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Abstract
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Lelystad, 1992.
Study of current experiences with automatic milking systems and its prospects.
Keywords: Dairy, automatic milking, robot.

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DAIRY FARMING AND AUTOMATIC MILKING

Present knowledge and prospects

Report of a working group

Editors:
A. Kuipers
A.T.J. van Scheppingen

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PREFACE

The expectation is that the first prototypes of "automatic milking systems" will be marketed the coming years. The system combines a milking robot (automat) and a management system, that incorporates automatic milking in the dairy herd operation. This study assumes, that automatic milking systems will mature some day. With maturity is ment that the time for testing has passed and that the equipment works technically satisfactory.
Preceding introduction in practice a testing period is often performed at the experimental stations. This testing is done in such a way that the use of the equipment on practical farms is imitated. During the testing period negative experiences can be adjusted and improved. This results in systems that are well developed, when introduced in the field.

Dairy herd management is traditionally centered around two times milking a day. In a few countries, on a very limited scale cows are milked 3 times a day. With automatic milking it is not needed any more that the farmer provides physical assistance during the milking of each cow. In other words, the linkage between human labour and the milking of cows will be ended. Realisation of this goal signifies a new era in the mechanisation and automation of the dairy farm. It will be a very important development for the management of the dairy farm, for the dairy man himself and for the cow on the farm.

Considering these technical developments the Board of the Research Institute for Dairy Cattle, Sheep and Horse Husbandry (PR) at Lelystad has requested to place the automatic milking system in a broader perspective. Also, the question is raised if further research in this field is needed and especially, if research should start towards implemention of automatic milking in a whole dairy farm set-up.

To answere these questions, a committee was appointed composed of representatives from various organizations and research institutes in the Netherlands. The members of the committee were:

ing. H. Los	Dairy farmer (chairman)
dr.ir. A. Kuipers	PR (secretary)
ir. J. Frouws	Department of Sociology, Agricultural University
ir. G.W.J. Heerink	Dairy Company, Coberco
ir. A.A. Jongebreur	IMAG-DLO

dr.ir. A. Osