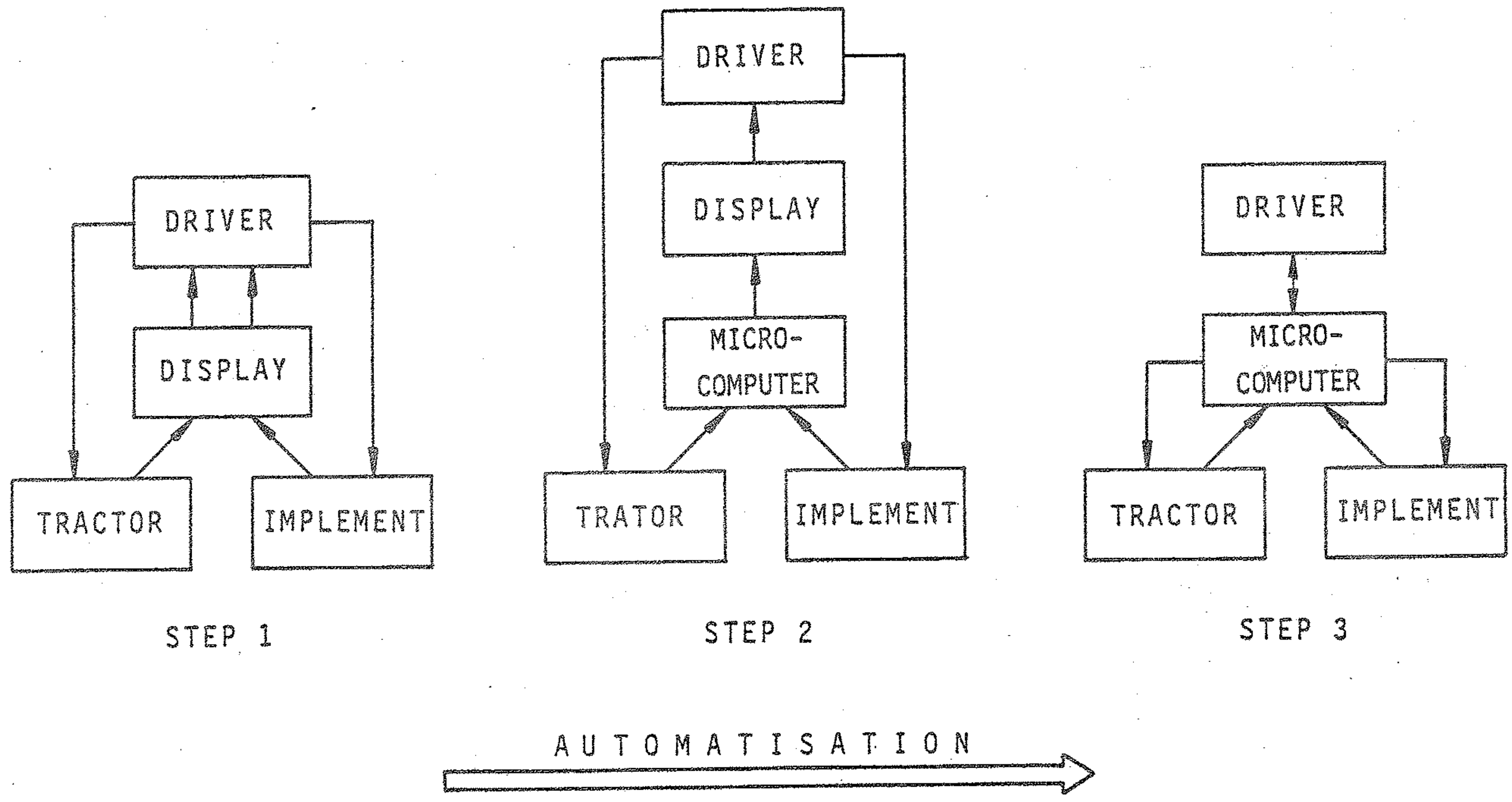
1. Amount of spray liquid flow versus the area covered per lime. Such a control unit needs an exact information of the liquid flow and the speed over ground, considering the area covered proportional to the speed. Such sprayer monitors are available and are already widely used in praxis. They presuppose the fact that all nozzles operate precisly and equal.
   Fig. 10 shows such a complete control unit.

2. The distance of the nozzle to the target:
   Nozzles distribute the liquid precisly only at a definite distance to the target. Considering that sprayers will need a control unit, which provide such a constant distance independently from the deviation of the frame on which the boom or the nozzles are mounted. Such an active suspension unit has been developed and tested in the field. The distribution of the liquid could be improved extensively by such a device.
   Fig. 11 shows the principle of an active boom suspension with one pivot point of the boom using ultra sonic sensors to measure the distance to the plant surface as well as to the ground.

Critical points of such a system are the same as with many others, namely the response of the sensors. Intensive investigations had been necessary to find out the most adequate and accurate type of sensor. Beside optical systems we found the ultra sonic sensors most suited for those purposes:
Ultra sonic sensors receive the reflected signals from an area, large enough that a mean value of the different momentary measurements represent a most reliable response of the wanted distance to the plants as well as to the open soil. Generally spoken, sensors for measuring distances for agricultural tasks will have to be improved. The seizing of stochastical distributed signals make a high sensor frequency necessary. Fig. 12 gives a approximate picture of the price situation of sensors for measuring distances contactless. The control circuit itself can be developed as an analog as well as a digital system. According to our experience digital circuits are more suited for such a task as analog ones because of a cheaper realisation.
Fig. 13 shows both circuits in comparison.

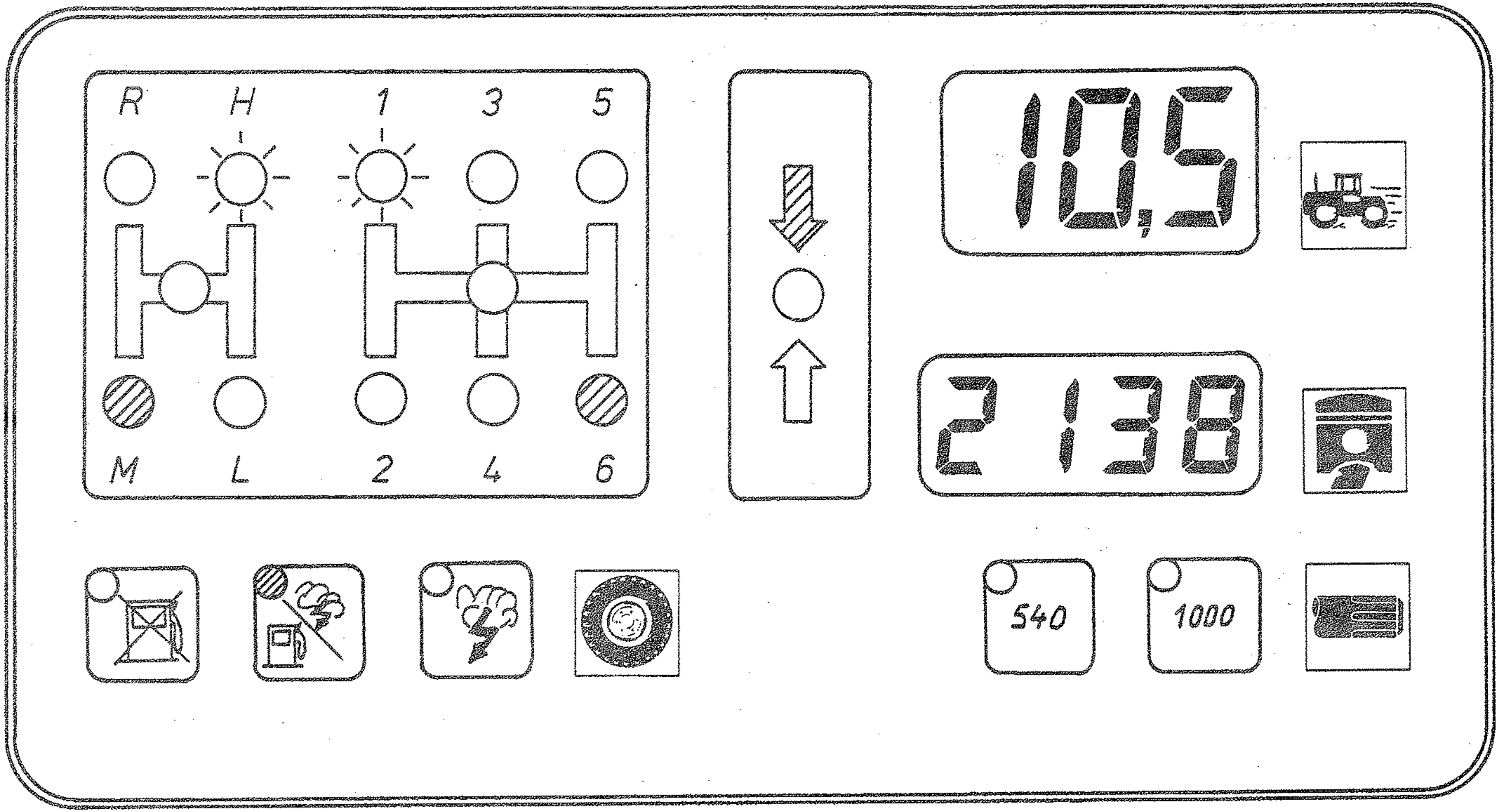
A simular task is the seizing of the depth of a plough furrow. Knowing the correct depth continously the control circuit for the plough could be improved such a way that instead of using force sensors as it is done e.g. on the Bosch EHR-system, we could better use distance sensors. A first commercialy offered ultra sonic control system for depth control on ploughs is known from an australian company (DE-AYE PTY LTD).

A drift warning method is another desired equipment for the future plant protection. Since drift has become a critical appearance it has been measured by sampling methods like A_A and A_G in Fig. 14. Isokinetic samples and passiv collectors have been used successfully in order to know the amount of drift after the complete application has been done. The requirements of today ask for an immediate information on the drift, when beginning with an operation. The farmer or advisor needs therefore a measuring technique which provides him with an information, whether a certain threshold is exceeded or not. We are working on sensors, applied close to the spray machine which will give us such an information. Sensor B is placed on the ground and measures particles in an area where actually none particles should appear. A simular way is the method C, which consists out of a sensor mounted directly on the machine. Both sensors use the principle of thermoresistance. As more particles evaporate on the surface of the sensor as lower the temperature reacts. The temperature drop is then a certain maesure for a threshold value and gives the farmer immediately a reference for the drift situation.



TUB LT-BM	Optimisation of the tractor-implement system	14 07 83 02 BE/KI

figure 1



T U B L T - B M	Shifting-display devoloped by TU-Berlin	14 07 83 11 B E / K I

figure 2

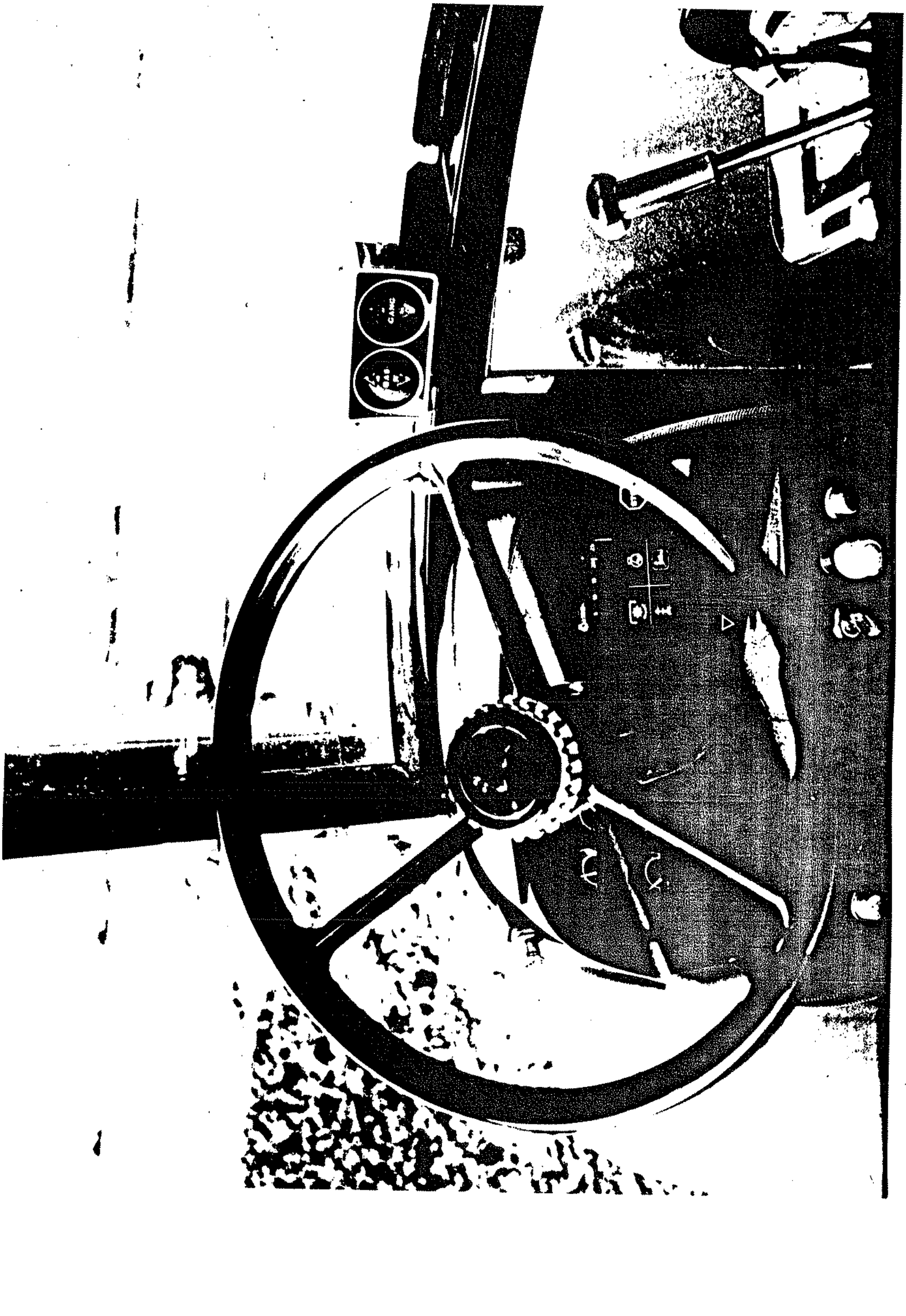


figure 3

Information system:

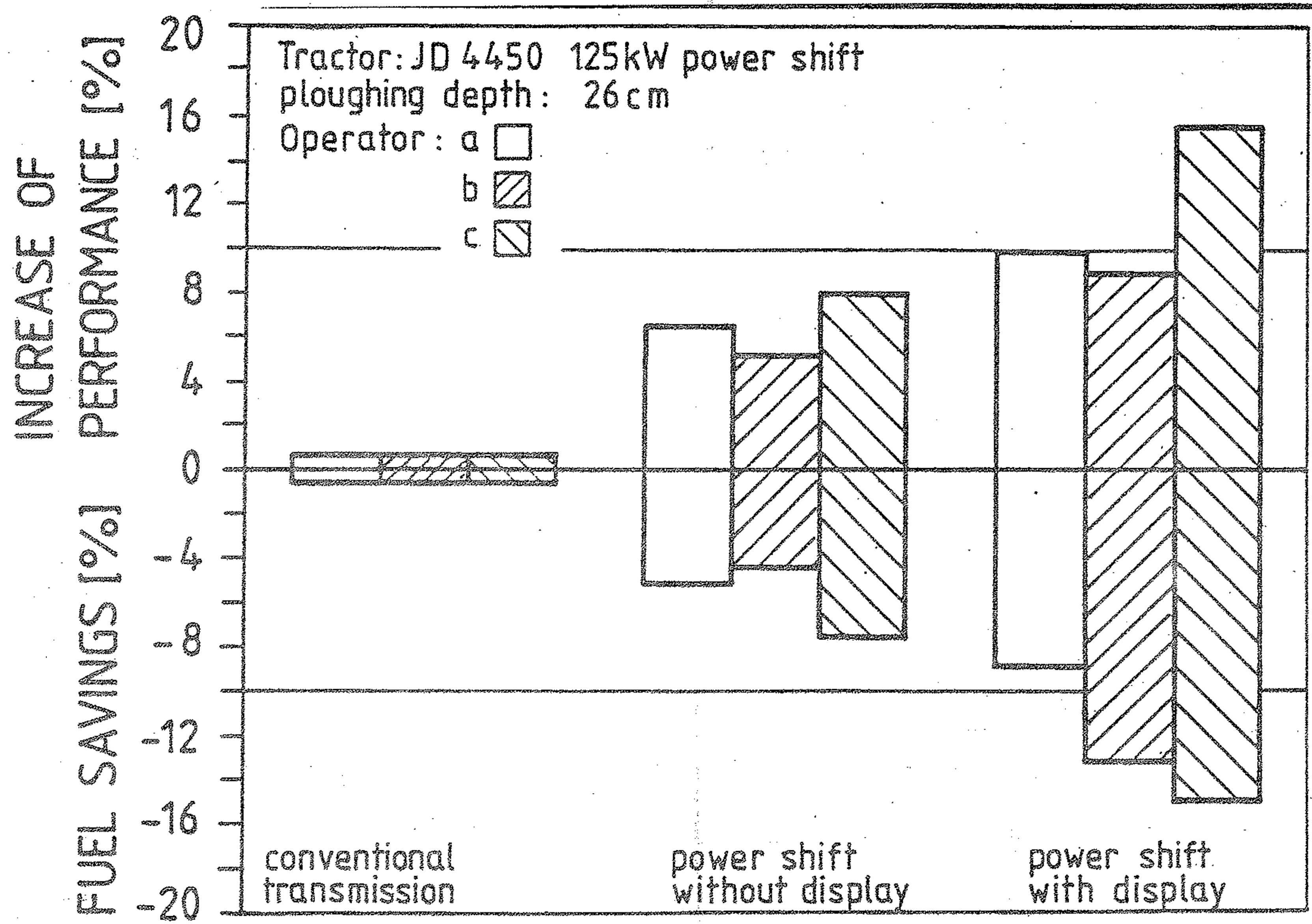
- Sensors
- Signal conditioning
- Microcomputer
- Indicators

Output data:

- Engine speed
- Engine torque
- Wheel speed
- True ground speed (may be omitted)

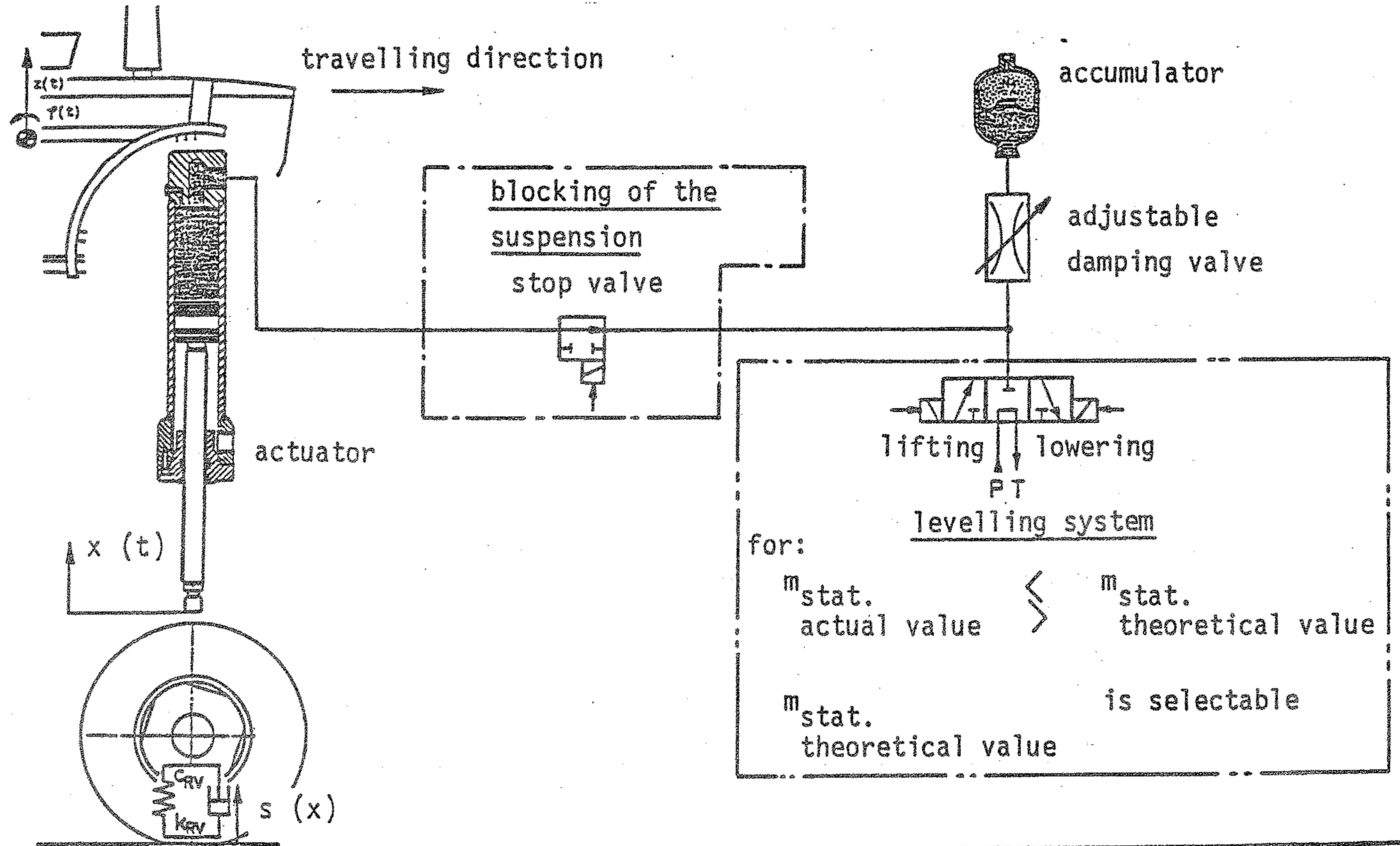
TU-Berlin LT-BM	Information System Tractors	8402 Gö/Be/Ki

figure 4



TU-Berlin LT-BM	Influence of Power Shift Transmission and Optimisation Algorithms on Fuel Saving and Performance	10 10 85 02 Ki

Figure 5



T U B LT - BM	BASIC CONCEPT OF AN ADAPTABLE FRONT AXLE SUSPENSION	10 007 85 WEI

figure 6

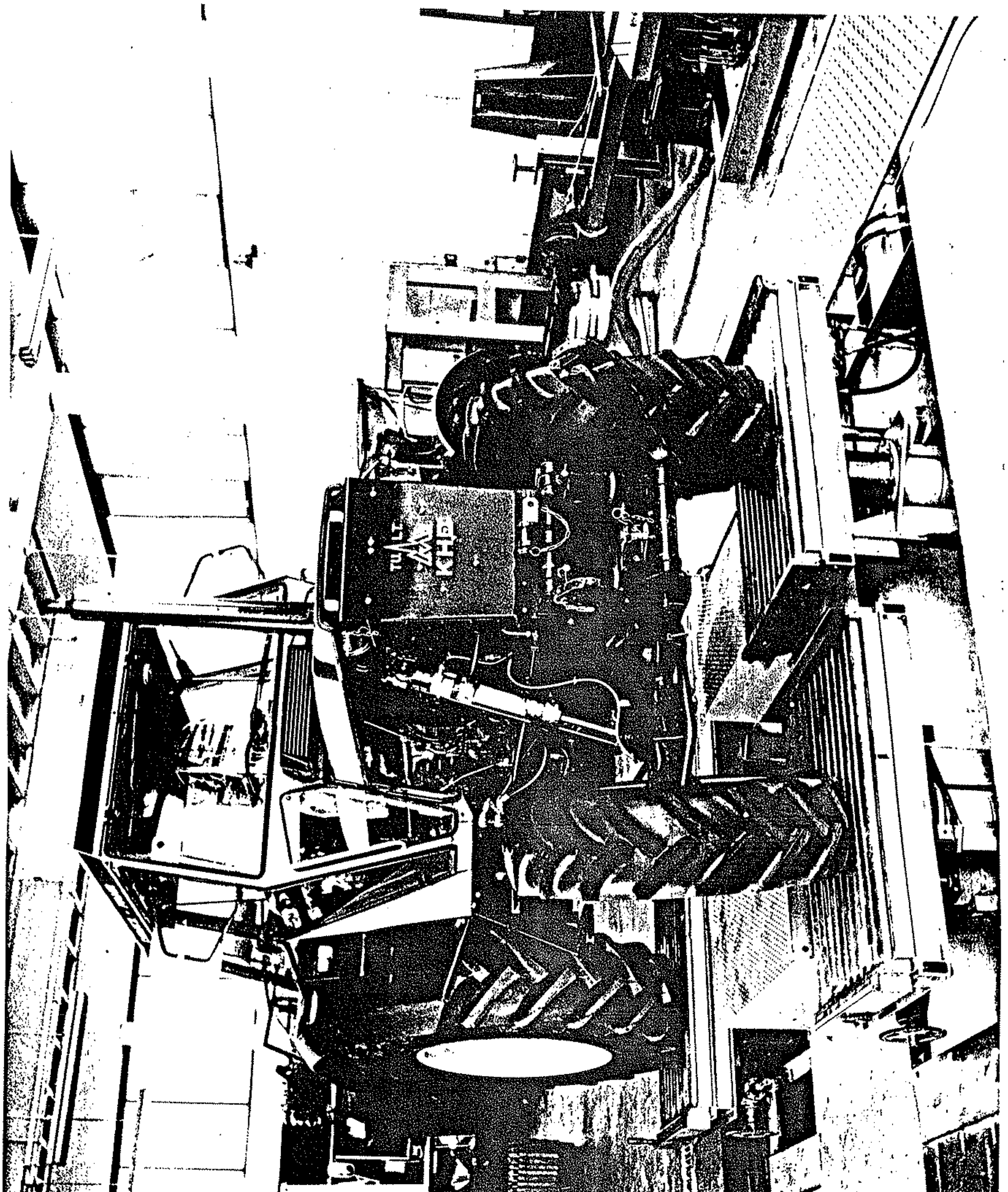
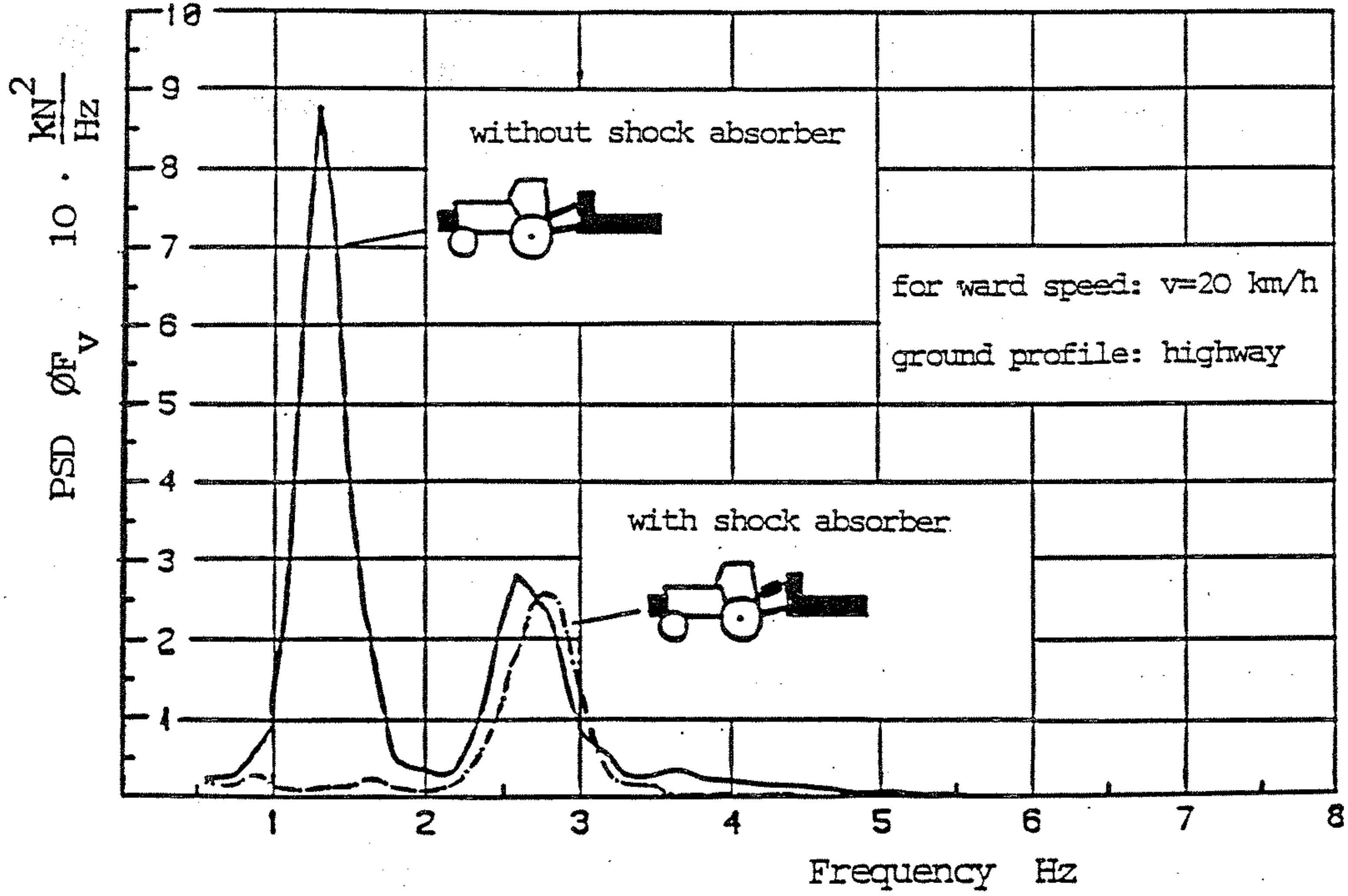
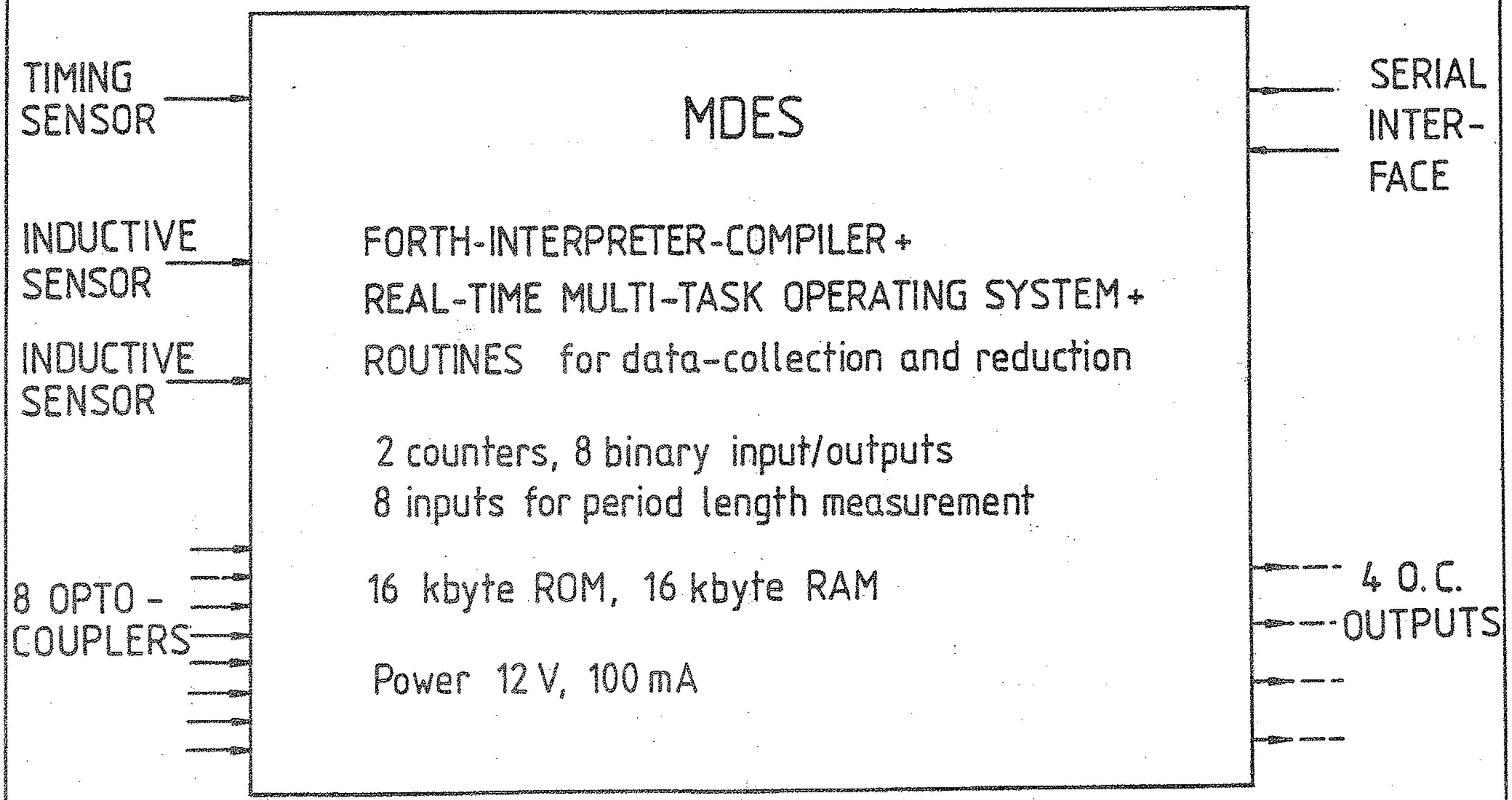


figure 7



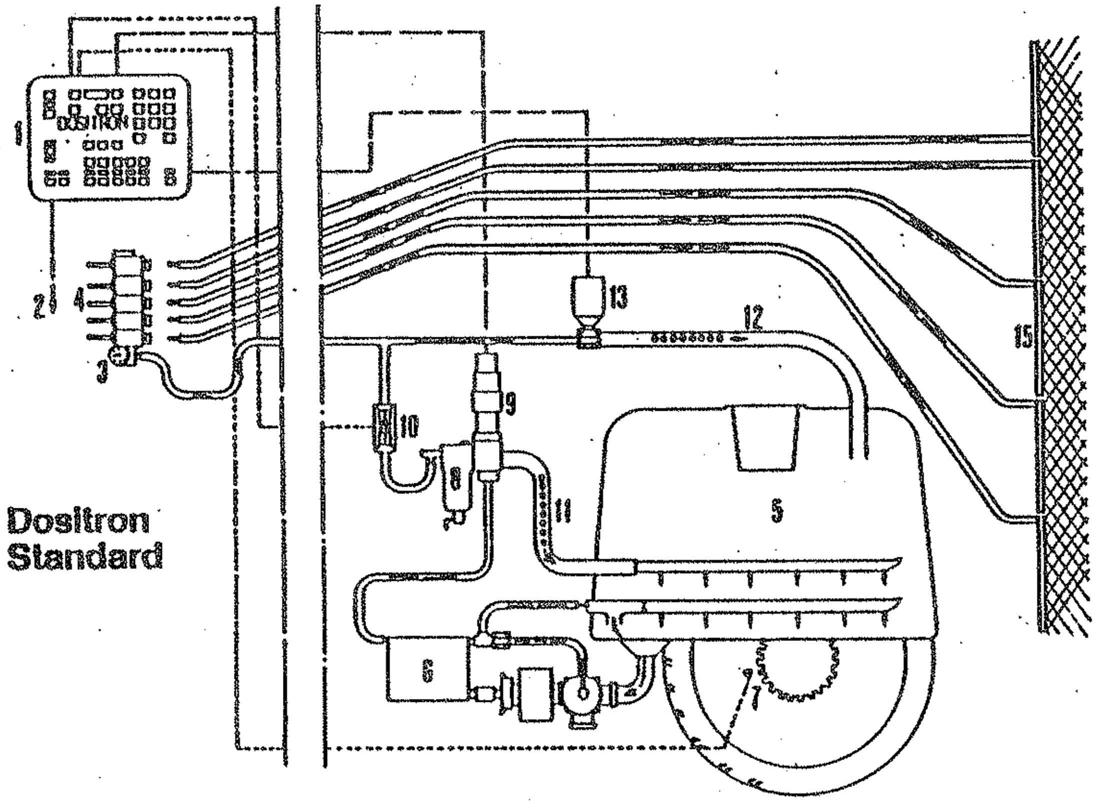
T U B LT - BM	POWER SPECTRAL DENSITY OF THE DYNAMIC FRONT AXLE LOADS WITH AND WITHOUT A SHOCK ABSORBER SYSTEM AT THE UPPER LINK OF THE THREE POINT HITCH	02 001 85 WEI

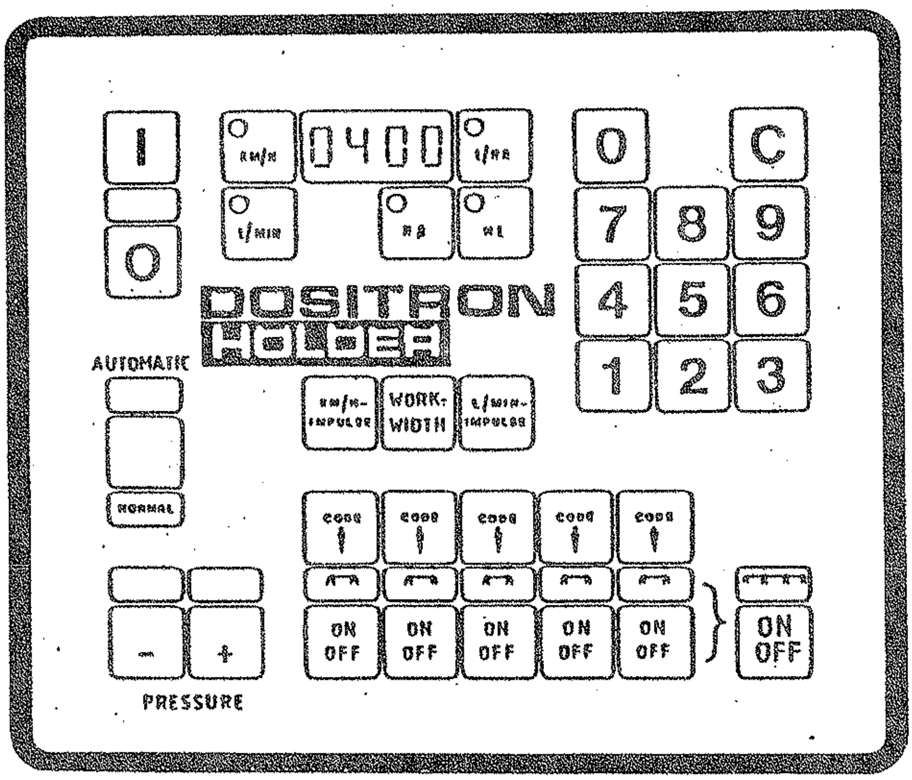
figure 8



TU-Berlin LT-BM	Configuration MDES 14, MDES 15	21 10 85 01 Be/Ki

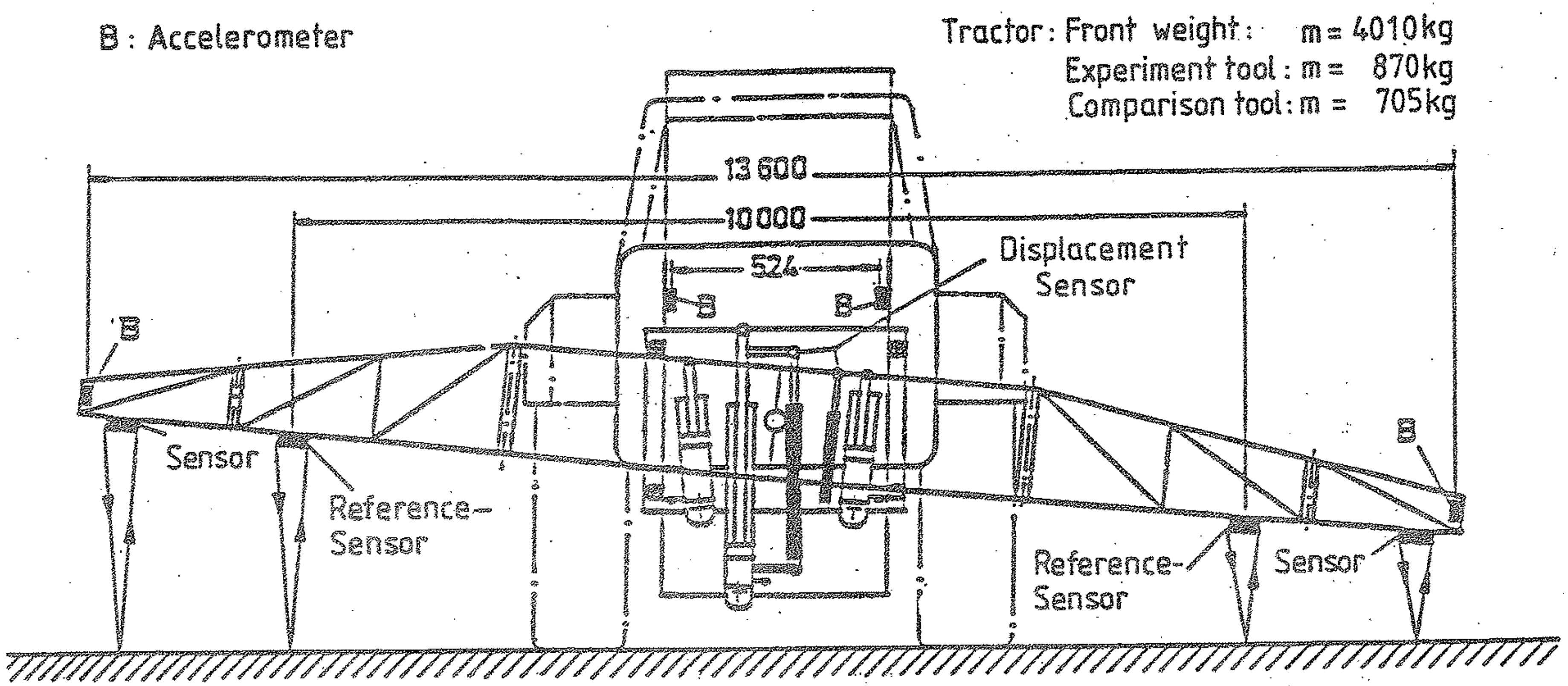
figure 9





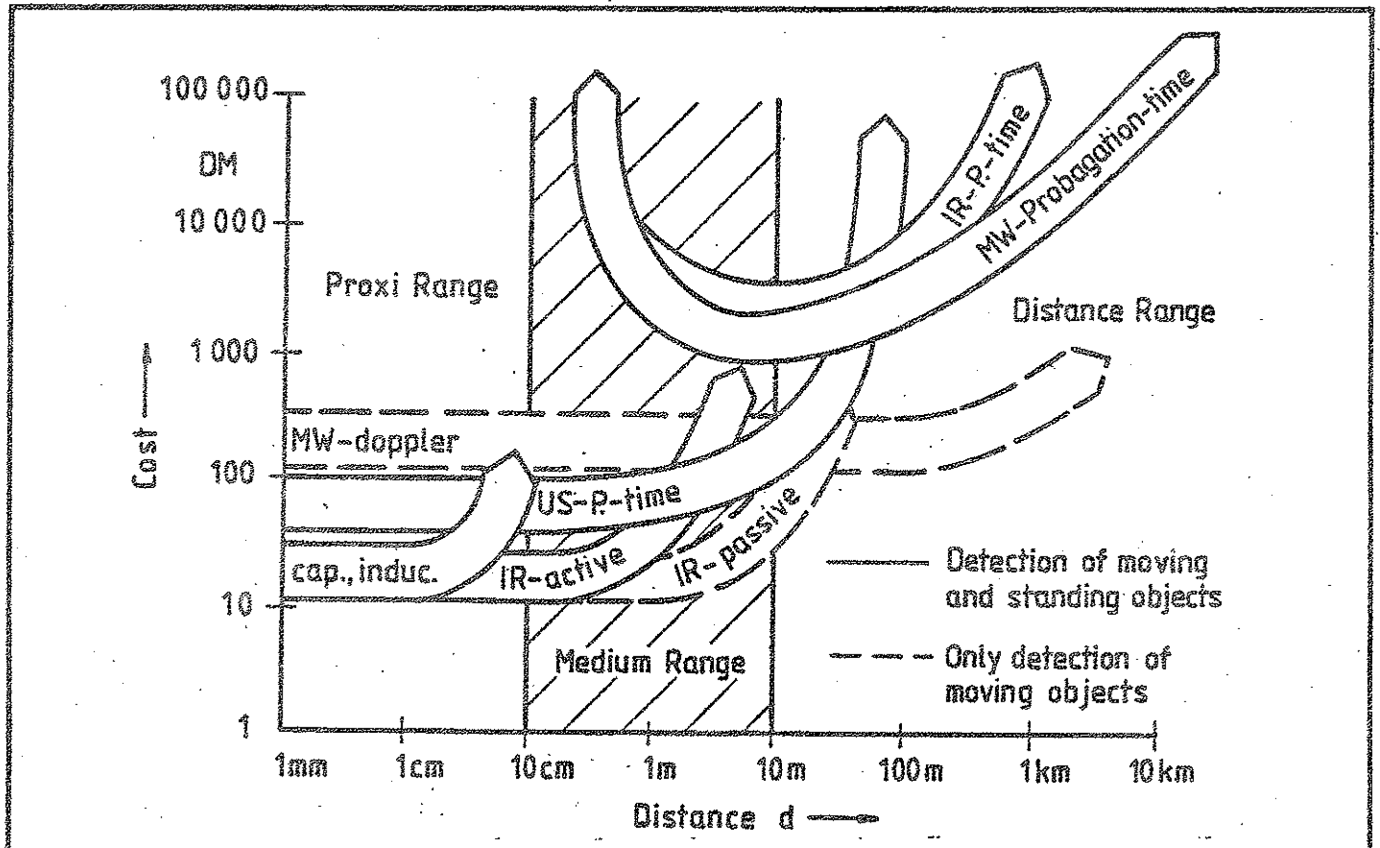
TU-Berlin LT-BM	Control-System	Bru 86 01

figure 10



TU-Berlin LT-BM	Measurement equipment for a crop spraying boom with height and positioning control system	Th/Bru-35 8508

figure 11



TU-Berlin LT - BM	Costs and measurement ranges of distance sensors	Th/Bru 35 8510

figure 12

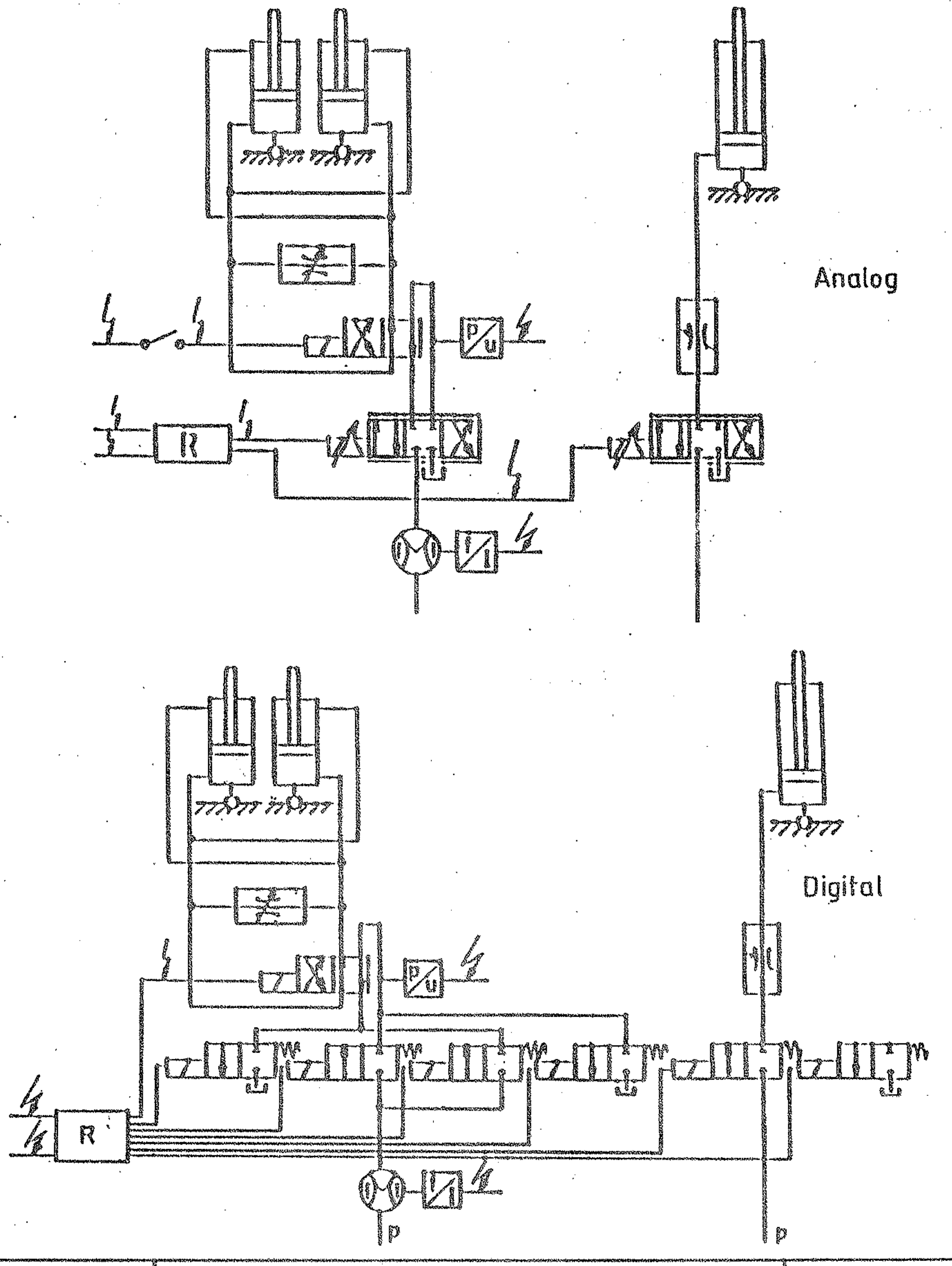


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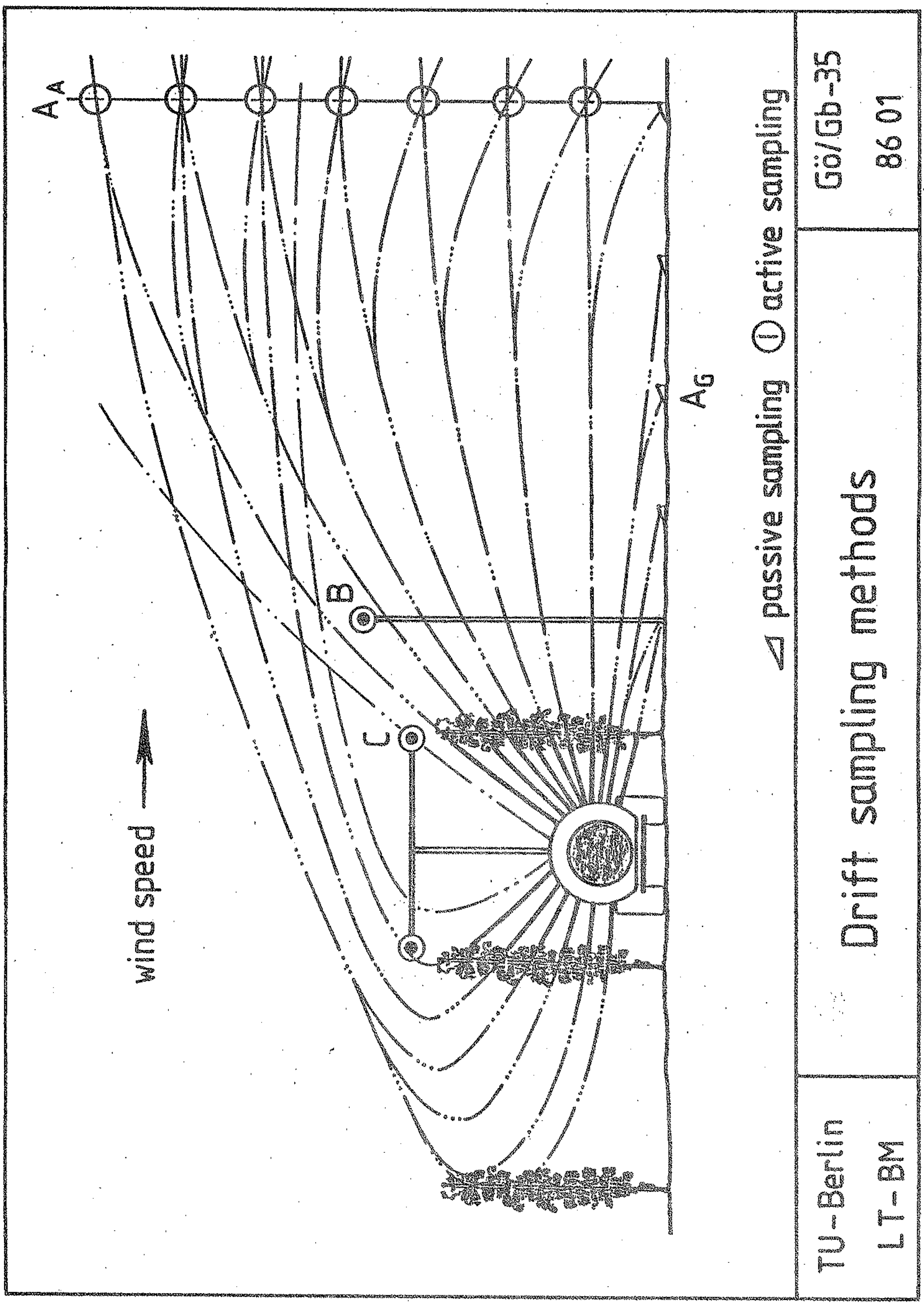
Figure 13



Drift sampling methods

A WEATHER INFORMATION SYSTEM FOR AGRICULTURE - FUTURE POSSIBILITIES

ERIK LILJAS

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1. INTRODUCTION

Agriculture is often considered as the most weather sensitive sector of the society in Sweden. Almost all activities undertaken by farmers are sensitive to weather. An increased weather information sensitivity is realized in combination with the technical development of farm management. Accurate forecasts for the next few hours and the day therefore is an essential prerequisite for effective decisions to minimize damage and to avoid wasted time and abortive efforts. In daily plannings and decisions also forecasts for 2-7 days are crucial for the quality, the quantity, the costs of labour, machinery, fuel and drying.

In order to meet the needs of weather information form a rapidly changing society and to use the possibilities offered by modern technology and science, a concept of a new weather information system for Sweden was worked out at SMHI (Swedish Meteorological and Hydrological Institute). The concept was called PROMIS 90 (PRogram for an Operational Meteorological Informations System). The system shall meet the needs for weather information from all weather sensitive branches of the Swedish society. The demand for site specific tailored forecasts on several time scales put new demands on a system for observation, communication, data processing, presentation and dissemination.

Considerable improvements have taken place in 2-7 days forecasts the ten last years, and it has been possible to extend the range of useful forecasts by several days. SMHI has direct links to the European Centre for Medium range Weather Forecasts (ECMWF) with one of the most powerful computers in the world.

2. PROMIS - real time and short range forecasts

In order to test PROMIS and get complementary data for the design of PROMIS -90 a pilot project PROMIS-600 is built up around Norrköping. The data sources are:

- 2 doppler weather radars
- Satellite data receiving and processing system
- 40 automatic weather stations
- lightning location system
- conventional meteorological observations

The data sources will feed a central computer. Processed data in the form of integrated analyses will be available to the meteorologist on graphical and alphanumeric screens at his or her working position. Fig 1 shows the observation and presentation system of PROMIS-600.

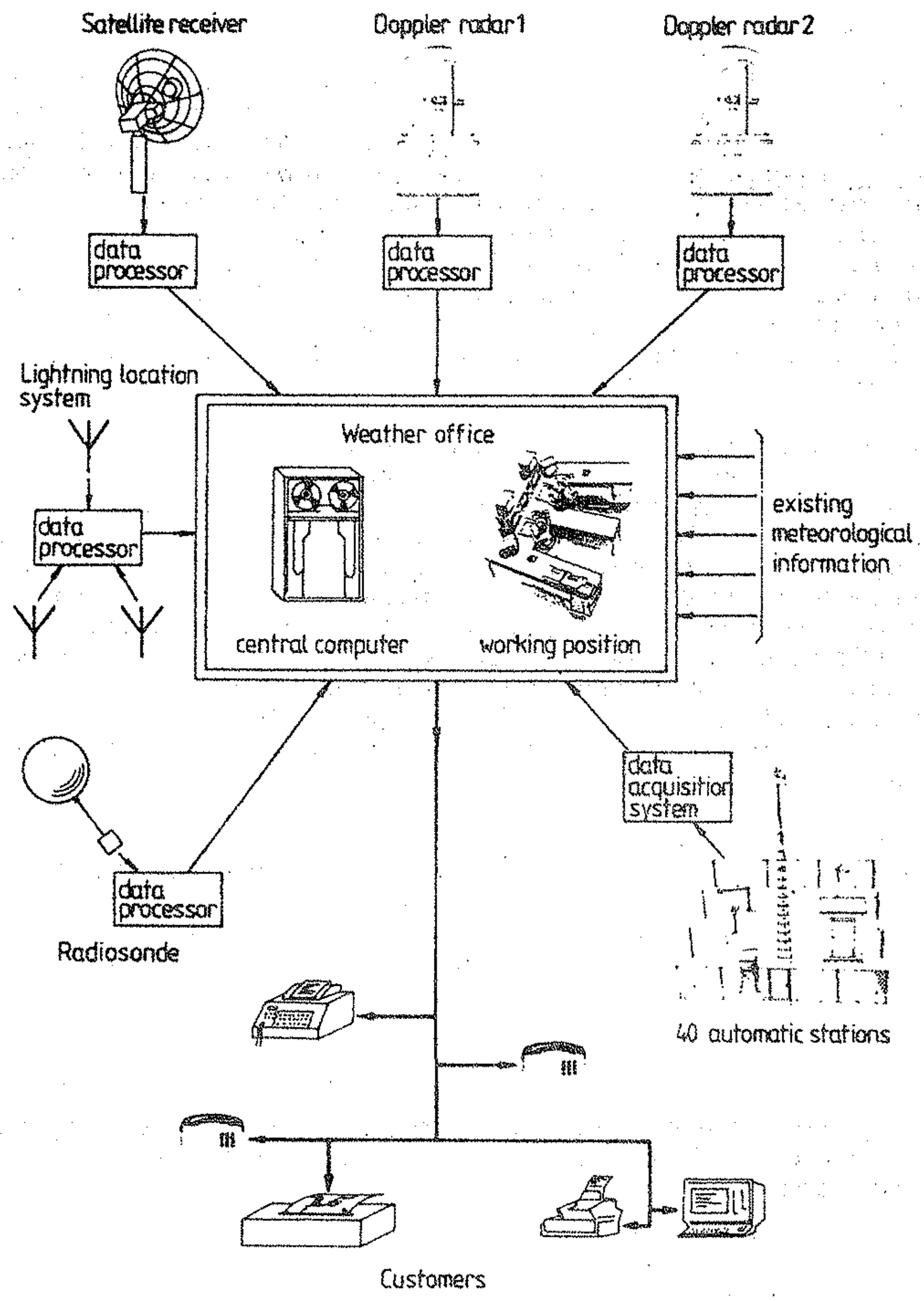


Figure 1 Observations, presentation and dissemination in PROMIS

2.1 Doppler weather radars

The first of two radars is now in operational use at SMHI in Norrköping. The radar can operate either in doppler mode or amplitude mode. The amplitude mode is used for the largest range (480 x 480 km area), while the doppler mode is used in shorter ranges. The doppler capicity makes it possible to exclude the ground clutter. The radar antenna makes two spiral scans (amplitude and doppler mode) each 15 minutes. The scannings are controlled by the radar data processor. The computer calculates precipitation and wind and loads the information into a three-dimensional memory. On command from the meteorologist the computer generates an image displayed on a colour monitor. Both horizontal and vertical sections are displayed on the meteorologist´s command. Time lapse sequences are often ordered to watch movement and evolution of precipitation systems.

2.2 The satellite systems

The satellite system will consist of an antenna/receiving system and a processing system. It will handle both high-resolution NOAA data and Meteosat data.

The processing system, PROSAT, will be installed this summer.

PROSAT will process data for different ares. The regional scale will use full resolution of data e.g. approximately 1 km, while the medium scale images will be presented with a resolution of 8 km respectively 4 km, and cover Europe and the north-western Atlantic.

The images will be user-oriented to make possible a quick reception of important information. Multispectral analysis will be used, classification, calibration, registration, map transformation (polarsterographic projection) etc. After each reception of new data a set of predefined products will be made and available to the user (meteorologist) after a limited time.

The processed satellite images will show how rainsystems and cloud systems move and evolve on different scales from small showers to large low pressure cyclones. In the satellite system it is also possible to present ground temperatures and some vegetation and humidity indeces.

2.3 The automatic weather stations

A network of 40 automatic weather stations are soon established in the area inside the 120 km circle around Norrköping (see Fig 2). All stations will give information on temperature, humidity and wind. Some stations will in addition give information on precipitation, air pressure and radiation. Some few stations will be equipped with laser cloud height detectors and backscatter visibility sensors. Supplementary sensors will be possible to add in order to meet special agricultural needs. A layout of a fully equipped station is shown in Fig. 3.

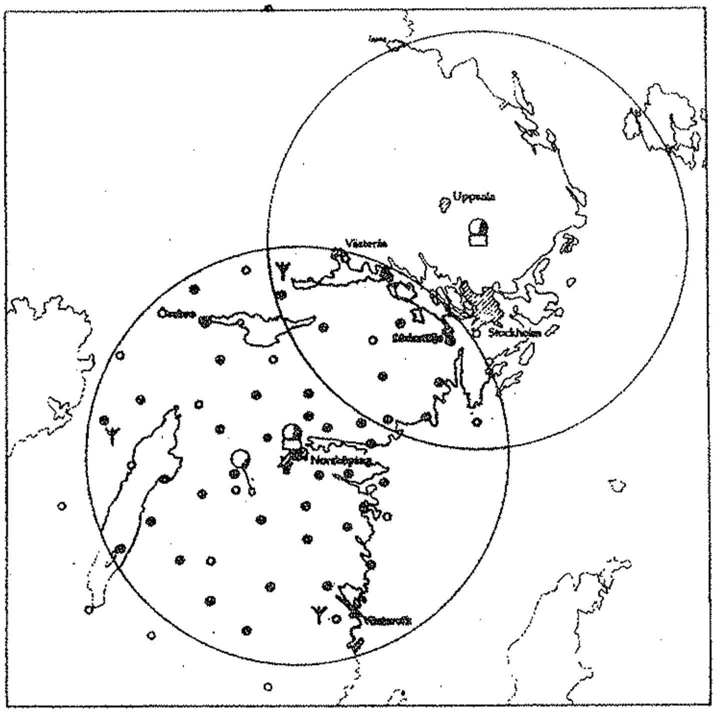
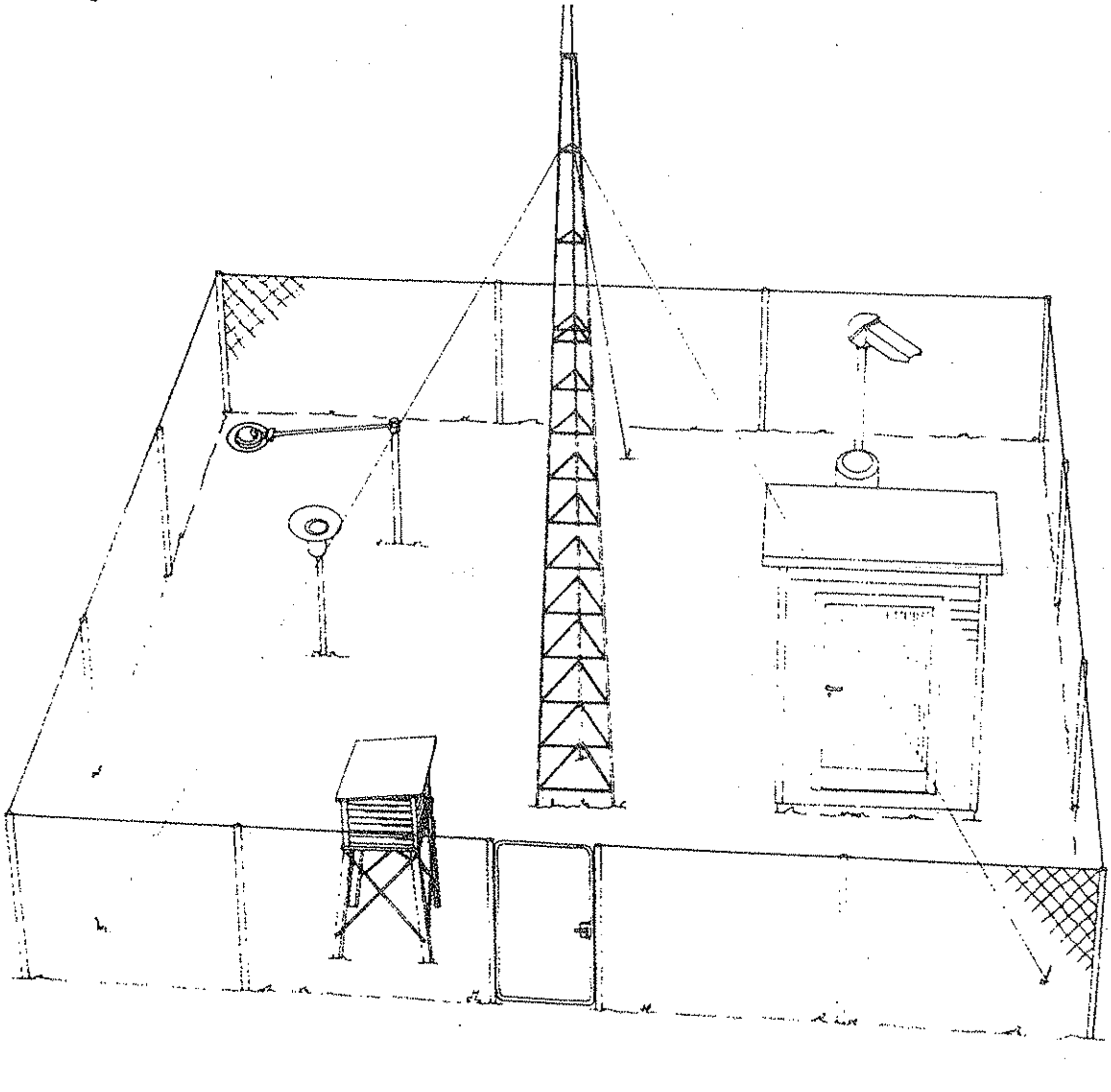


Figure 2 Automatic weather stations spread within the PROMIS-area

Figure 3 Automatic weather station



The stations have primary been spread evenly over the are but other reasons have also affected the locations, like requirements of weather data from large communities, from important highways, from main agricultural areas etc.

Data from the sensors will be collected and preprocessed locally by an automatic data acquisition terminal. They will be transmitted via telephone lines to the automatic data acquisition central in Norrköping and further on to the PROMIS 600 computer system. The acquisition frequence will be selectable with a maximal rate of data collection every 10 minutes.

2.4 Real time information and forecasts up to 12-24h.

The integrated information displayed on the PROMIS' colour screens is the diagnosis from which the forecaster makes his decision about weather in the very near future. The meteorologist's forecasts on rain, wind, cloudiness etc are supported by statistic and dynamic prognostic methods. The forecasts will have high resolution in time and space which means that large data volumes will be put on the line for dissemination to the end users.

3. ECMWF - medium range forecasts (2-10 days)

3.1 Development during 5 years operation ECMWF, daily called

The Centre, began operational forecasting 5 days per week in 1979 and extended to 7 days per week one year later. In 1983, the grid point model was replaced by a model using a spectral representation in the horizontal. Finally, in 1985, a very high resolution model, with spectral truncation extended to wavenumber 106, was introduced. (This is approximately equivalent to the resolution of a grid point model of 100 km resolution). A considerable improvement in forecasting skill has beeen achieved since 1979, as can be seen in Fig. 4, useful predictive skill has improved by somewhat over 2 days.

The Centre's computing capacity has grown to support the needs of research development. When operational forecasting commenced, the Centre had a Cray 1-A 'number cruncher' with a Cyber 175 as its front-end and sufficient room in the computer hall for a game of football (this space was never utilised!) In 1983 the Cray 1-A was replaced by a Cray X-MP/22 dual processor including a separate Input/Output Subsystem and Solid State Storage Device (SSD). This, in turn, was in December 1985 replaced by a Cray X-MP/48, a four processor model.

In telecommunications too, considerable progress has been made. When the dissemination of operational forecasts began, only seven Member States had telecommunication links to the Centre. Since, then, Member States have gradually implemented connections, so that currently all Member States are connected to the Centre and only three by low speed lines. The present Network Front-End Processor is in the process of being replaced by a new telecommunications system based on a cluster of VAX machines, which will provide considerably enhanched facilities for the Member States.

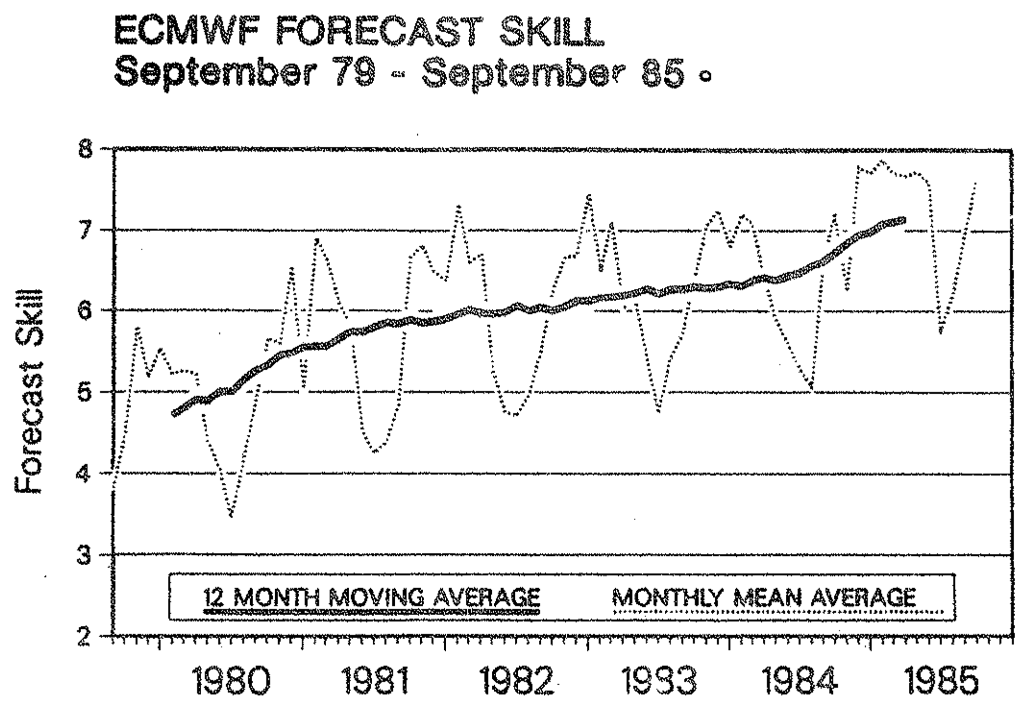


Figure 4 Development of skill in ECMWF forecast. Drops in skill occur in summer

3.2 The next ten years

By improving the accuracy of the way in which the forecasting model represents the atmosphere and by utilising ever more power computers to increase the resolution of the model, the Centre has achieved a considerable and continuing increase in the skill of the forecasts it produces; the present four day error is approxomately equivalent to the error seen a year ago for three day forecasts. However, studies have shown that the theoretical predictability of the atmosphere is greater than the present predictive skill of the Centre's model and so give justification and incentive for continued research. Below, a short summary of the Centre's plans for the future is given.

Observations

On fundamental element upon which accurate forecasts depend is the availability of sufficient and accurate observations, with a better coverage of currently data sparse areas, for instance, the oceans, the polar regions and the Tropics. Studies have suggested that if observational error were reduced by half, a gain of two days' predictability could be achieved over a ten day forecast period. The Centre will also be attempting to increase the amount of observational data it receives, such as data from vertical atmospheric sounders on board polar orbiting satellites.

Model improvement

The accuracy of the model's depiction of the atmosphere can be improved in some obvious ways. Numerical errors, caused by the fact that the equations used are only an approximation of reality, can be increasing the resolution of the model. A doubling of resolution would result in four times more grid points. However, with more dense grid points, the time taken for the atmospheric flow to move from one grid point to the next decrease, and therefore necessitates an increase in the frequency of the forecast time steps. If timesteps were reduced by half, this would result in a total of eight times more processing time.

4. PROFARM

A project called PROFARM has been worked out at SMHI the last two growing seasons. The objective of this project was to test new types of meteorological forecasts and dissemination methods that should meet new need from the customer and at the same time correspond to new possibilities at the weather service.
The preliminary results indicate that farmers are depended on both short and longer forecast.

Short range forecasts for the next few hours up to 12-18h are necessary at herbicide spraying. A rain some hours after a spraying operation spoils the achievment and leads to environmental demage. Short range forecasts of rain are important almost every day for the daily operations.
Long range forecasts with high quality of rain and other weather conditions can result in considerable savings from the beginning of the season from sowing time to haymaking and to the time of grain harvest and autumn sowing. If the harvest season is very unfavourable with steady wet weather or if the weather is very favourable with good drying conditions at the time when the quality is on the top, then the weather information is of less value.
New methods, technical, chemical and biological, have made the farmer partly less weather sensitive. The farmer, however, is more flexible due to better methods and systems to operate larger and bigger machinery.
This makes him more weather information sensitive. The farmers in the PROFARM project indicate that quantitative information will be more and more important in the future.
The uncertainty in the precipitation forecats should be treated in probability forecasts. With probability forecasts the farmer is able to optimize the economic result and he (or she) has a quantity adjusted to decisions. A automatic telephone answering system can provide a lot of valuable information if it is coded and the user notes the values in

SMHI V:8 50001211

PROFARM VIKBOLANDET

Tisdag 20/8 kl 1600

TID	VADER	SANNOLIKHET >0.1mm	>2mm	VADERTYP
08-11	x	x	x	x
11-14	x	x	x	x
14-17	Molnigt	10	5	Lok.skur
17-20	Molnigt	10	5	Lok.skur
20-02	Dimma	0	0	--
02-08	Dimma	0	0	--
08-14	Kortv.regn	50	30	Lok.regn
14-20	Molnigt	20	10	Lok.skur

Tag 9 för temp/vind.S

SMHI 50001212

PROFARM VIKBOLANDET

Tisdag 20/8 kl 1600

TID	TEMP	VIND	medel/max
08-11	x	x	x / x
11-14	x	x	x / x
14-17	18	V	3 / 5
17-20	17	Vx	2 / 3
20-02	15	SV	2 / 3
02-08	14	S	3 / 5
08-14	17	S	4 / 7
14-20	17	SV	5 / 8

FROSTRISK UNDER NATTEN 0 %

Tag 5 för femdygnsprog

Figure 5 Agrovision - distributed weather forecasts during the PROFARM-project. Five day forecast and irrigation information can be find on other pages in the VIDEOTEX.

special tables. Videotex is however a system that is capable of providing more specialized information to farmers with different or varying needs.Via Videotex the farmer is able to receive and communicate most information that is necessary in the farm management. Lantbruksdata AB has developed a farmer oriented Videotex-system called Agrovision. When this system has become more common and technically less vulnerable it will constitute a very useful system for data tranfer between meteorological service as well as other institutes and users. An example from a Videotex screen is given in Fig 5.

5. Summary

Technical, chemical and biological contributions to a modernized agricultural management is often not resulting in optimal results if the daily weather information is excluded. Weather information can be an important part in advice, controls and in the farmer's decision process if the information is formulated in quantitative terms. The weather service has in the near future many of the essential requirements for providing weather data with higher quality on different time and space sclaes and in a form suited to agriculture. For economical, quality, environmental reasons in future farming, good cooperation between Meteorological Instutute and Agricultural Research Centres are a pre-requisite.

DISCUSSION, SECTION 1

Henning Nielsen

As an electronic engineer you meet this problem: When a mechanical engineer have a trouble he very often go to the electronic engineer and says: "Do you have some device to solve my problem?" Very often I have to say no, don't use it - go back and try a mechanical solution. I think it is very important to know if you can get an electronic solution but in many cases when you know there is an electronic solution you have to go back and find a mechanical solution. It is a great thing to realize.

Ove Berkefelt

To me the chip is just another way of solving a biological problem. I think you cannot take the step from a biological solution direct to a chip. You have to pass through a sort of development stage. You have to know what you want to do before you can put it into a chip and then if you know exactly what you want to do, it is a matter of one or two or possibly three million SEK to transform your solution into a chip. That might be alright in some cases where you need perhaps a very small instrument or if you have a big volume instrument, then it might be possible to do it. In other cases, I would say expecially in Sweden where we have a very small market and if you like the home market to be economical, then I think it is very difficult, but in some cases perhaps.

John Matthews

Could I just contribute that we are all aware that biotechnology and particularly the use of genetics engineering in improving plant resistance could require less treatment against fungus, against disease and so on. Also in thinking about the nutrition of plants that we have hopes that in a few decades there will perhaps be cereal plants which can produce there own nitrogen. I think the general feeling of the biologists at the moment is however that it is going to take rather longer then we all thought with a lot of excitement three years ago and I believe probably for the next two or three decades the electronic improvment of plant protection of nutrition is likely to be the more realistic one.

Björn Sundell

John Matthews was talking about how he should find methods to determine the actual need for plant nutrients. In Sweden we are trying to use the biological method to determine the need for nitrogen assuming that a high yield requires more fertilizer than a low yield. This is a project we are running between the Swedish Institute of Ag. Engng and the Department of Ag. Engng at the Swedish Univ. of Agr. Sci. We are trying to see what a high yield require when it comes to optimal fertilization rate in relation to what a lower yield require. And the technique we are investigating is that we measure the momentaneous yield when harvesting and record the yield together with the position of the combine in the field and then we try to relate the yield to the fertilizer requirement. At the moment we are working with fertilizer experiments to see how this connections is. Some experiments, especially for winter wheat, seem to support the idea pretty well, while it doesn't look that good at all when it comes to the spring planted crops. When we have done this conversion, we could distribute the fertilizer according to the fertility map we have been generating through the yield, and hopefully we get a more appropriate fertilization than if we just distribute a standard fertilization rate.

But there are still a few biological questions to straighten out. But we can say that instead of measuring the actual content of nitrogen in the soil we are so to say using the plant as a biological indicator. We are using the biological solution instead of some electronic in the first step of the process but then we need a lot of electronics to close the circuit.

Henning Nielsen

It seems that some companies making small devices or small electronic pieces of equipment are going for greater success at the moment than people making sophisticated solutions. The thing is that the farmer is very aware of the economy and therefore if there is one button too much on a box then he says it is too expensive for that purpose. He looks at the money and therefore a solution has to be a piecewise solution if you are going for a sophisticated solution like the mentioned closed loop solution about yield fertilizing and so on.

Per Almgren

I think that it is very important to analyze what the adequate question is when you try to find solutions. Often, when you try to get a solution you maybe do a suboptimization and I agree that it will probably turn out that environment and economics will be very much stressed in the future. Here we have a lot of discussion about increasing the yield but we know that we are already producing the amount we need. The problem may be that we shouldn't increase the production but we should produce what we need in a much cheaper and better way considering the environmental problems. I believe that electronics will play an important role considering the fact that we will be able to come up with some very sophisticated equipment that will not be so costly, and that we could tailor things in a cheap way to different requirements in the future.

Arne Hilmersen

For the discussions we have to distinguish between two major areas. The first concerns the engineering part where the technological possibilities are developed and described in general. The other concerns the application of suitable methods and the economic aspect. The solution chosen depends very much on the situation of the place in question. - In short we have to distinguish between the WHATS and the HOWS.

John Matthews

Could I make two points. We have carried out a certain amount of study on reduced inputs and the possibilities of using less fertilizer, less protecting chemicals and the effect on profit. It is quite clear that, with the current fixed costs; this is the value of land and the value of machinery; none of these things make sense for farmers as they are at the moment. One could, I suppose, argue that with land costs dropping and less prosperity in agriculture and, sad news for all of us, less being invested in machinery, the optima might come down a little in input and in yield. However, against that can I quote one example of the value of machinery in using the crop sprayer. I believe that if one can reduce the cost of spray chemicals by 10 %, by saving 10 % of the chemical quantity, even though if we double the cost of the spraying machine to achieve this better targeting, it will still benefit the farmer.

Now this is an encuraging thing. You may like to know that we carried out analyses on 8 projects spread right across the field deliberately choosen to be different. And we found in each of those 8 that the benefit-cost ratio to the farmer of higher sophistication was good. I will not quote them all now, it will go on too long, but can I say that with fattening pig, the provision, with additional fans and so on, of a better housing environment for the animals was worth 30 SEK per pig produced on top of the costs of the machinery. And that I think must show us all that we can still do a lot for farm economics.

We could reduce compaction by going faster, and hence by using lighter vehicles. The soil compacts less if you spend less time on each patch by moving across it. How much should we be designing mechanization systems for faster operation, and how fast could we reasonably aim?

Horst Göhlich

This is really a good question. I think we have to find other ways where we can reduce weight, at the same time we can increase the covered area and decrease the amount of passes, and therefore we need still better operations which will be better combined to each other and which will reduce the amount or the number of passes in any respect. This is a question of optimization and it might be a question of a better help for the decision. Decision when, at which time, and at which soil conditions, the best and most successful operation has to take place. And so far I think more information also for the farmer is needed from the biological side, from the technical side, from the meteorological side to have a help for the decision and for the most optimized way to do the job. From all sides we need more information I think.

Per Almgren

I think that quite a lot of information could be gained from using short range remote sensing. If you can apply some of many knowledge in doing some rough estimates, you could also get a good picture and have this handled with a computer and perhaps extract more information from it. This is an area that is developing very fast now, so I feel that resources would be well utilized in this, as well as other areas in the field.

Horst Göhlich

I would like to ask a question: Mr Matthews pointed out the system, the controlled traffic system, on the field. I think this is an area were we havn't discussed so far and I think I want to mention this point once more so that we have certain impressions out of the other people here, which way they suggest to go: wether controlled traffic is an aim or is a possibility for operations to reduce soil compaction as well as improve tillage. I think we already have some steps done for fertilizing and for spraying - this is the first step. To my impression I believe we have to think still more in this way; there are several types of solutions which doesn't seem to be worth while at the moment for further consideration. To a certain extent I believe such a development might be a good and promising way for the future.

John Matthews

We have been running some experiments in which we have compared three systems, each with ploughing and traditional, secondary cultivation and with direct drilling or minimum cultivation. One system is normal tractors and normal machines going anywhere. The second system is one in which all machines have very low tyre pressures, approximately 50 % of todays tyre pressures. (Nothing more than 0.4 atm.) The third systems has all machines going down the same routes and operating all processes from these same routes so that there are no wheelings over most of the soil.

Now certainly we are reducing power requirement very substantially on the controlled traffic system but the sad thing is that we are not reducing it at all on the second system with low tyre pressures. I do not know why but there is no power advantage. I stuck my neck out a year or two ago in a paper that I wrote about the mechanical farm of 2030, 50 years from now, and based it on gantry farming which has some good features. One can forecast that gantries could reduce tillage power by a factor of 8 or so by more shallow tillage, no furs to overcome, no soil compaction to overcome. Harvesting is the difficult area but there is now work going on in more than one country on different methods of harvesting, not collecting the straw, taking the ears off only. Suddenly it becomes easier to look at harvesting from a gantry and certainly in the U.K. there are one or two commercial gantries already in use in harvesting vegetables.

I mentioned during my talk one farmer on a cereals farm who runs a gantry. The Americans have 3 or 4 research gantries. The Israelis have them on the market. It's certainly something that is attracting the whole world as a possible solution to soil structural damage. And it is, of course, for electronics or for computer controller a much more stable work place from which to work than with tractors with all the dynamic movements that are inherent.

The whole process of automatic adjustment of more precis processing from a gantry, suddenly becomes a lot more appealing. Maybe this will justify some serious thought, but I don't believe gantries will start on cereals. I believe they will develop on high value crops, such as vegetables.

Henning Nielsen

About controlled traffic. According to my judgement tramlining is used in about half of the danish grain farming.

In my opinion it is so that if you are using this system of short range remote sensing as Per Almgren was referring to, using those ultrasonic level sensors (described by mr. Matthews) you can get some measure of tilth.

Björn Sundell

At Uppsala we have been looking at different sowing techniques. We have started with the knowledge we have got from our soil scientists. They want to have the seed evenly distributed at the moist bottom. They also want to have the plant nutrients evenly distributed a little bit below the fine soil close the seed. The straw they want to have on the top.

We have been trying to design a planter that does that job. It shuffles off some 2 inches of the soil, lifts the soil up, broadcasts the seed, goes down with the fertilizer in rows an inch below where you get the seeds, sorts the soil, puts it down again and compacts it a little. It is a little bit of a new concept for planting. At present we have a 3 m experiment machine that has been run for 2 years. When we are getting right with planting depths and moist and so on, it seems to be doing like 8-10 % above traditional planting. But so far we don't always come right. So far there is questions about what the preparation should be in advance. It seems like we shouldn't plough, we should have done some easy cultivation or maybe even out the soil a little.

Horst Göhlich

One point in order to improve fertilizer is connected with vibration. I just got some results from the company which is producing the common centrifugal fertilizer spreader. They told that they have experience from field and laboratory tests about the influence of spreader vibration on the accuracy of the distribution. The mounted spreader creates partly a deviation from its normal position that a suspension of the whole spreader might be recommendable. The questions is whether one should mount the spreader in such a way so that it is always kept leveled to the ground.

John Matthews

In my paper I tended to dismiss the recording of harvest yield as being too unreliable for deciding nutrient requirements for the next crop because of differences in drainage or in local soil conditions. But it was mentioned that experiments using harvest yield data to determine fertilizer needs are in progress. Am I wrong to ignore that? Is there a good chance that those experiments will show that the previous harvest yield is a useful indicator to variable fertilizer addition for the next crop or does it look unpromising?

Björn Sundell

Well so far the data are somewhat conflicting. For winter wheat for example it looks like the model works pretty well. But when we have been looking at experiments with barley we don't get as all as nice relationships as we have from winter wheat and that's messing upp our thoughts somewhat. At this moment we can't really say if the hypothesis is worth developing or not, so we are doing a kind of preliminary study to see if it works and then in the next step it's a matter of designing the necessary engineering for it.

Staffan Klensmeden

We have tried to monitor the application rate from a fertilizer distributor. The method was to put the hopper on load cells and then try to adjust for the vibrations by measuring the acceleration with a fifth load cell attached to a very well defined mass.

The problem is to get a high accuracy. You can reduce the influence of the vibrations by the factor of 20. That is not enough. The hopper weight is say 4 000 kg and after 100 m it's perhaps 3 900 kg. You should measure that mass 100 kg with the accuracy of let's say 1 % and that's

0.25 promille of full scale deflection, and that is very difficult to achieve even if you simultaneously measure the vibrations.

<u>Horst Göhlich</u>

When we are talking about spraying we mostly think of field sprayers. Field sprayers work today acceptable as long as they are applied properly and the nozzles are in the right set and the right shape. Improving spraying from the practical side of view and inspection of sprayers is advisable from time to time. In Germany we have quite a good inspection network already. It works still on a voluntary scale. 30 % of the farmers make use of these inspection services. On the other side there are orchard sprayers which are much more sensitive what drift is concerned. Therefore we have also to find ways to inspect or to control such sprayers. Developments are on the way which might provide a better control of the distribution of such air-sprayer. Distribution measurements are not easy because of the fact that we have a two face stream. The two face stream makes the complications, and that is the reason, why we don't have such a device so far. We just developed a collecting unit with special profiles already applied in the chemical industry for separating droplets out of an air stream. Such a technique may help the farmer on one side and the producer on the other side to develop and to adjust air-sprayers in a better way than it can be done today. There is another task, as I mentioned, to find ways of measuring the drift or drift failures of the sprayer. It doesn't make sense if we measure it after the job has been done or during the job. It has to be done at least in the beginning of a work and the farmer himself should be able to decide whether he can do the job or not. It is also important to convince the people from the legislation side that all efforts are done, in order to avoid any critical pollution by plant protection operations.

Wim Rossing

One problem is the distribution of the sprayer. Another problem is, that at the end of the field you have a rest of your spraying liquid. We inject the chemicals in the water flow so at the end of the field we have no rest. This flow is controlled by measuring the speed of the tractor and the pressure.

I also have a question to John Matthews and prof. Göhlich:
They are measuring the height of the end of the spraying boom but what to do with the movements in the direction of the tractor?

Per Almgren

For a special combination of the tractor and the sprayer you could do some sort of mathematical model and when you are driving you measure the air speed and tractor speed. With the model you can then do a rough calculation of where the particles will go and perhaps the pressure on the nozzles should also be measured. Another way would be to do something like the Swedish Met. Inst. are doing when they measure precipitation. They measure what's raining far away from the place where they have the measuring equipment, a radar doppler system, and it should be possible to do something like that. Maybe not with micro-waves but it might be done with ultrasonics. You get information from the different places about speed and directions from the measurement equipment, and this gives you a pretty good idea of as to where the droplets are going and you see how much that goes far away. This will need some research and developing work.

John Matthews

I agree that yaw vibration is something which is of next importance following height control. We have some records showing that the tip of the boom often travels backwards over the ground. I think that can be reduced considerably by a proper passive suspension of the boom against the tractor yawing and I don't think we have been convinced that an active suspension of that characteristic can quite pay for itself. If it could, one would have to use either an accelerometer or giroscope sensor. Unfortunately giros would be weighty, so accelerometers are probably the best, or perhaps doppler velocity meter on the boom could give the forward motion vibration response signal.

Spray drift: Electrostatics has now reached field machines and we have one commercially available from our developments. I think this has tremendous prospects. We can already prove that it certainly reduces spray drift. When it is based on a normal nozzle sprayer as ours is, it generates a droplet in which inertia is controlled by the pressure within the sprayer. Also the droplet attraction is controlled by charge on the droplet. Now I see that going much beyond the present single setting, is a system where you adjust the amount of charge or the amount of velocity and in fact tune the sprayer to the type of crop that you are spraying. Then it has real possibilities of saving spray chemical quantity.

How seriously should we be looking up weed detectors? Should we be considering selective spraying where we only spray where there are big patches of weeds, in response to electronic detection of the weeds. I could convince myself that the operator can see weed patches. Maybe we only need a range of switches to switch boom sections on and off. But there are others that say that we should be looking at weed detection.

Wim Rossing

Can I mention on this last point of John Matthews, image processing of weed detection. We have looked a little bit at it, but at this moment I think the problem is the speed of the equipment. I mean you must sense the weed spots and than processing the data batch. This technique must be possible in a certain time.

David Bruce

I can see that the weather information being transmitted directly to the farm computer could be of great use for controlling near ambient grain driers, where the drying process is going to depend on not only the weather that's occuring at the time but the optimum drying process is going to depend on the weather that's going to arrive in the next two hours or 24 hours. In that case the information being transmitted straight to the farm could then go into the drying controller and be used directly to optimize the process.

Arne Hilmersen

A question about the driver operation and data monitoring. Your paper was very interesting, Dr. Göhlich. I would like to ask you what should be left for the operator, for the human, in your opinion.

Horst Göhlich

Answer to Arne Hilmersen about what is left to do for the driver.

I think he has still a lot to observe and to do, having big machinery in front of and behind him. There is quite a few left for observing and maybe also for adjusting something.

The young modern farmer likes the full automation of a process. I think the final aim in mechanisation will always be full automation of the process. This will really help the farmer and the manager whatever he is doing in his job to fulfill his task in a better, more successful and more economical way. Information alone is not sufficient. The control circuit should be closed without the man as always as it is possible.

Per Almgren

One fact related to the process is that if you have a process control working too well, then the operator gets negatively affected from this and has nothing to do for very long periods of time. Then suddenly something happens. We might never get into quite that situation in the agricultural business but there is, I think, a sort of optimum. You should not leave almost everything to the automatic equipment - you must have something meaningful to do for the operator, otherwise it's better to have a system that is completely automatic with no operator at all. Just start it in the morning and then let it run for itself for the required time. Perhaps we can make much smaller equipment, lighter things and less compacting of the soil and so on.

Horst Göhlich

According to what Per Almgren was saying about totally automatic systems.

I don't agree. I ploughed with such a machine quite a bit and I asked the farmer what his impression is on this system. I think he has to do still enough to keep the whole thing running. He has to steer, observe the process and so on. It wouldn't bring him to a stage where he is getting tired maybe, and is closing his eys. He has still enough to do. This is actually a very important help for the farmer. It is not very complicated anymore to close the circuit in this particular field using full automated transmissions. And the farmer I think will appreciate it. I'm convinced that he will use it and that he will like it.

Frode Guul-Simonsen

Electronic equipment will give the driver som new possibilities. He can use automatic pilot-driving, he can save fuel and so on. He can put in the labour-price per hour and then the machine computes the optimal driving - not to save fuel but to save money per hour. There can be so many ways the farmer can make optimal driving. Therefor a combination of traditional and robot control of tractor is interesting for the future.

Hisamitsu Takai

I agree that full automatic or almost full automatic operations will contribute to give the farmer more economical production systems and creative life. But I still believe the poor or unskilled farmer is still poor and unskilled even if he get automatic equipment. Of course the farmer and those technical developments should go together, hand in hand. And, my question is how fast we shall develop this automatization. How fast the development shall be to progress.

Henning Nielsen

About driver information systems. Are they not in fact distracting the driver so he will look at his instruments and not at the field and other things which would be more necessary for a driver to do?

Data collection and weather information has to be put together in the farm computer. In that area we have in my opinion a very important point. It is the problem of standardisation of data transfer and I think it's a problem that can be taking up in the general discussion.

Lars Sjøflot

I thought that the program was designed so the human factor aspect should come in the last day.

I just find that this aspect have taken a lot of the time in the discussion today. And I will say I'm very happy about that. You have been talking about sub-optimal systems. I think that's most clear by the picture shown by professor Göhlich. He showed a picture with the title tractor-implement system. What he forgot was the really important part: the operator. Why not operator-tractor-implement system. I think that is just a kind of characteristic of the discussion here today. I hope we can systemize and get bit further on on Wednesday.

SECTION 2

MICROBIAL GROWTH IN FEED PRODUCTS
Analytical methods for identification and control

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Abstract

Developments and modifications of feed storage systems during the last decades have mainly focused on efficiency and economy of handling. These developments have resulted in systems with deficiences in biological function. For many of the new systems, unacceptable microbial growth can be frequently observed.

Experiences obtained over the last years during evaluation of different storage methods techniques, indicate a demand for analytical instruments to be used for relevant estimation of factors affecting microbial growth and limiting conditions for existing storage systems. One important area is the development of instruments to be used for measurement and modelling of extrinsic conditions affecting microbial activity. Another area is the development of analytical instruments for continuous measurement of biological activity in stored feeds. For this purpose the "head-space" technique would be a suitable scientific tool. This technique could be an important tool for evaluation of the safety of procedures for drying and dry conservation of grain and hays.

Introduction

After death, biological structures of animal and vegetable nature are subjected to a rapid microbial deterioriation. This fundamental recycling of nutrients is in conflict with the ambition of man to preserve food and feeds for later consumption. When proper storage conditions are not obtained, deterioriation restricts the availability of harvested products for animal feeding. The growth of microorganisms reduces the nutritional value and can lead to health hazards e.g.

mycotoxiosis, infections and respiratory allergies for animals as well as for humans (1, 2). Other complications are a heavy contamination of raw material for food production, which can cause problems in a subsequent processing or storage.

Basis for feed storage

Throughout the ages, man has learned by trial and error to exploit different methods to preserve his food and feed products. Within the feed area drying has been the main preservation method, but examples are also available on (an ancient) storage of wet grains in underground-pits by Indians in South America and by the Egyptians many centuries ago.

Drying. The growth of microorganisms demands the presence of water in an available form. Some of the water molecules present in a feed are associated with soluble molecules while others become adsorbed onto insoluble feed constituents. This restricts the availability of water for microbial growth. The most useful measurement of the availability is water activity (a_w), which is related to the equilibrium relative humidity of a product.

$$\frac{\text{Relative humidity at equlibrium}}{100} = a_w$$

Various products with identical water contents usually differ in a_w. To obtain information on the relation between a_w and water contents, a water sorbtion isotherm is plotted. The isotherm obtained on adsorbtion of water differs from that obtained by drying. This effect is termed hysterisis, and shows that a_w for a drying product is lower compared to a wetting product at identical water content.

The demand of water differs among microorganisms. Water activity in a product governs the selection of organisms able to grow under the prevailing situation. Generally, moulds and yeasts survive at a low water activity, while bacteria need higher water activities.

Airtight storage. Obligate aerobic organisms need oxygen as an electron acceptor. Airtight storage is mainly based on depletion of oxygen that prevents the growth of moulds. Deteriorative bacteria are inhibited by a relatively low water activity. Anaerobic conditions are obtained by an initial respiration of grains or hay in sealed containers which reduces the oxygen content. At a later stage harmless facultative organisms will respire the oxygen. Moulds are generally prevented, but it should be observed that some mycotoxinogenic strains might grow at reduced oxygen tensions (3).

Acids. The effect of organic and inorganic acids as preservatives is partly based on pH reduction. At low pH the protons (H^+) restrain transportation through microbial membranes. However, microbes are usually rather resistant to low pH levels. It is generally accepted that it is the undissociated molecule of the organic acids which penetrates the membranes and lowers the internal pH (4). That means that there is a correlation between pH, pKa and concentration of acids used as preservatives.

Silages. Successful ensilage of forage depends on the absence of oxygen, in combintion with a low pH. The main concern in an ensiling process is to favour the growth of lactic acid bacteria while restricting the growth of other bacteria. Yeasts and moulds are prevented by anaerobic conditions, since they are generally insensitive to low pH in aerobic conditions.

Chilling. Chilling retards enzymatic activities and thereby causes a decrease in biological activity of spoilage organisms. Low temperatures have an important selective action and affect the composition of the contamining microflora towards psychrotrophs during storage. Scandinavian climate conditions indicate that chilling is an important method for preservation during the winter season irrespective of storage method.

Chemicals. The use of chemical preservatives is often a technically very convenient way to achieve storage stability. Biologists are, however, rather ambivalent to their uses because of the toxicity of the substances. Sensitivity to chemicals vary, and some organisms tolerate higher concentrations than others. This aspect has generally not been taken into consideration when evaluating different preservatives. Microorganisms can also be adapted to increasing concentrations of preservatives during growth.

Synergistic effects. In several situations synergistic effects of preserving properties can be observed. The sensitivity to reduced water-activity is more obvious at low temperatures than at high. Similar effects are also observed for acidification, which affects facultative anaerobes more strongly in anaerobic than aerobic conditions.

Microorganisms

The microbiology of feed products is mainly a result of the selectivity of the environment. Deterioration is caused by bacteria as well as fungi. Generally yeasts and moulds are more common in dry conditions and bacteria in wet.

Bacteria and fungi involved in deterioration of feed belong to a restricted number of genera and are reported in table 1.

Aspects on storage methods

During the last years, much effort has been focused on identifying problems in storage systems of animal feeds used in Sweden.

Hay storage. Hygienic quality of hay depends on climate conditions during harvest and intake. Slow field drying always reduces the quality. The effect of preservative chemicals is restricted. Artificial drying is the only recommendable method for hay preservation. Baling directly after wilting without additional artificial drying often causes severe mould problems (5, 6).

Grains. As with hay storage, quality of grains are first affected in the field. Later, climatic conditions may restrict the drying capacity in cold driers. Mycotoxin production can be the result (7). During the last year, aflatoxin production in formic acid treated grains have been observed. A change in the composition of the additive and a high variation in water content among kernels seems to be two reasons behind these findings.

Under Swedish conditions, airtight storage generally prevents the growth of moulds from harvest to late spring. Initially anaerobic conditions are obtained; later the low temperature during winter is the main preserving factor. Inlet of oxygen during winter, in combination with a lack of biological activity to consume this oxygen, restricts the ideal function of the system. In late springtime or at the beginning of summer a rapid growth of moulds is observed (8).

Silage fermentation. Basis for a proper silage fermentation is a rapid initial acidification by the activity of lactic acid bacteria, sometimes in combination with the addition of acids. Conditions mainly supporting silage quality are affected by additives, low oxygen tension, and high sugar content. Rapid fermentation prevents the growth of enterobacteria and clostridia. Air leakage during storage supports aerobic metabolic activities by yeasts on sugars and lactic acid. This activity is involved in aerobic heating and in a reduction of preserving properties. Other conditions affecting aerobic deterioriation are quality of plastic covers, wall-construction, wilting, slow filling and use of big bales (9, 10, 11).

Demand of knowledge

Several of today's preservation methods and storage systems frequently lead to deterioration of stored products since, in many cases, the limitations of the systems are not clearly defined. A drawback in this connection is the lack of reliable methods for assaying microbial activity during storage of different feeds.

Because of variations in sensitivity to preserving conditions shown by different deteriorative organisms, more fundamental knowledge is needed to improve or increase the flexibility of existing storage systems. Conditions affecting feed spoilage and measurements for identification and quantification of microbial activities are summarized in Fig. 1.

Microbial identity and biological activity. Usually the evaluation of hygienic quality relys on sampling and on the enumeration and identification of the contaminating microflora. For estimation of fungal activity, this method is not reliable. Thus, heavily sporulating species will be overestimated and less abundantly sporulating species underestimated. There is a demand for methods capable of a more exact quantification of biological activities. For this purpose useful measurements for quantification are ATP and ergosterol contents. Chitin, another substance occurring in moulds is of secondary interest since this substance is also found in insects.

For many purposes indirect measurements of biological activities are attractive. In some systems, CO_2 can be used as an indication of biological activity. However, respiration occurring in the crop itself restricts the usefulness in several applications. In this case headspace technique would be a good alternative (12). By this technique, which depends on an evaluation in a gas-chromatograph attached to a mass spectrometer, "finger prints" can be obtained. These reflect the identity as well as activity of growing microorganisms.

Areas for collaborative work. In order to understand the limitations for a proper preservation in relation to the diversified flora of feed spoilage microorganisms, instruments for reliable evaluations are required. Factors like a_w, ERH, pH, temperature and oxygen affect preserving conditions for different storage systems. Modelling of measurements obtained from pilot experiments could be an important tool for this purpose.

Another area is the development of instruments to be used for continuous evaluation of identity and activity of microorganisms in storage systems. These can inititally be used in order to observe characteristic metabolites during controlled conditions in pilot systems. Later the conditions affecting microbial spoilage during full scale artificial drying and during storage of dry and semi-moist feed products like hay and airtight-stored grains can be more satisfactorily controlled.

Equipment for application of additives (acids, inoculants and enzymes) and methods for assessing the distribution are other fields where technical development is needed.

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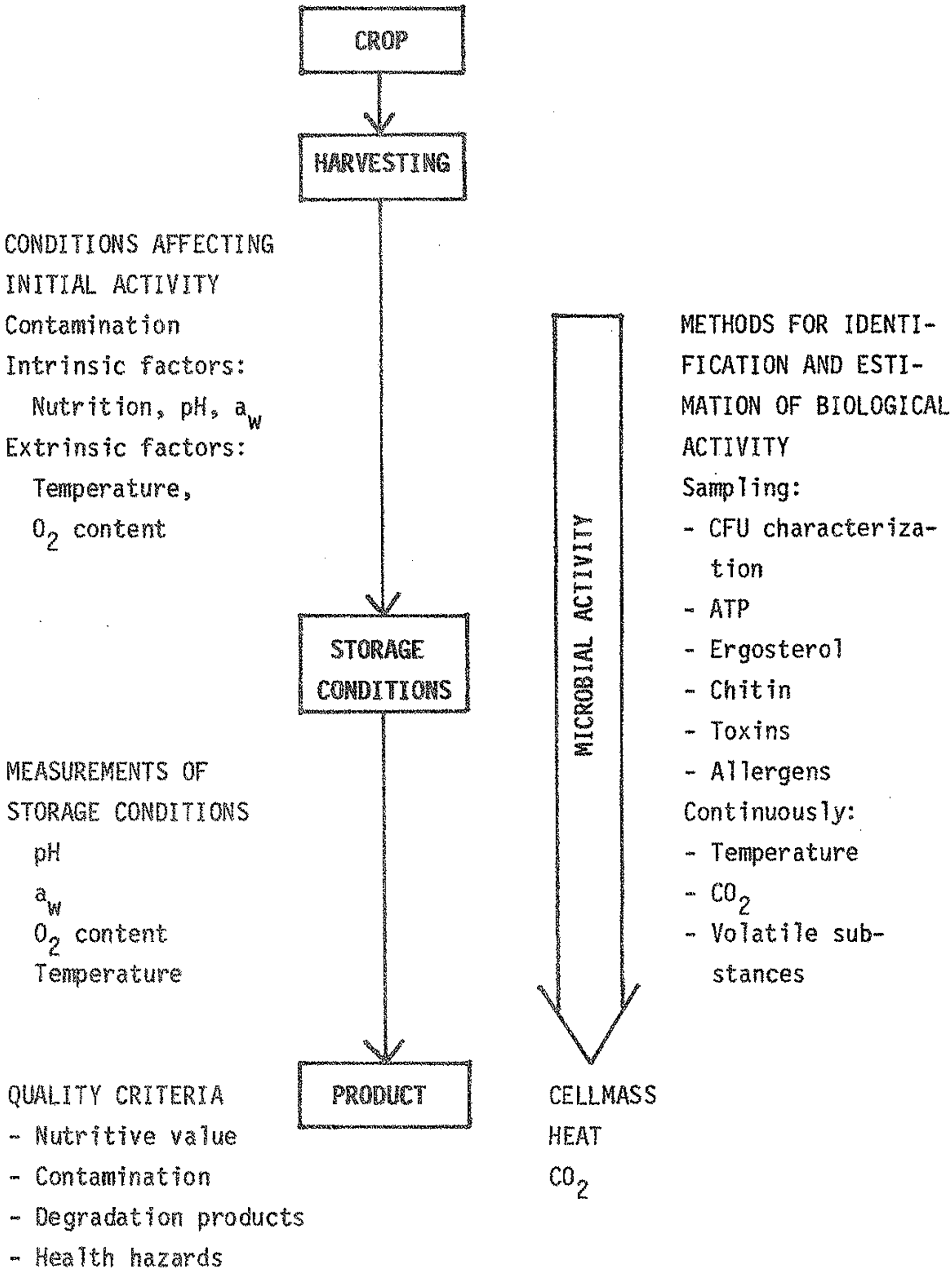
TABLE 1. Characteristics of spoilage organisms in stored feed products.

Organisms	Spoilage symptoms	Growth-limiting conditions
Bacteria		
Enterobacteria (Facultative anaerobes) Escherichia Citrobacter Klebsiella Salmonella	Endotoxins, NH_3, amines proteolytic activity. Some strains are infective or enterotoxic.	pH <4.4-4.5 a_w <0.95 Temp <0-8°C
Clostridia (Strict anaerobic) Saccarolytic	Spores and butyric acid in silages and cheese. $H_2 + CO_2$ in cheese.	pH <4.2-4.5 a_w <0.95 Temp <10°C
Proteolytic	Proteolytic activity. NH_3 and amines in silages.	pH <4.7-5.0 a_w <0.95-0.97 Temp <10°C
Bacillus (Facultative to strict aerobes	Spores, heat in silages and wet hay. Bitter taste in milk, B. cereus-toxin.	pH <4.5-5.0 a_w <0.93-0.95 Temp <0-5°C
Streptomyces (Strict aerobes)	Allergy causing.	pH <5.0 a_w <0.92 Temp <0°C
Fungi		
Yeasts (Aerobic and facultatives)	Assimilation of lactic acid. Heat production in silages.	pH <2.0 a_w <0.62-0.85 Temp <0-5°C
Moulds (Aerobes)		
Field fungi: Cladosporium Alternaria Fusarium	Allergy causing spores. Mycotoxins	pH <2.0 a_w <0.85-0.90 Temp <0°C
Storage fungi: Penicillium Aspergillus	Allergy causing spores. Mycotoxins Infections	pH <2.0 a_w <0.65-0.80 Temp <0-5°C

Figure 1. Factors affecting microbial deterioration of feed, and methods for their estimation.



Preservation of grain by aeration - computer simulation

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Introduction

The temperature and moisture contents of grain harvested in Denmark are normally too high for safe storage without drying or other kinds of preservation. However, drying is costly, and besides the drying capacity often is too small to keep up with the capacity of the combiners. Therefore, a great part of the grain crop having a rather high moisture content is stored for shorter or longer periods. Most of this is stored in large ventilated grain stores, about 15 % at farms in airtight silos, and - especially in wet harvest seasons - appreciable amounts without any preservation at all.

In the following, the problems concerning respiration, spontaneous heating, deterioration and dry matter loss in stored grain will be discussed. A mathematical model for respiration rate will be presented. Design and control of ventilated grain stores and in-bin drying systems will be discussed in connection with drying and cooling patterns.

Respiration and deterioration of grain

Grain is live seeds and is infected with microorganisms, insects and mites. The respiration of all these organisms gives rise to dry matter loss, oxygen consumption, evolution of carbon dioxide and moisture, spontaneous heating and deterioration of the grain (Fig. 1). The respiration rate is mainly dependent on moisture and temperature (Fig. 2).

The respiration from insects is only to a lesser degree influenced by moisture in the grain, but cooling to below 17 °C greatly reduces the activity of the pests. Many insects survive at low temperatures - even at freezing temperatures - but their metabolism is slowed down to a magnitude almost eliminating the risk of "hot spots" in the grain caused by insect activity.

The respiration from mites is normally negligible, but in some years the grain may be heavily infested with mites. Then chilling is no effective means to prevent deterioration of the grain. Drying to below 14 % moisture, high temperature treatment, airtight storage or winnowing of the grain are better alternatives.

Mold is the principal cause of respiration, spontaneous heating and deterioration in grain. The growth of mold is very dependent on moisture, but can also be reduced by chilling. Figure 3 shows the lower limit of water activity for growth of different microbes being common in grain. The damages caused by fungi comprise unpleasant taste and odor, decreased germination, dry matter loss and in some instances formation of toxic metabolites - mycotoxins. Infection of grain with toxin-producing fungi without any mycotoxins is often encountered. The optimum conditions for growth are often different from those of toxin-formation (Fig. 4).

Heat and moisture are generated by respiration from mold and pests, and fungal heating is then an accelerating process. The heating rate in dependence on moisture and temperature is an important factor for an appropriate design of aeration and in-bin drying systems. The respiration rate of barley and rapeseed samples at different moisture contents (15-26 and 9-20 %, respectively) and different temperatures (10-39 and 10-35 °C, respectively) was determined experimentally using the apparatus outlined in Figure 5.

Based on the experimental results on oxygen consumption and carbon dioxide formation, different mathematical models were tested by statistical regression analyses. The best adoption was found for a model, which showed an exponential increase in the respiration rate with water activity and a proportional increase with temperature (Fig. 6-7). Oxygen consumption can be converted into heat generation, rise in grain temperature and dry matter loss using the factors 450 kJ per Mole oxygen, 2.2 MJ per ton barley per °C and 20.5 g dry matter per Mole oxygen, respectively. Figure 8 is based on these factors and the experimental results on oxygen consumption including a safety factor of 2.9 corresponding to the dashed line in Figure 6. The Figure may be used to compare the drying and chilling effects, but then you must keep in mind that 10 °C of chilling by ventilation normally will reduce the moisture content by about 0.4 %. The respiration is dependent on several other factors than moisture and temperature - e.g. mold content. Therefore, the values read from the Figure may deviate as much as a factor 5-10 from the actual values.

Simulation of grain ventilation

In design and control of ventilated grain stores many factors have to be considered - air distribution, resistance of grain to air-flow, cooling time as affected by temperature and moisture of ambient air, spontaneous heating of the grain, condensation and absorption of moisture, etc. Proper experimental work is difficult and expensive. Then computer simulation is a valuable tool for improving the ventilation plants and the control systems. Biotechnical Institute has developed a mathematical model for simulation and transferred it to a computer program for a Wang MVP minicomputer.

When grain is ventilated, heat and moisture are exchanged between grain and air, and simultaneously the respiration produces heat and moisture (Fig. 9). The rate of temperature equalization is proportional to the temperature difference between air and grain and to the specific surface of the grain. The moisture exchange is proportional to the difference between the actual moisture content of the grain and the moisture content in equilibrium with the air. The rate of this exchange is temperature dependent. Heat and moisture from respiration are calculated using the developed mathematical model.

Based on these relations, differential equations can be made for each of the processes, and changes in temperature and moisture can be calculated for very thin grain layers and for very short periods (Brooker, D.B. et al., 1978). However, the processes are interdependent, and a general mathematical solution for deeper layers and longer periods is not possible. Numeric integration of the differential equations demands excessive computer power.

The problem is solved by an approximate integration of the differential equations for use on somewhat deeper grain layers and for a little longer periods. The integrated equations are then used for numeric integration, where the total grain volume is divided into about 100 elemental volumes, and the integration time corresponds to 800 times air exchange in the elemental volume. By this, the computer time is reduced to a reasonable time on the Wang 2200 MVP computer.

Laboratory experiments on chilling of barley were carried out using the apparatus outlined in Figure 10. The same experiments were then simulated and the experimental results were used for determination of rate constants for equalization of temperature and moisture in the simulation program. The experimental and simulated results are compared in Table 1 and Figure 11. Furthermore, the simulation program was validated to experimental results from a 10 ton, 5.7 m high grain silo (Fig. 12-13).

Design and control of ventilated grain stores

When air is passed through grain, the air movement is followed by a rather sharp cooling or heating front and a drying or absorption front. These fronts moves much slower than the air - e.g. if the air passes through the grain layer for one minute, the front of temperature change will pass in the course of about 13 hours, while the front of moisture transfer needs more than 100 hours.

By in-bin drying there is a maximum allowable drying time. Therefore, the air rate per ton grain shall be about ten times higher for in-bin drying systems (100-500 m^3/ton · hour) than for aeration systems (10-50 m^3/ton · hour). The design of the grain store and particularly the ventilation plant will be different for the two systems.

A typical aerated grain store in Denmark is about 1,000 m^2 and has a maximum grain depth of about 10 m. In these large stores it will be very expensive to keep effective inspection on temperature and local spontaneous heating. Usually, the temperature is only monitored at 10-20 places in the upper layers of the grain. A real need exists for a better and not too expensive technique for temperature monitoring in grain stores.

The ventilation is mostly controlled manually or by thermostates and in a few cases by hygrostates. Much more effective chilling and energy savings will be possible using computerized control technique.

By design of a control system, the following points may be considered. Excessive temperatures must be reduced to below 15 °C as quickly as possible, irrespective of air moisture. In all events, some drying too will occur, because, as a rule of thumb, the moisture content is reduced by 0.4 % for every 10 °C of chilling ventilation.

Subsequently, the grain is only ventilated when the air temperature is well below the maximum grain temperature and the relative humidity is below about 85 %. Besides, the wet-bulb temperature and the dewpoint of the air, compared to the lowest grain temperature near the ducts, must be considered in order to avoid condensation of moisture in the grain. This is a real hazard because grain expands by absorption of moisture, and the resistance against the air flow increases.

The consequences by using alternative control systems may be checked in a quick and cheap way using simulation instead of experiments. Proper computer programs are then a valuable tool for developing control systems for chilling and drying of grain.

Table 1. Experimental and simulated results on chilling of barley

Forsøg nr. Experiment no.	112	113	122	123	212	213	222	223	312	313	322	323
Byg, Barley												
Vand, % Moisture	16,2	15,9	16,4	15,3	18,4	18,5	18,9	18,6	22,0	22,6	21,8	22,3
Rumvægt, kg/m^3 Weight of volume	697	697	698	694	647	645	644	627	635	642	632	635
Starttemperatur, °C Initial temperature	19,9	18,9	46,5	38,8	22,2	20,1	38,5	39,6	22,6	19,9	41,5	37,0
Beluftning, Aeration												
m^3/(time · ton byg) m^3/(hour · ton barley)	21	35	25	47	22	51	18	44	26	38	22	48
Temperatur, °C Temperature	13	11	13	11	8	10	8	10	9	10	9	10
Relativ fugtighed, % Relative humidity	38	29	38	29	28	36	28	36	28	33	28	33
Byg efter beluftning, målt **Barley after aeration, experimental**												
Vand, % Moisture	15,8	15,4	14,2	14,2	17,1	17,9	16,5	16,9	20,6	21,5	20,3	19,6
Vægttab, % Loss of weight	0,67	0,49	1,80	1,23	1,15	0,94	1,78	1,77	0,98	1,08	1,85	2,02
Byg efter beluftning, simuleret **Barley after aeration, simulated**												
Vand, % Moisture	15,6	15,5	14,4	14,0	17,3	17,8	17,0	17,0	21,2	21,9	20,1	20,7
Vægttab, % Loss of weight	0,67	0,54	2,11	1,51	1,14	0,90	2,03	1,95	0,98	0,91	2,09	2,00

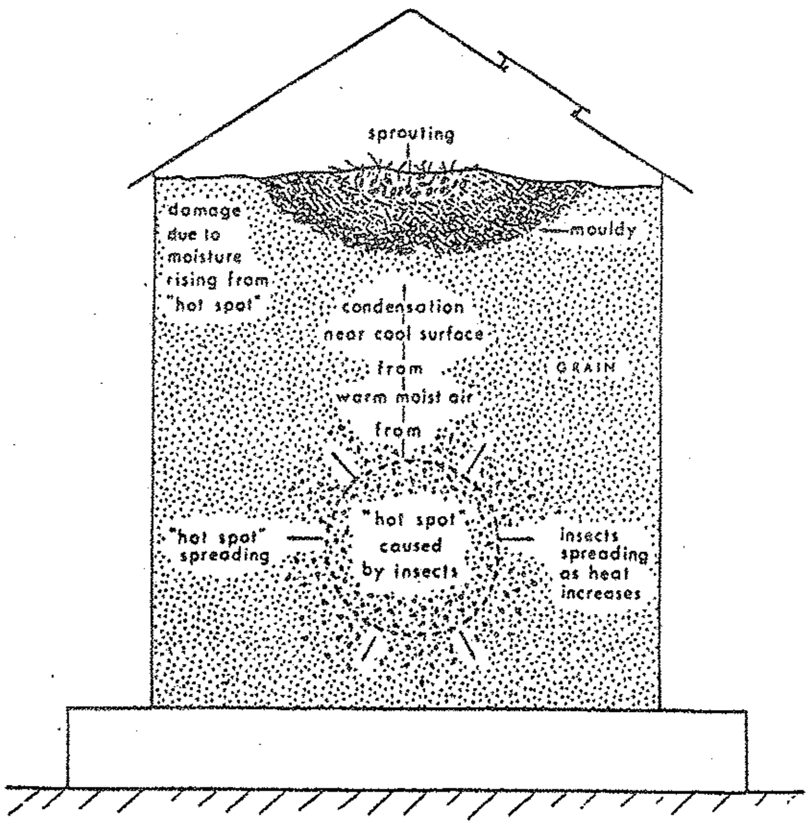

Figure 1. The results of grain heating caused by an insect infestation (British Crown Copyright).

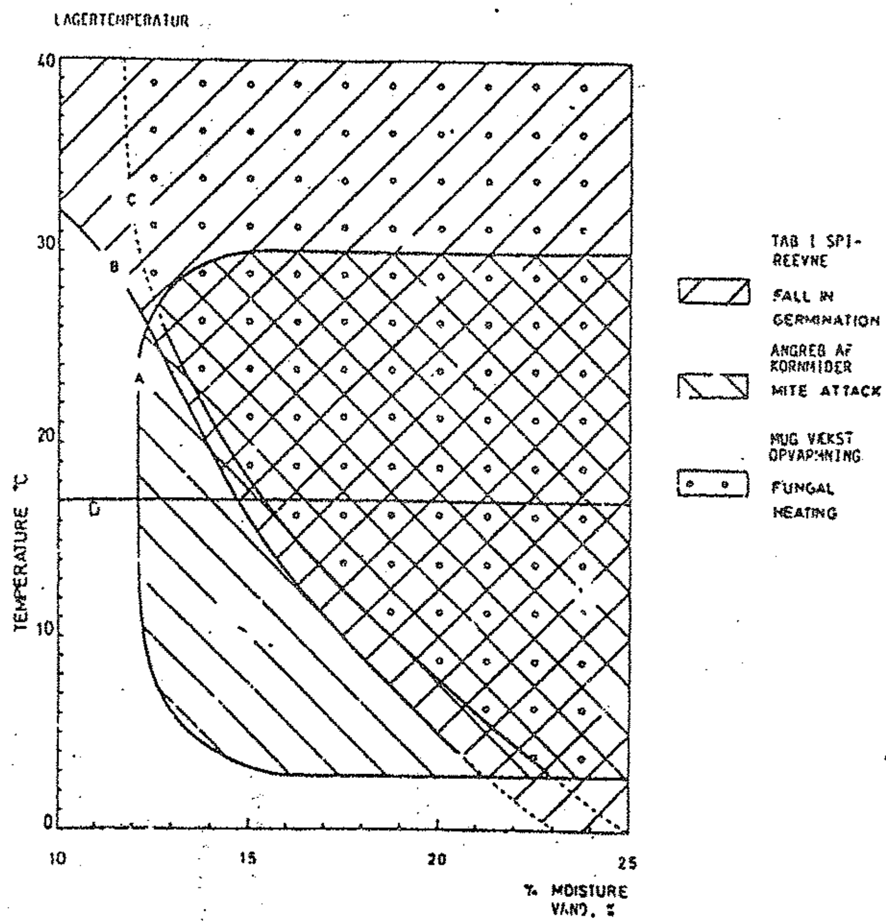

Figure 2. Relationship between storage temperature and moisture content in grain to insect heating (line D), fall in germination (to 95 % during 35 week's storage, line B), fungal heating (line C) and mite attack (line A). (According to Burges and Burrell, 1964).

Fungus	Minimum water activity for growth	Mycotoxin
Aspergillus		
restrictus	0.70	
ochraceus	0.75	Ochratoxin
flavus	0.80	Aflatoxin
parasiticus		Aflatoxin
versicolor		Sterigmatocystin
Penicilium		
viridicatum	0.85	Ochratoxin
		Citrinin
		Xanthomegnin
		Viomellin
citrinum		Citrinin
Fusarium	0.85	Zearalenone
		Vomitoxin
		Trichothecenes

Figure 3. Major storage fungi.

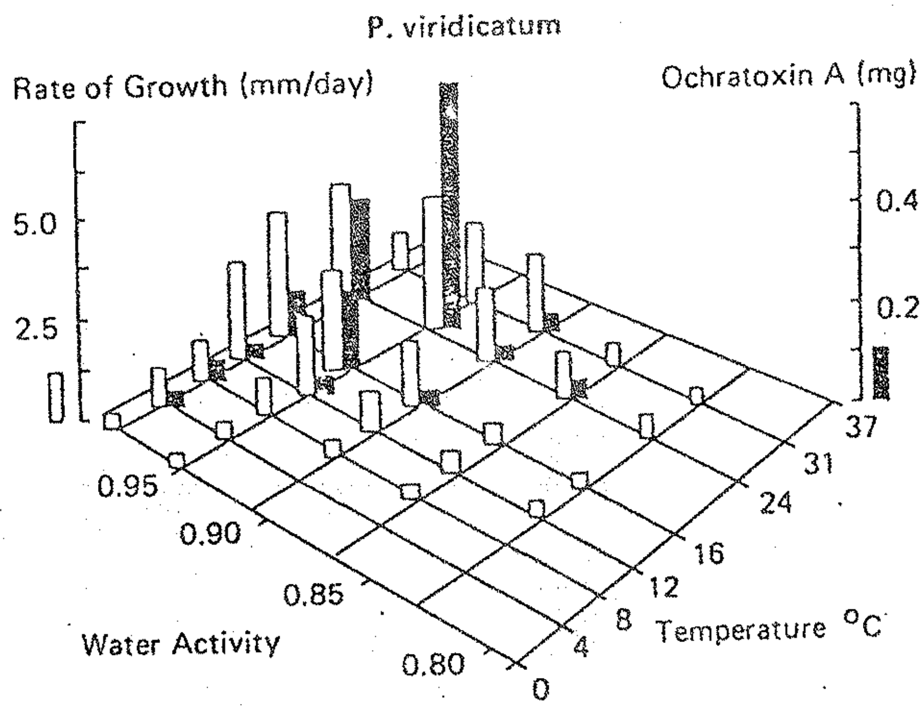

Figure 4. Growth and toxin-formation by P. viridicatum on Czapekagar. (According to Northolt et al., 1979).

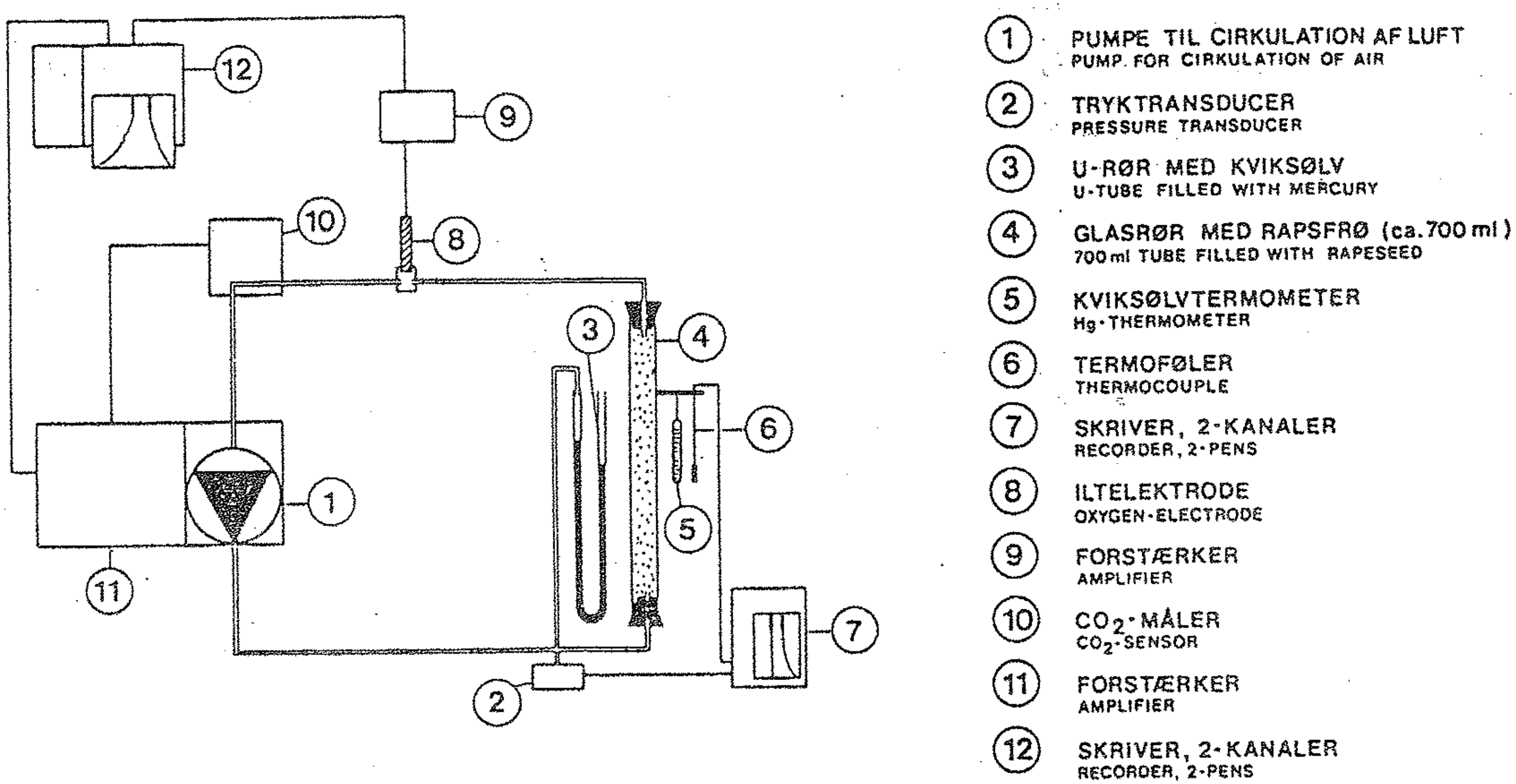

Figure 5. Apparatus used for respiration research in barley and rapeseed.

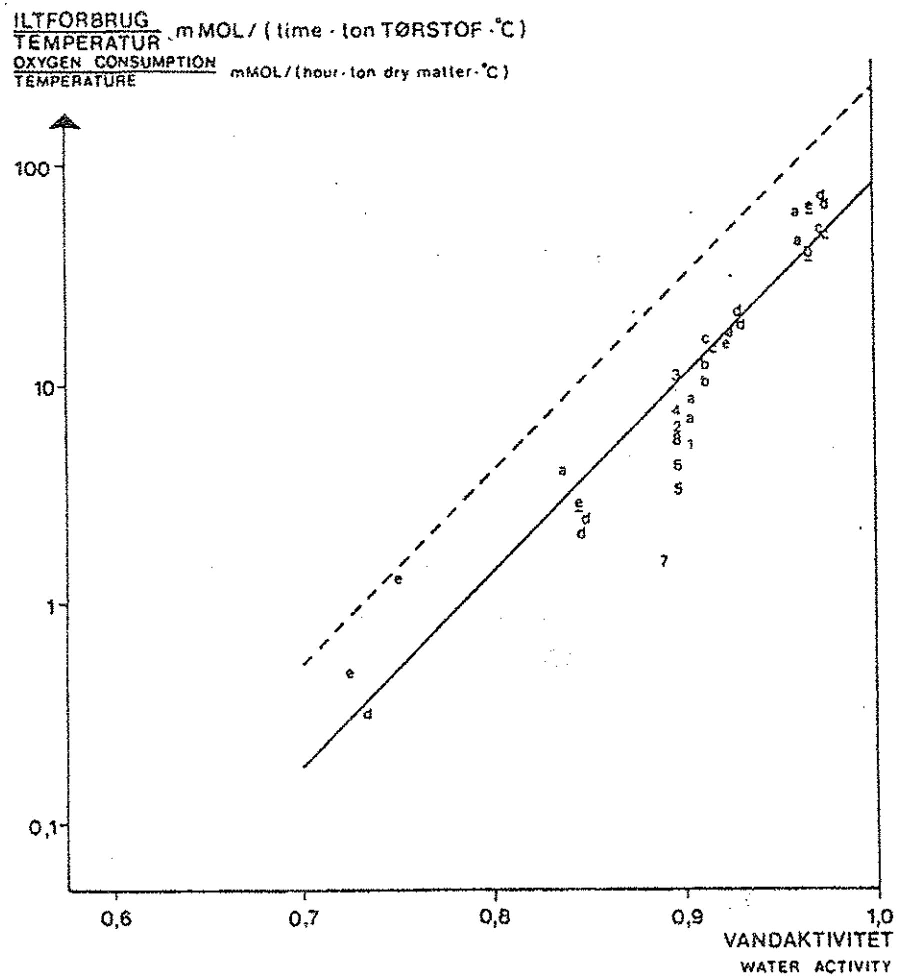

Figure 6. Experimental results on oxygen consumption by respiration from barley, adapted to the mathematical model: $\ln (O_2) = k_1 + \ln (\text{temp.}) + k_2 \cdot A_w$. (a: 10 °C, b: 17 °C, c: 24 °C, d: 30 °C, e: 39 °C).

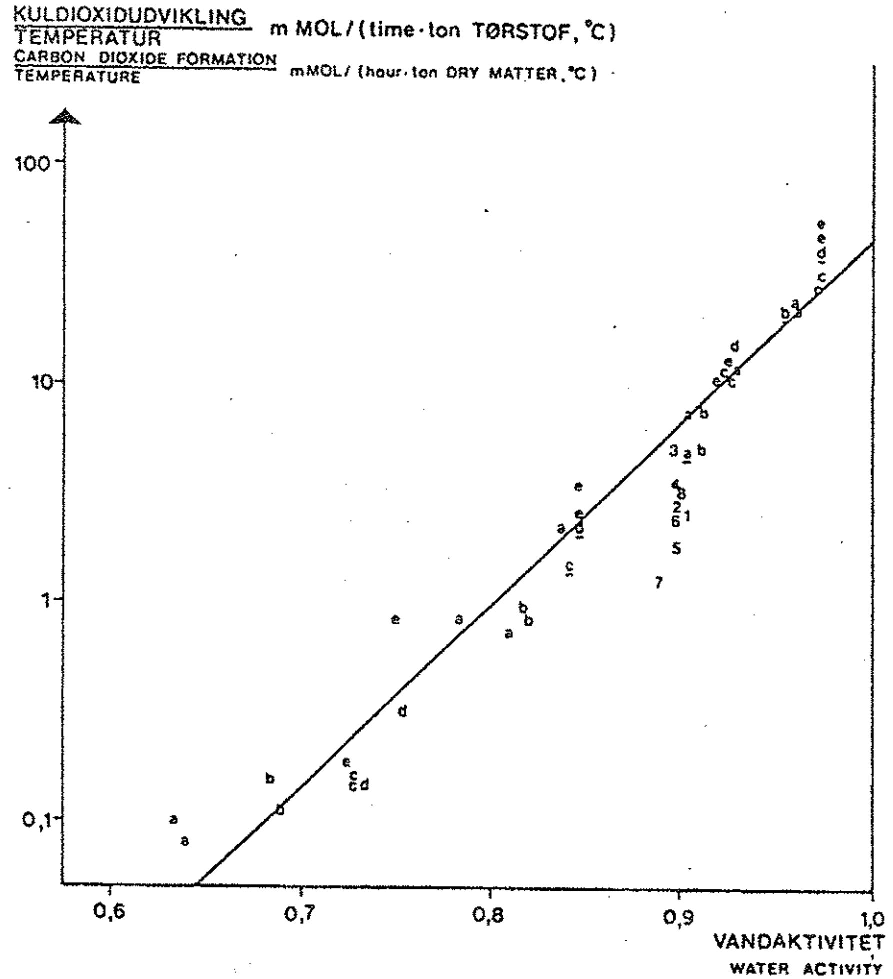

Figure 7. Experimental results on carbon dioxide formation by respiration from barley adapted to the mathematical model:
$\ln (CO_2) = k_1 + \ln (\text{temp.}) + k_2 \cdot A_w$.
(a: 10 °C , b: 17 °C, c: 24 °C, d: 30 °C, e: 39 °C.
The figures represent results from different varieties and lots of newly harvested barley.

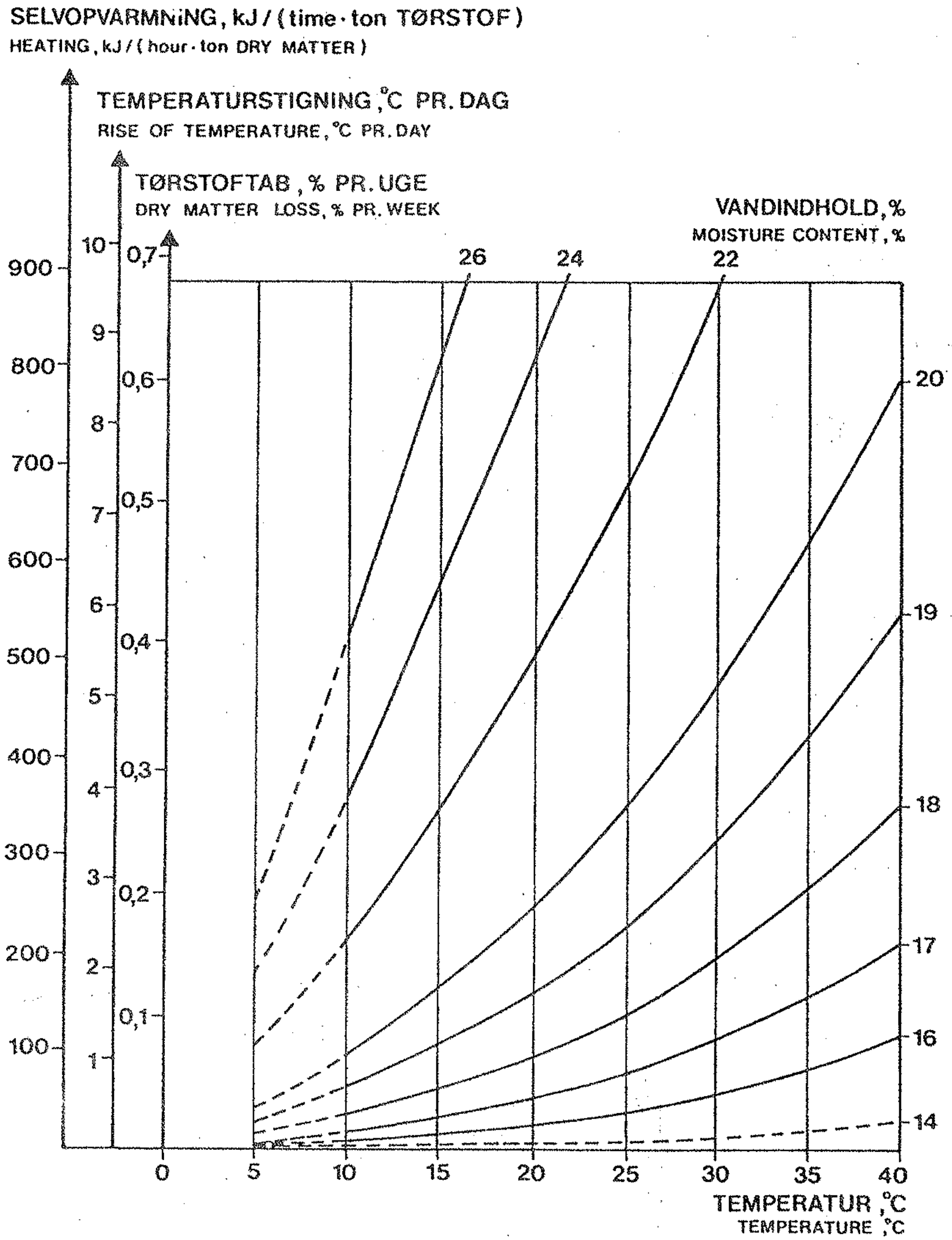

Figure 8. Spontaneous heating, rise of temperature and dry matter loss in barley based on experimental results on oxygen consumption by respiration (cf. Fig. 6).

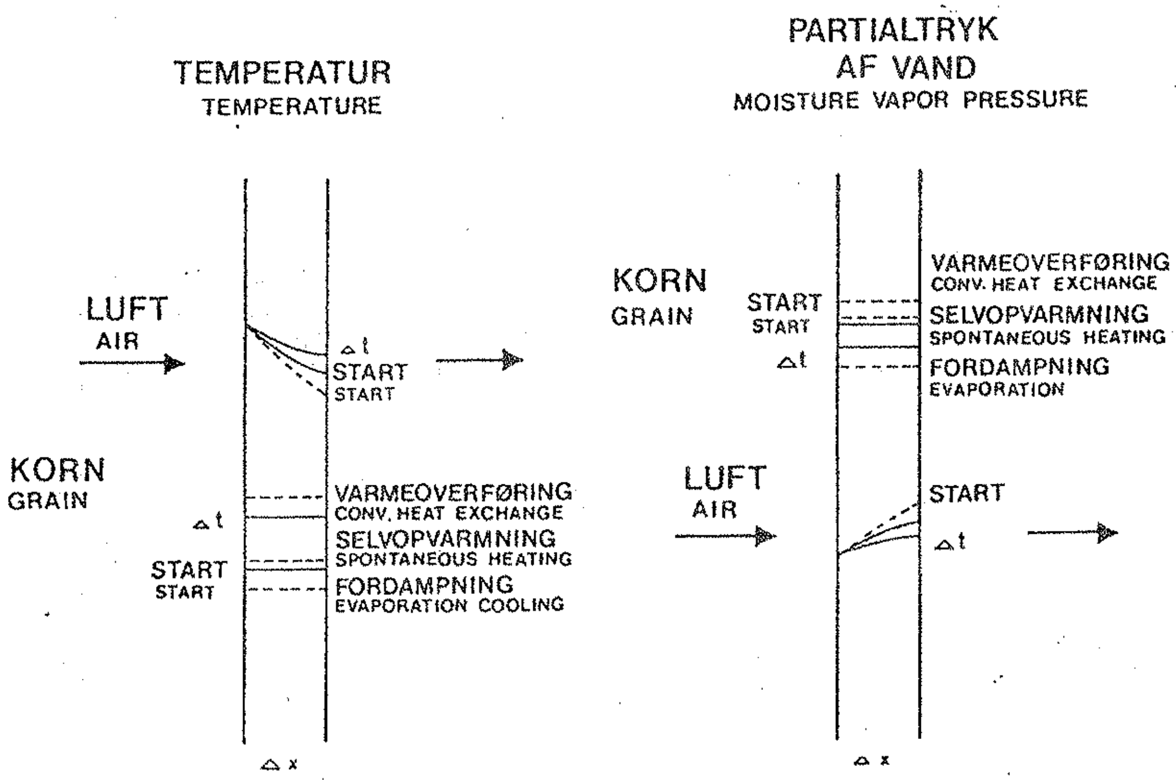

Figure 9. Heat and moisture transfers by grain ventilation.

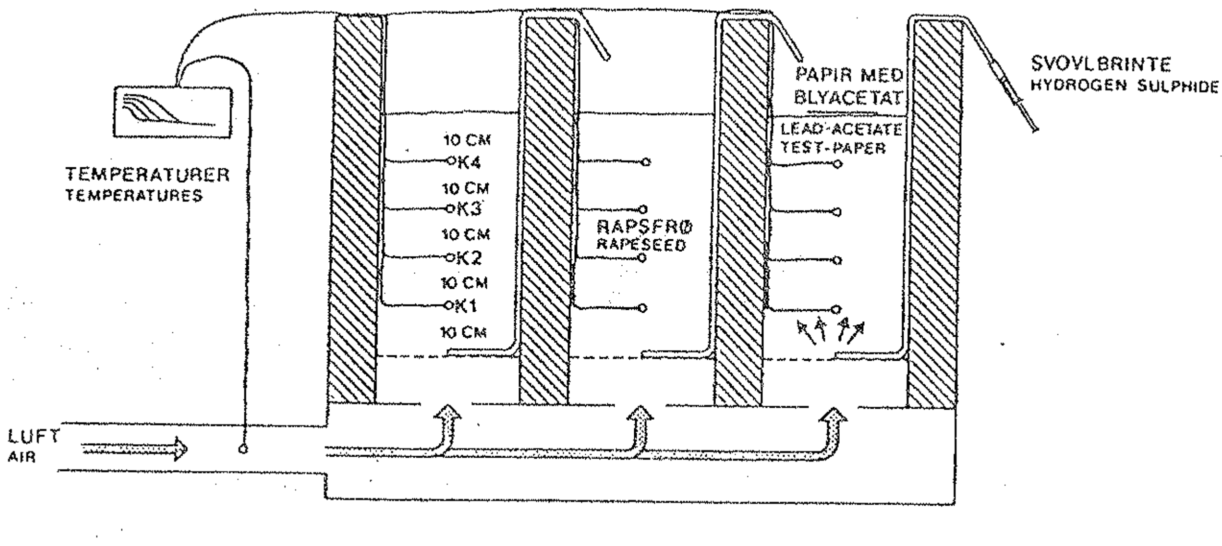

Figure 10. Apparatus used for chilling experiments.

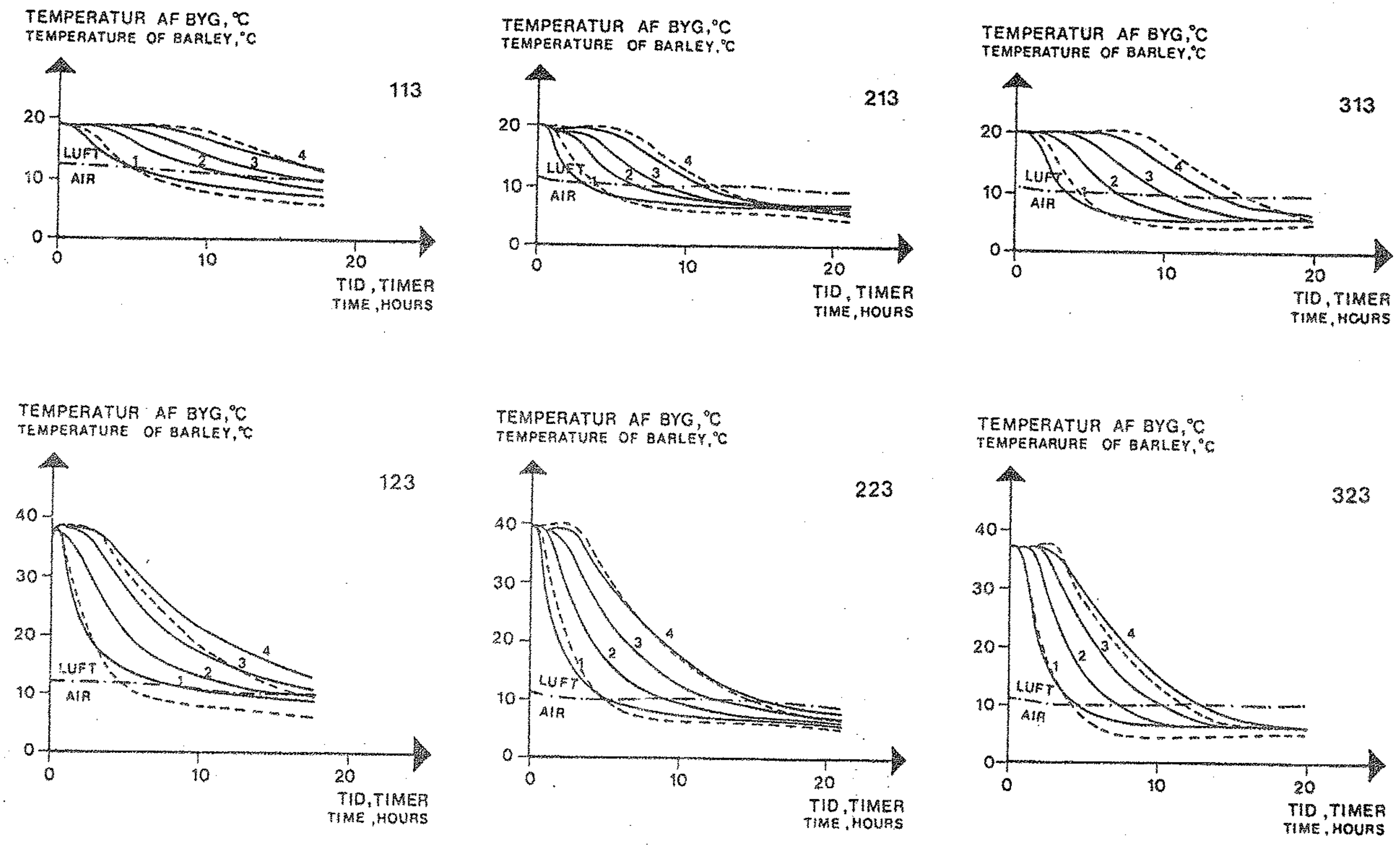

Figure 11. Experimental (——) and simulated (---) results on chilling of barley. (cf. Table 1).

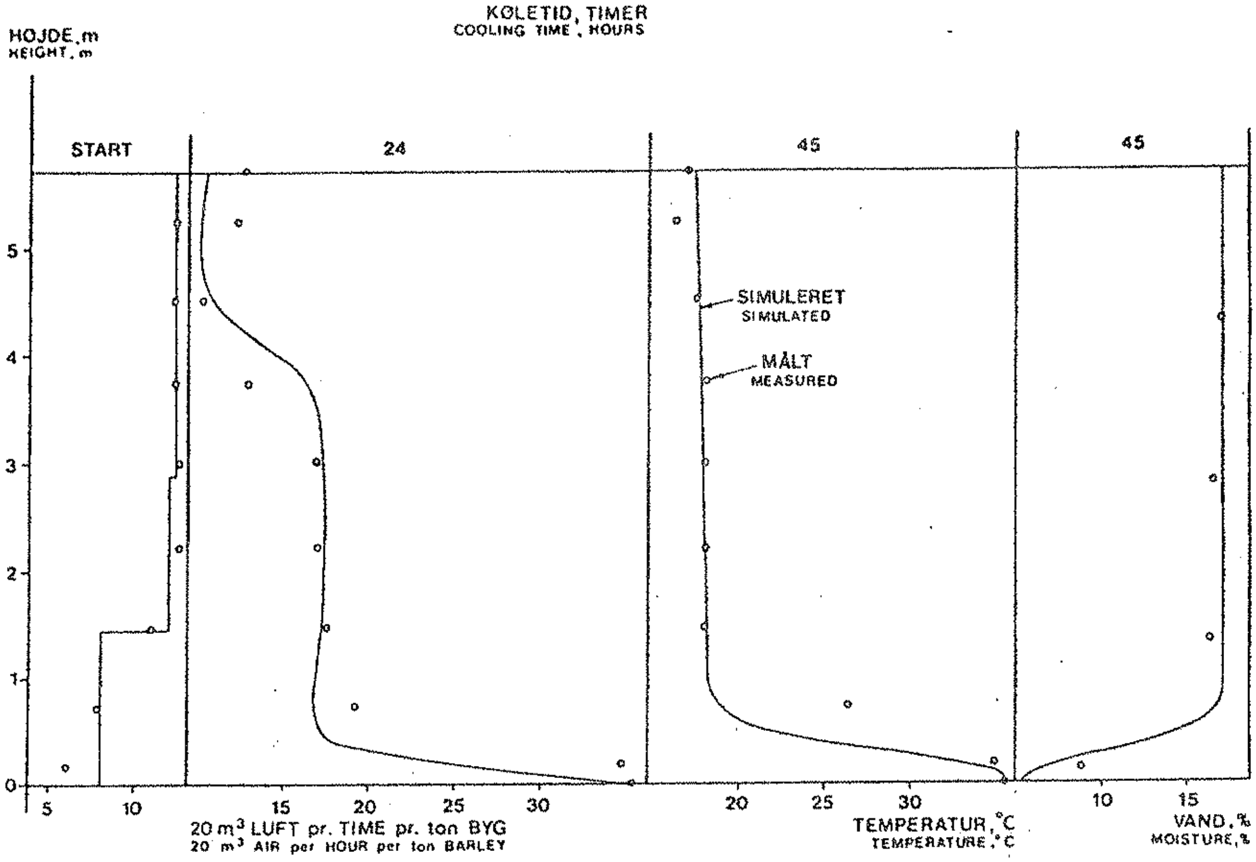

Figure 12. Experimental (∘) and simulated (——) results on chilling or barley.

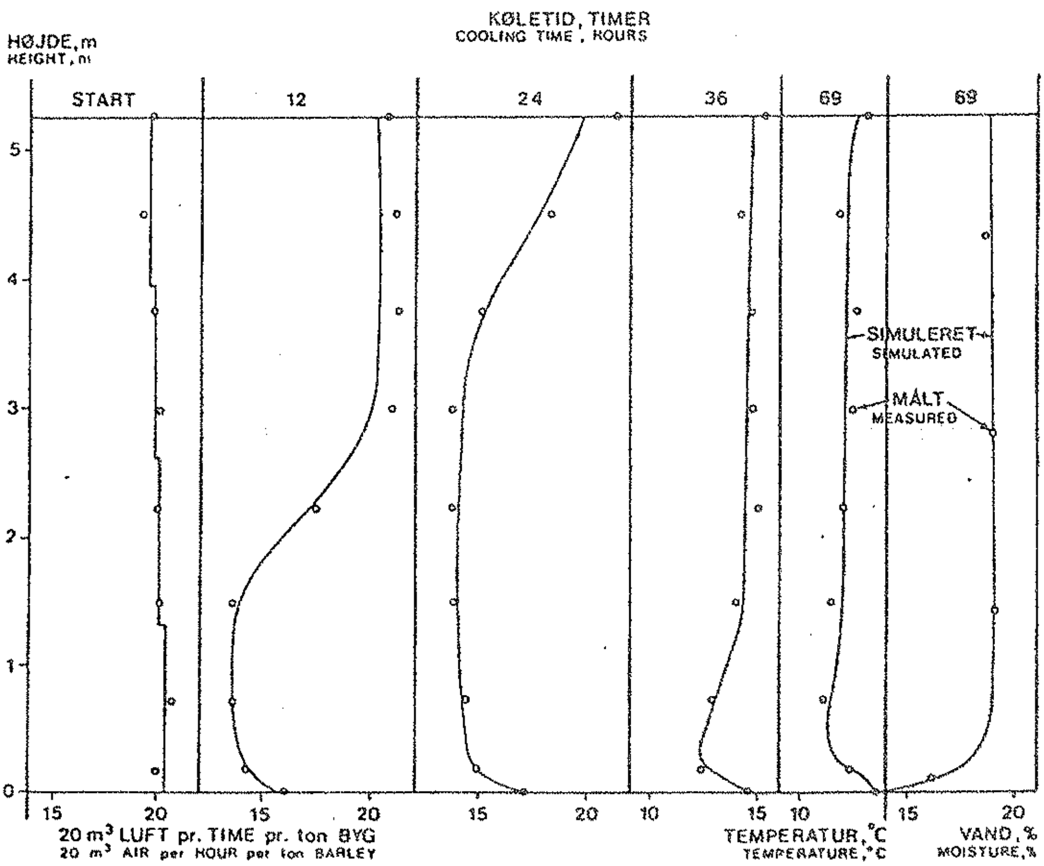

Figure 13. Experimental (∘) and simulated (——) results on in-bin drying of barley.

Some advances in simulation and control of dryers

D M BRUCE*

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Summary

Research on grain drying at the National Institute of Agricultural Engineering, justified by the economic importance of cereals in the UK, is centred on mathematical modelling of drying processes occurring in both heated-air and near ambient drying. The strategy of near-ambient dryer management has been investigated, and current work is aimed at optimisation of strategy, and measurement and control of dryers using microprocessors. In heated-air drying, improved descriptions of heat and mass transfer rates developed for single grains will increase the precision of existing models of farm-scale dryers and in particular the calculation of loss of grain quality. Using a dynamic version of the model, a new control algorithm has been developed to regulate the moisturecontent of grain discharged from a continuous-flow dryer. Computed performance is superior to conventional methods.

1. Introduction

Cereals grown in the UK worth some £m 3 000 annually, are often dried and stored on the farm - most of the 69 000 farms involved have a drying system. Some 60% of that grain which is artifically dried is ventilated with air at near ambient conditions in ventilated-floor buildings or bins. The remainder passes through heated-air dryers, of batch or continuous-flow type, before being stored at 14-15% wet basis moisture. Whilst in a

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dry harvest the crop may need no artificial drying, farmers nevertheless need a drying system to be able to deal with a normal season in which drying the crop would cost between £0.7 and £1.20/tonne (plus a similar fixed cost per tonne) making the national fuel bill for cereal drying some £m23 for the 1984 harvest of 26.5 mt.

The NIAE's research programme on grain drying, aimed at helping UK farming, comprises work on both heated-air and near-ambient drying systems. In both cases, mathematical models of drying processes solved by computers have been developed because such models are the best means of investigating and understanding drying phenomena, and as tools for applying that understanding to problems of dryer design, operation and control. I shall deal briefly with work on near-ambient drying, before concentrating on two aspects of heated-air systems; heat and mass transfer rates and control of continuous-flow dryers.

2. Near-ambient drying research

Equipment for near-ambient drying systems is relatively simple, but the strategy needed for successful management can be complex because the process is dominated by the weather which is more unpredictable in the UK than on larger land masses. A computer simulation based on an equilibrium type model[1] has been developed and used to study the design and management of near-ambient dryers using meteorological data from 20 years at 5 geographic locations. Further development of this model is underway to improve the predictions of grain spoilage by reviewing both spoilage data and models for wheat. Work on the optimisation of fan and heater control using dynamic programming will be started soon and linked with this is a study on the use of microprocessors for the monitoring and control of near-ambient dryers/stores.

3. Heated-air drying research

Heated-air dryers for cereals may be batch or continuous-flow machines using air from 40°C upwards and completing the drying process in around 1h. Though there are many categories of heated-air dryer, the fundamental drying process is the same and it can be described by the laws of conservation of mass and energy plus a description of the exchange processes involved - the heat and mass transfer[2]. The differential equations derived can be solved by computer to simulate the process in static or moving grain beds of various shapes. Features have been added to the NIAE model[3] to make it mirror the operation of a real machine[4], eg air recirculation, operation under steady-state or time-varying conditions. Grain deterioration is also calculated, as discussed further below. Predictions from the simulation have been checked using results from both published and confidential tests of full scale dryers. For mixed- and cross-flow machines the throughput of grain can be calculated within 5% of experimental figures in 90% of cases. Energy consumption is only slightly less well predicted, partly because heat losses are not allowed for in the model.

The accuracy with which grain deterioration can be computed is not yet acceptable and this is an active area of research. As the supply of lower quality cereals exceeds demand in Europe, premium prices are attracted by grain of high quality. Farmers are increasingly aware that careful drying is needed to maintain grain quality. At the same time bigger yields force farmers to run their dryers at the best throughput, ie highest air temperatures, they can achieve within the constraints set by grain quality. For these reasons the need has intensified to develop simulation models capable of calculating the damage to grain during drying. Such models can not only be used both in the design and development stage of a dryer to help select suitable parameters for the machine but also as the basis of a controller to ensure its safe and efficient operation[5]. A further use is in interpreting the results of performance tests and adjustment to standard rating conditions.

The calculation of damage to germination can be approached by "probit" theory. In essence this method involves linearising the normal distribution of seed death, and accumulating damage as grain passes through a drying bed[6]. For a given type of seed, the death rate in probit units has been shown to be a function only of grain temperature, moisture and time. Thus if the grain conditions through the dryer can be calculated so can the damage to germination. But because death rates increase exponentially with temperature the grain temperature must be known to within 5°C if the damage is to be calculated with the precision required. A method similar to probit analysis may also be applicable to the estimation of damage to baking quality.

Improvements to the model to try to achieve this precision have been made in three areas; the form of the fundamental equations, modelling of air and grain flows, and modelling of heat and mass transfer between air and grain. The fundamental equations were examined from first principles by Parry[7]. As part of his work he developed computer programs to solve the equations and hence showed that the description of grain properties, particularly the drying and heating rates, influenced the solution more than the equations themselves[8]. Parry's equations are therefore used as a reference while a simpler form[3] suffices for normal calculations. Flows of air and grain in some dryers are non-linear and in the case of grain are poorly understood. Mixed-flow dryers, where grain has to flow around a series of air ducts, are both a popular type of dryer and also difficult to model realistically. At present this type of dryer is represented as a series of concurrent- and counter-flow beds[4], but a new program has been written which divides the drying beds into small blocks of concurrent-, cross- and counter-flow and proportions the airflow between each. As yet this promising approach is suspended because of staff shortages. The third area of research models for heat and mass transfer rates between air and grain is a critical part of drying simulations, and the substantial improvements made in this area at NIAE are described in the next section.

3.1 Heat and mass transfer

Grain conditions in a dryer bed are greatly influenced by the characteristics of the grains themselves, ie their drying rate, diffusion-controlled in the case of grains, and the rate of heat exchange with the air. The two effects are linked by the evaporative cooling which occurs during drying. Measurements from which heat and mass transfer coefficients can be derived for grains have been done previously by many workers but in entirely separate experiments, i.e. heat transfer without mass transfer, and mass transfer ignoring the heat transfer. Using an advanced laboratory apparatus developed at NIAE[9], layers of grain have been dried under a series of constant air conditions while both the moisture content and surface temperature of the sample were monitored[10]. These thin-layer drying tests have enabled the drying and heating behaviour to be examined simultaneously. On the basis of this new data a model has been devised which accurately reflects the behaviour observed during thin-layer drying, by using moisture dependent diffusion equations for heat and moisture movement inside the kernel[11,12]. A single kernel was represented as a sphere comprising a number of concentric shells for which the diffusion equations are solved numerically by a finite difference method. The two aspects of the model, the mass and heat diffusion, are described next.

Moisture diffusivity, D, is dependent on temperature and moisture content, M, but the form of the relationship of D with M is not known from theory. Using the data on drying and heating, a function $D = \alpha \exp(\beta M)$ was developed to fit the observed data, in which α and β are themselves functions of grain temperature. An assumed boundary condition was that surface moisture approached equilibrium with the air at a rate dependent on air temperature. Using this model a marked improvement over previous, empirical models was achieved in predicting the observed thin layer drying behaviour (Fig 1) while not increasing computation effort unacceptably.

The heat conduction model[12] was developed using the mositure model just described. Because the latent heat of vaporisation of water is so large, small errors in evaporation (ie in drying rate) change the grain temperature significantly. Therefore the moisture loss model was employed to describe the drying accurately so that the experimental surface temperatures could be used to check the predicted temperatures at the surface of the outer spherical shell. A semi-empirical correlation for surface heat transfer coefficient was developed to interpolate between the equations given by Gamson et al[13] and this was found to give very acceptable results. The dependence of heat conduction on moisture content was modelled with an equation by Kazarian and Hall[14]. To solve the diffusion equation for heat conduction within the sphere a Crank-Nicholson method was used because it enabled larger time steps to be used than did the simpler, explicit method employed for the moisture model. Even so the calculations of heat conduction are demanding in computer time and, for deep bed use, they will probably be implemented only when significant intra-kernel temperature gradients exist. Otherwise a "lump" type model (no internal moisture gradients) will be used as at present. The marked improvement produced by the heat conduction model is shown in Fig 2.

To summarise, the improvements described to the basic NIAE model are expected to improve its predictions of grain conditions in deep-bed, heated-air drying sufficiently to allow better prediction of drying performance, and more accurate calculation of drying damage to germination and to other measures of quality such as loaf volume for milling wheat.

3.2 Control of continuous-flow dryers

In a continuous-flow grain dryer, a means is needed for keeping the m.c. of the discharged grain close to a set value. For practical reasons this control is achieved by altering the throughput of grain at the discharge of the packed bed, and though this is sometimes done manually, it is usual for an automatic control system to be installed. Good regulation of the m.c. is made more difficult by three factors; the long residence time of the grain in the dryer, the fact that a change in discharge rate affects all the grain simultaneously, and that the perturbations in inlet grain m.c. can be step changes as large as the expected moisture reduction in the dryer. Dryers fitted with conventional controllers employ a stop-start or fast-slow discharge cycle usually based on sensing exhaust air temperature. Such controllers may give problems due to lack of accuracy, robustness, speed of response and stability, four important requirements of any control system. Of these, lack of robustness is perhaps the most difficult to deal with. Marchant[15] showed how a very simple model can help to illustrate the problem, the key to which is the non-linearity of the drying process.

The drying process can be crudely represented by Eqn 1.

$$\frac{M_{out} - M_e}{M_{in} - M_e} = \exp(-kx/v) \qquad \ldots(1)$$

Where M_{in}, M_{out} and M_e are grain inlet, outlet and equilibrium m.c. respectively, k = drying constant for the grain, x = length of dryer and v

= grain velocity. Letting $k = 0.025$ and M_{in}, M_{out} and M_e be 0.20, and 0.17 and 0.085 m.c.d.b. respectively, then we can calculate the required velocity, V to be 0.0827 m/s. If the error signal changes to 0.01 d.b. then a gain of 2 will increase V to 0.1027 m/s. Now if M_{in} is still 0.20 d.b., substitution of the new velocity in Eqn (1) gives an M_{out} of 0.1752 m.c.d.b. i.e. an increase of 0.0052 m.c.d.b., and we can calculate the sensitivity as 0.0052/0.01 i.e. 0.52. However, if we begin with an M_{in} of 0.30 then the initial steady-state velocity for an M_{out} of 0.17 m.c.d.b. would be 0.0269 m/s. Now if the error changes to 0.01 d.b., then the same gain will alter the velocity V to 0.0469 m/s and substitution back into Eqn (1) gives $M_{out} = 0.2111$. This time the change is 0.0411 d.b. and the sensitivity = .0411/.01 i.e. 4.1, which is eight times the previous sensitivity. It is not surprising therefore that the control system behaves differently with different operating conditions. The lack of accuracy, robustness and stability of a proportional controller is shown in Fig. 3.

A control loop with constant sensitivity and therefore with robustness can be achieved by writing equation (1) in logarithmic form

$$\ln(M_{in} - M_e) - \ln(M_{out} - M_e) = k.x/V \qquad \text{... (2)}$$

Thus the modified feedback control system calculates the logarithmic excess moisture and controls and inverse grain velocity to suit. The other system requirements of accuracy, speed of response and stability can be met by using fairly standard control system design techniques. The method is based on frequency domain compensation using a describing function to represent the frequency response of the dryer. To use these methods a quantitative description of the dynamic behaviour of the dryer is required, which has been derived using the full heat and mass transfer models referred to earlier.

As a result, an algorithm for a robust proportional plus integral feedback scheme has been derived, in digital form, for a particular design of mixed-flow dryer. The computed performance of this algorithm is satisfactory (Fig 4) and it is now being tested in the laboratory on the machine for which it was designed. Performance in the few tests done to date has been promising and it is hoped to install one or more "target" systems on farm dryers for this year's harvest. Such a controller, being microprocessor-based, could be programmed to perform improved control functions, particularly stabilisation from start-up, feed-forward for better response speed and optimised control with quality constraints. On a more basic level, the microprocessor could handle sequencing of grain handling equipment start-up and shut down, alarm and emergency procedures and could provide information and records for the operator.

4. Grain drying research - the future

The future of research in grain drying poses questions relating to further development of drying models, control of both heated-air and near-ambient systems, grain quality measurements and modelling, and sensors.

Now that the thermodynamics has been modelled, a better understanding of the flows of air and grain in dryers is required. Drying performance on alternative crops from rapeseed to onions, from foodstuffs to biofuels can be modelled, provided that crop characteristics are measured and described. However product quality is vital and must be incorporated if drying processes and their control are to be optimised. Distributions as well as mean values of quality measures will be needed to characterise fully the materials, and rapid, on-line methods of sensing quality-related parameters are needed. There is also scope for improvements relating to noise and dust emissions from dryers. All this applies equally well to near-ambient and heated air drying. These points, and other possibilities opening up from advances in technology of computing, control and sensing, leave no doubt that there is much valuable research to be done in this area.

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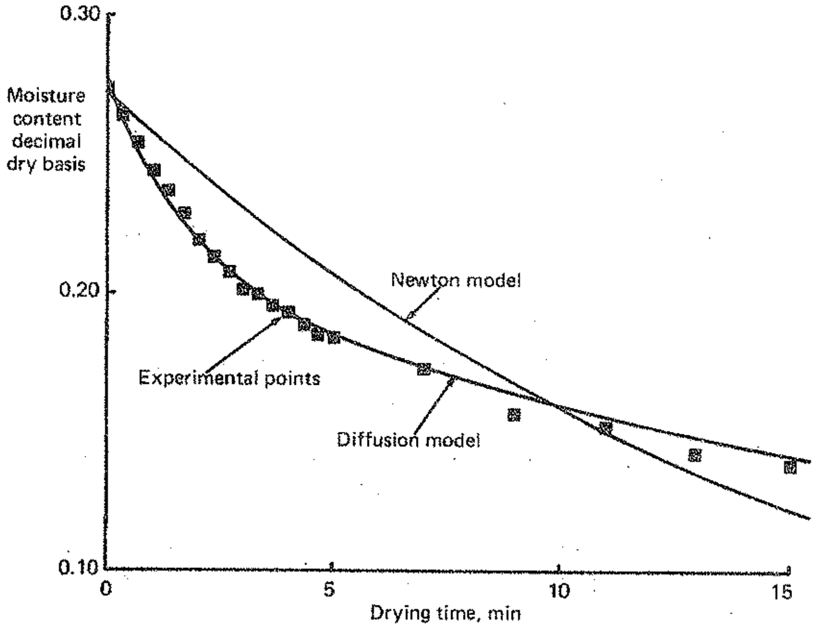
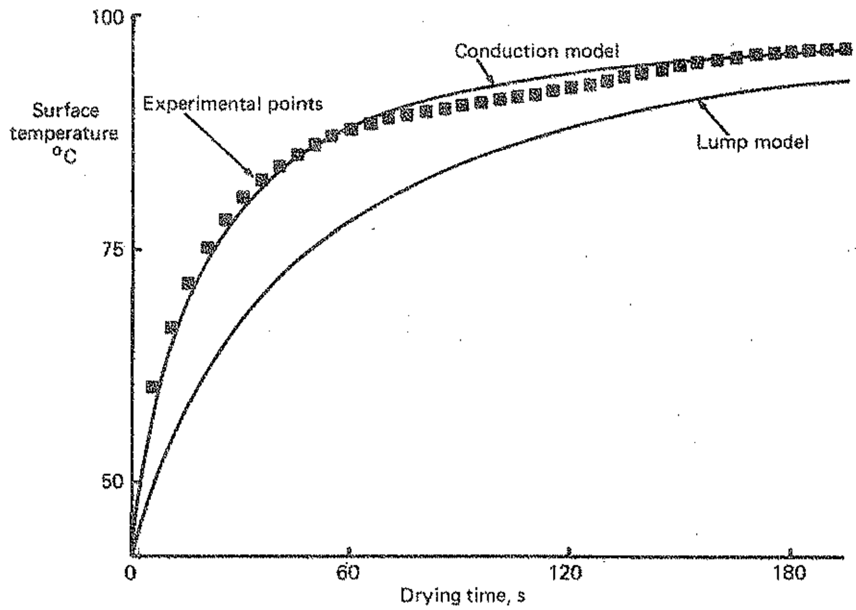


Fig 1. Drying of a thin layer of barley with 100°C air

Fig 2. Surface temperature change during thin-layer drying of barley with 100°C air



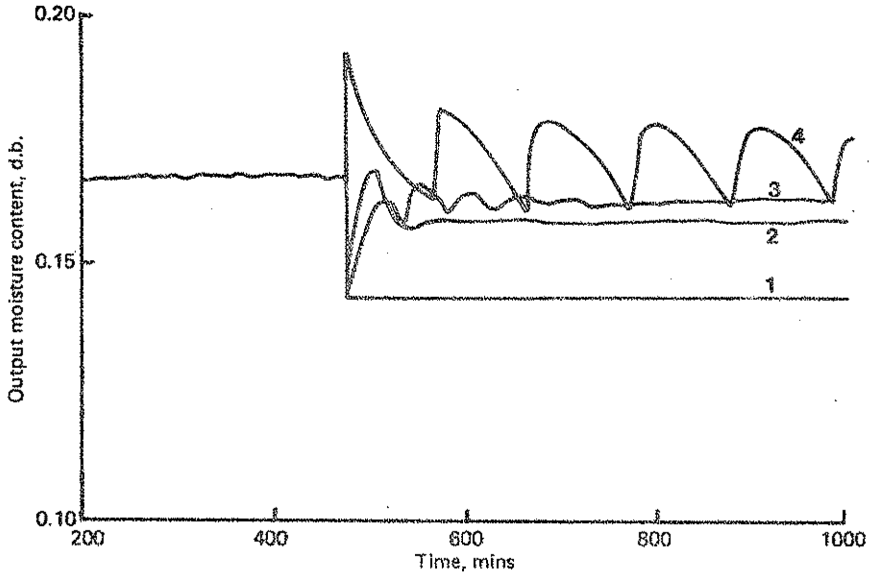


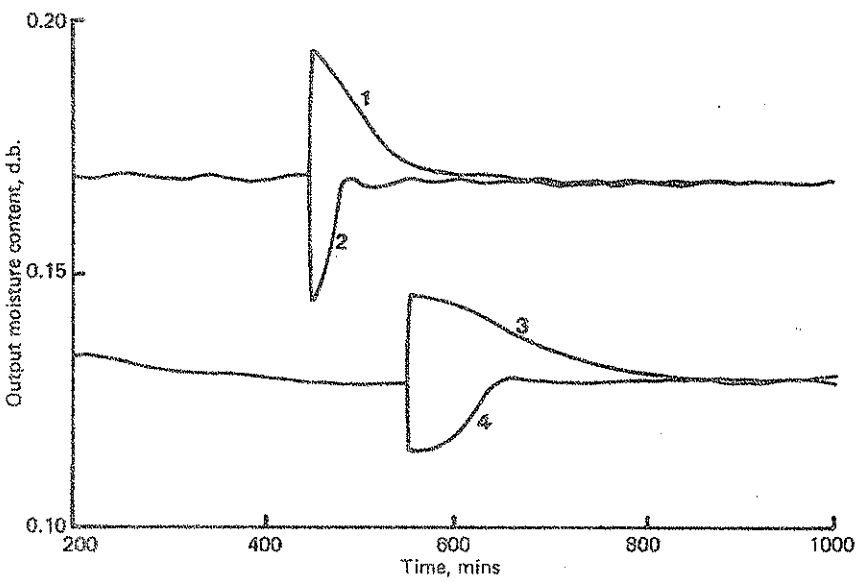
Fig 3. Computed response of a single dryer model with proportional control to a 0.05 step change in input grain moisture, initially 0.25. Target m.c. = 0.17

1. step down, gain = 0
2. step down, gain = 2
3. step down, gain = 5 (instability evident)
4. step up, gain = 2 (severe instability and lack of robustness evident)

Fig 4. Computed response of simple dryer model with robust control algorithm, showing effect of step change of 0.05 in input m.c.

1. step from 0.25 to 0.30, target 0.17
2. " " 0.25 " 0.20 " "
3. " " 0.22 " 0.28 " 0.13
4. " " 0.22 " 0.17 " "

Accuracy, stability robustness and speed of response are all acceptable



POSSIBILITIES FOR USE OF COMPUTERS, ELECTRONICS AND CONTROL ENGINEERING IN HARVEST, CONSERVATION AND STORAGE OF HAY AND SILAGE

Edvard Nilsson, Swedish Institute of Agricultural Engineering, Uppsala

Silage

The silage system can be described using the following chain of events: Mowing - Wilting - Loading - Filling into the silo - Sealing - Fermentation - Storage - Unloading the silo- Feeding to the animals.

A characteristic of silage-making is that after the silo has been sealed there is practically nothing that can be done to control or govern the biological process resulting in conservation of the feed. Thus, before this point in the chain of events it is essential that all necessary measures have been taken in order that:

- the material loaded into the silo should be a suitable substrate for lactic acid fermenting micro-organisms
- the physical environment in the ensiled and sealed plant material should be suitable for the process desired (lactic acid fermentation)
- the micro-organism composition is suitable so that it promotes and does not disturb the process.

The complicated relationship between all the many factors influencing the silage-making process is poorly quantified today. The measures taken during practical silage-making in order to obtain good results are, thus, based largely on experience and on the various sub-relationships described in various experiments. This is insufficient. Also experienced silage-makers are sometimes unsuccessful without being able to explain why.

What is foremost needed is, thus, that the relationship between the factors influencing the silage-making process is quantified and described in a mathematic model which must be computer-based owing to its complexity. This model should be available to provide data on optimization of the silage-making system on the whole and also to aid decision-making in connection with ongoing silage-making. As an example of decisions which the model can support the following can be named. When mowing it may be necessary to assess which wilting strategy should be selected with regard to the crop in question and the anticipated weather conditions. When loading the material in the field decisions on whether silage-making additives should be added must be made and the decision must also include the type of additive which should be used and its application rate.

In addition to this it is useful to have rapid access to analytical values to support the model. Here the primary requirement is for reliable and rapid methods of determining the dry matter content, contents of fermentable carbohydrates and perhaps the number of harmful microorganisms. It is also useful to have daily access to long-term weather forecasts.

Among the technical systems requiring control techniques it would be of value to have equipment which doses the silage-making additive according to requirements. Under certain conditions there may also be a need for equipment to detect and separate undesirable material in connection with the loading of the crop or when it is filled into the silo. Such systems already exist.

Hay

The hay-making system can be described with the following chain of events: Mowing - Wilting - Loading in the field - Loading into the barn - Final drying - Storage - Unloading from the barn - Feeding to the animals.

In the hay-making system the final drying is open to control, at least in principle. However the drying usually occurs throughout with cold air. It is then only the ventilation time which can be influenced. Systems for this are available and they can certainly be improved. Nonetheless, there is little to gain in this way. The drying time is probably shortened but only marginally. The cooling during periods when the fan cannot be used owing to poor weather may possibly be better done when systems are used which are programmed for this than when the equipment is operated manually. As there is an exchange relationship between energy lost through combustion of hay dry matter and the input of energy in electric current, the hay-drying economy is probably influenced negligibly by a moderate change in fan efficiency if the design of the drier has included a correct optimation between these forms of energy. However, this assumes that the manual operation of the fan is not neglected so that mould occurs. In general, it appears that the most important advantage of control systems for the fan is increased convenience.

A difficulty in barn drying during poor weather is to know how far the drying has actually proceeded. This knowledge is needed when planning the next loading. Here it would be of great help if suitable aids were developed. They could either work on a sensory basis or by calculating removed water using data on incoming and outgoing air from the drier.

In addition, it appears at present important to describe the entire hay-making system using mathematical models. As in silage-making, these models should be capable of use both when optimizing hay-making systems on the whole and also as aids when making decisions in connection with ongoing hay-making. Work along these lines is presently ongoing in co-operation between JTI and the Department of Agricultural Engineering at the Swedish University of Agricultural Sciences.

A reliable and quick method for determining dry matter contents would be of great value also in hay-making. The need of daily long-term weather forecasts is even more important in hay-making than in silage-making.

DISCUSSION, SECTION 2

Dr Egil Berge

Mr Lindgren, it was a very interesting paper and I noticed to my surprise that there are micro-organisms that will be able to work at low temperature and low pH without oxygene. We do have the experience that silages can be kept for more than one year in Scandinavian countries. If you have silage left over, you have to keep it till next year, and the year after it comes out with surprisingly good quality. Does this really mean that the kind of deterioration that you have shown us is something that may occur, but happens very seldom? I would like to know how often this is taking place. Thank you.

Sven Lindgren

I think nothing is to be preserved forever, nature wouldn't accept that. We know that we have two main problems that seem to cause deterioration of ensilages. One is the aerobic deterioration where we quite clear know the origin. We have also observed an aerobic deterioration in silages during conditions when we haven't got enough of sugar. This is probably a process relying on an anaerobic respiration. This means that heat can also be produced anaerobically. During this process acetic acid and ecetic acid increases the pH and then we have an anaerobic deterioration. What I would just like to stress out a little more is the term "quality". With quality we mean what we can measure today. I think quality is going to be much more defined for the future. What is really quality? That is a very important question. We know that there are a lot of factors which we can't measure but which must of course affect the use as an animal feed.

No I wouldn't say that anaerobic deterioration is very important. Have you got a good quality silage it will be possible to keep it for longer periods than just one year.

John Matthews

Can I ask Mr Lindgren about the relationship between temperature and moisture content and cereal deterioration times. If during a time of deterioration one has a rapid drop in temperature, then deterioration will be inhibited. Will this then bring one back to a state somewhere near the beginning of colonisation? Let me give an example: an example of perhaps three months to serious deterioration at particular water and temperature levels. If after two months the temperature drops rapidly, for example due to the winter, and then rises again in the spring, is serious deterioration still three months away or will one only have one month left before deterioration is serious? Does the low temperature destroy the colonies or just inhibit them?

Sven Lindgren

This is of course a very important question you are raising. After winter most of the products we have stored have a better stability because we have injured the microorganisms surrounding. If they have no internal energy, they use energy to get rid of acids. That means that they can survive during acid conditions if they can grow. You know that even if you use organic acids or another preservative, a growing organism can use a substrate. That means that if they are surviving and you have a stress condition then they will be killed off much more efficiently. What is very important to remember is that the microbial world is static. We work with a dynamic process. One product during one condition have some kind of organisms, another product during the same condition has a content of other organisms and they are not alike.

Frode Guul-Simonsen

I have a question and find it to be relevant to ask: When you are producing electronic equipment the price will be progressive raising with the demand of exactness to electronic equipment. Therefore, if you want to control biological processes, how exactly do you think measurements need to be when you i.e. measure contaminations of water and temperature?

Sven Lindgren

I'm very sorry, I don't think I can give very exact information, because we don't have it. I think neither the Danish paper nor to the English papers showed how they deal with precision. But for me it is very important to know its kind of organism under what conditions it can grow. We don't know what organism is causing more problem or causing more damages and so on and it's mainly those organisms we think is very important to control. So I'm sorry, I can't give you the exact limitation on the instruments today but I know it's a demand to get instruments to measure the methods we have, because I think that a lot of the methods used in Scandinavia we have got from other countries and they don't work very exact under our conditions and the climate we have here in our part of the world.

Per Almgren

It is important to realize that there there is almost always a possibility to measure very accurately if you can afford it. If you spend a lot of money you can measure things with a very high accuracy but there is of course also a question of whether this is the right thing to do. The situation may be so that you really don't know how good data you need. If that is the case then you should examine the total situation. It may turn out that you should measure quite different things.

Sven Lindgren

When we are talking about measurements and biological activity we know that very, very small differences in moisture content can cause biological activity. If you want to have the exact biological activity it's also very important to have exact measurement methods. Sometimes as a biologist it is a problem to discuss with engineers because we know that small differences affects the speed activity and when differences in water activity affects temperature we even more speed up the growth of the microorganisms. That means, the better we can measure the better data we will get on the biological activity. In the food industry they have rather exact demands on the precision of these measurements, but in the agricultural sector we haven't got exactly the same information about testing system and how exact they should be to be used. While we are talking here about temperature we know that temperature affects the enzyme activity and with 10 centigrades increase it will double the activity.

Henning Nielsen

One of the problems around physical measurements contra biological influence is that you have not a smooth curve, you have an uneven one. Then you have some intervals on the curve where you have a very strong influence of the physical parameter and on other segments where it's very little. That's the problem of speaking between the engineering discipline and the biologic one.

David Bruce

I would suggest that another possible use for the model is to look at the sensitivity analysis. Once you have a model you can then vary some of the factors in your model and see the effect it has on the output. Once you can see the effect, you can then see how accurately you have to measure the inputs to your model. I've got an example of that for the biological system of low temperature grain drying. If you want to measure the relative humidity of the air to control when you turn the fan in an attempt to dry, some work on simulation has shown that the difference between 80 % and 85 % relative humidity is very critical. If you have a sensor which is 5 % inaccurate then it can be disasterous for controlling the dryer. That puts a limit on how accurately you need to measure relative humidity in the farm situation to be able to get adequate control.

Egil Berge

I think that it will be very difficult to go into the local situation around each microbe in the same way as David Bruse did around each corner. Which means that we probably will have to use a limped model. Then it's not any longer a deterministic one. So when Mr Bruce talked about stochastic variables in the weather inputs: Why not stochastic variables when it comes to the risk of past development? It is a lot of different things which has to be present. Among them are some which we never know for sure: Is there, or is there not a given kind of microbe present? So it would probably be better not to demand so accurate measurements. When it comes to stochastic variables, for instance the air-flow resistance, we know from grain-drying and from hay-drying that on the average it seems to be OK. Still we get those bad spots because there's a local resistance to air flow. Let's go back to Ejlif Jacobsen and his excellent speach. He is looking for a sensor, "a wild idea". There is no way you can measure long-distance down in the grain. But the first sign you see, that's on the surface, because heat goes up. Why are you not trying to use an infra-red camera on the surface? Try to detect the heat as soon as possible. Thank you.

David Bruce

I like the idea of the risk-function for microorganisms. Is it not possible to identify the worst case microorganism for human problems or animal feed problems and then to investigate that one more thoroughly to be able to control the process of that particular microorganism, and keep it under control. On the question of air pressure drop it is certainly true that you can load a dryer in a poor way so that you get a severe reduction in the air flow through parts of the drying bed. You can always load the dryer poorly. I think we have to assume that you have reasonably good practice on farm to be able to have any chance at all of controlling a process. That's a basic question of making sure the farmer knows how to load the dryer and has the right equipment before he can hope to carry out drying effectively. On this question of measuring temperature in a low temperature dryer, would it be possible to install a net of temperature sensors, very simple cheap ones, across the top of the bed and then when you ventilated the bed for a short time any high temperature spots in the grain bed would indicate to the temperature sensor above them that there where something going on underneath that point. So one sensor could then cope with the full depth of the grain on that particular point in the store.

Ejlif Jacobsen

Infrared thermometers and sensors are now available, and they are specially designed to measure low surface temperatures accurately. At Biotechnical Institute we have investigated whether this type of instruments may be usable to monitor and control temperatures in aerated grain stores.

We found that it was possible to obtain rather accurate measurements of the grain surface temperatures using an infrared thermometer. However, the surface temperatures were more dependent on the air temperature above the grain than on the grain temperature a few centimeters below the surface. Besides, we found that a hot spot deep in the grain only moves a few centimeters per day by natural convection, and by aeration (20

m^3/ton x hour) of the grain it may last more than 24 hours until a slight temperature rise can be detected at the grain surface.

Consequently, I can not recommend the use of infrared sensors for control of temperature in grain stores. A quadratic net of thermo-sensors - placed at intervals of about 2 meters and about 0.5 meter below the grain surface - will be a much better alternative. Still a hot spot deeper in the grain may cause considerable damage before it is detected.

Sven Lindgren

As I have said earlier, when we are talking about measurement, I know that people measure what they can measure. But that is not important. I think what we have to understand is: Each storage system should prefere control that prohibit all growth of harmful organisms and I wouldn't say that you should just select one organism and check the system for that. You should know that there is no growth at all, and that is the main point with preservation. And that means that it is very important for both biologists and engineers to discuss whatever are we going to measure for the future? What are we going to control? I don't think I need to go deeper into it than that. It is quite clear that this is the importance with our contacts nowadays.

John Matthews

I would perhaps join the engineering side here compared with the microbiological view, but it does seem to me also that for the farmer solution, whilst accepting the researcher's need to know a great deal of detail about the conditions of growth, of micro-organisms, and of deterioration, our best chance of providing economic systems for the farmer is to monitor deterioration. Our best chances are more likely to lie with monitoring the results of these deterioration processes, the changes in temperature as a result of them or the changes in gaseous content as a result of them, rather than monitoring the very precise conditions which will judge whether they will take place or not.

Could I also comment on the barn drying of hay and the suggestions of methods which might be used there. Many present might know that one of our NIAE specialisations at the moment is the use of tailored wavelengths, infrared light emitting diodes for measurements of moisture, and this works very well on forage. It's expensive compared with, say, capacitance techniques which perhaps are more likely for grain, but with forage where the capacitance and resistance techniques are not satisfactory then infrared reflectance look a good one. It seems to me that with the increased practicability of fibre optics light tubes it is possible one could distribute fibre optics around the barn of drying hay and use a single instrument from a number of different light tubes ended at different points in the hay. It could just begin to be practicable economically although I accept it would still be expensive. We are producing an in-field moisture meter at the moment and I don't think we can get the price much below 10 000 SEK. One of our big questions at the moment is, will such an instrument sell to the farmer for £900. As part of a control system, in a barn drier maybe £900 (10 000 SEK) might be acceptable.

Per Almgren

Just one remark on the last subject. I personally have experience in working with these systems for drying hay. We can make equipment at approximately 4 000 SEK that controls the fan system. It measures temperature differences in the level of about 0.1 degrees centigrade to judge if there is a drying process going on or not. This has been used for some years and the farmers who used this equipment in their farms were quite satisfied with it, and very interested in buying the equipment as well.

Hisamitsu Takai

Measurement by gas chromatography could be very expensive for use in agriculture, but this is not always true. It is quite depending on which concentration we would measure. I know we have very cheap chromatography, if the concentration is relatively high. I have a question to Sven Lindgren about head space technique. Did I understood you correct? The biological activities in the storage affect the gas concentration. Do you have any idea of which level of concentration we are talking about? Is it a ppm level?

I mean gaschromatography has limitations if you have very low concentration, maybe you have to use spectrometer or some other very still more expensive technique.

Sven Lindgren

Head space technique is a combination of gas-chromatography and masspectrometry. It has been used in grain stores and we know a little about of what kind of substances we will find there. It has techniques for scientific purpose and not for common purpose out in the field. But if we know what substances are important to be given identity of some organism we can use approximately the same technique that we are using today when taking a sample of the air and you will get a direct information on the quantity. This can be very useful in the future, but we need more information in this field.

David Bruce

I meant to say during my talk that the work on dryer control that I've reported is done by the control group at NIAE. I can't say I am expert in control by any means. What I tried to do is to give you the idea of what was happening there. I know they've done an economic analysis and I gave you an estimate for the U.K. per annual profit of a quarter of million pounds for improved grain dryer control. It very much depends on what assumptions you make about how much you can improve the control and also what assumption you make of how bad it is at the moment. On the question of linearisation, I think that controlling one over throughput is a general principle for dryers where the drying rate depends on the residence time in the dryer rather than on the throughput. If the dryer worked like that then the same technique for linearising should work and you might not have to model the dryer in great detail.

Egil Berge

Not a question, a suggestion.

Not a very scientific, but a very practical way of detecting a hot-spot might be to use a trained dog.

Frode Guul-Simonsen

When you have control system for feedings of animals, you also need to have a test procedure both for hard-ware and for soft-ware. When we get more and more computers I think we have to put up some demands for electronic equipment. I can tell you that in Denmark we have started up a project for appropriate and reliable needs for hard-ware but not for soft-ware. A test procedure for soft-ware would be very difficult. But by hard-ware it is more simple. Our goal is to make some proposals for standards and we want to bring them to international discussion. Then you can put some signs in the electronic equipment so farmers can see that it is of quality because it is not possible to see with the eyes if you have a good quality. This is a new thing. If you have buildings you can see that it is quality by eyes. If you have machines, you can see qualities by eyes. But not by electronic equipment. Therefore you are able to put some signs on it and these signs have to live up to some international standards which are recognized by authorities from assurance companies, associations and manufacturers.

John Matthews

Thank you, chairman. I would like to assure Mr Simonsen that he would have allies in the United Kingdom and that we too have recently formed a Standards Committee for agricultural electronics and we see as one of the first two or three needs interface standardisation as well as a need for some work on reliability. I think we all have evidence that certain farm electronics have a bad name. The farmers mistreat it, it is left outside and it is covered with toxic spray chemicals. We know, nevertheless, there are vibration problems, and there are moisture and chemical ingress problems, which are causing farmer resistance to some electronics. I support the idea of some work in the International Standards Organisation.

While I am speaking, can I say that the other subjects high on the priority list are ones that we talked about earlier including standard interfaces. I believe we need to standardise an interface between the tractor and the implement working with it and an interface certainly between the field machine and the farm management computer; I would suspect also between, say, the milking equipment or the feeding equipment and the farm management computer. Electronics will fit into a hierarchy of management from the farm office down to the separate units.

Henning Nielsen

About interface. I myself is working on a project around interface between tractor and the implement, and different problems about that. I know that NIAE and Braunschweig are working on something like that. There are some system like these, around which some standard work is done in USA in the area of trucks and buses (SAE J 1708 draft). There is also a group in Denmark, working on standardisation of on-farm data transfer. In our project we are trying to make some mapping of the problems around field machinery and we have planned to make a short paper.

Wim Rossing

On the farm we need a form of standardization. We think about a "farmbus". The equipment on the different places on the farm can be plugged in the system in a easy way. All the data is going along this farmbus to the farm computer. When the different firms can come to the same protocol. Also equipment from different firms can be used on the same farm. Another point is the communication with the external systems. In future it is also necessary to exchange data with extern computers. When we will come to a national system for identification, there must also be a form of standardization. When namely a cow from a farm is going to an other farm the cow must be identified by possibly another system. This is not possible by the identification system which are in use now, but by the next generation of system we must take this in our mind.

Hisamitsu Takai

I wonder, there is no discussion or comment about the possibility around artificial intelligence. I wonder if it is too early to start to consider about this possibility. I believe that such a system or the next generation computer will give the possibilities to make machines which are able to learn from the experiences, like a skill farmer does. This gives a lot of possibilities to make individual automation, for example individual milking or individual feeding etc., which are adjusted to the individual needs.

Per Almgren

About standard interfacing.

I wonder if it wouldn't be more reasonable to use one of the standards that already exist for communication. There are different types, depending on which speed you need, and I think that they ought to work rather well in the type of equipment we are considering here as well. There is no need to do a job that is already done.

Henning Nielsen

Of course we have to use the standards known, but there are different places where we need to make some choise between existing standards. There are too many standards. The purpose of the standardization work I was speaking of is not to make new standards, but to choose the right of the existing standards. Then if you miss some part of the standard you, of course, have to make new ones.

Frode Guul-Simonsen

A group of manufacturers in Denmark who are working with feeding problems have made a protocol system, a proposal for transformation of data. It is a proposal near the finish and will be sent out for critics. In Denmark we are very interested in this because we export a lot of this kind of machinery.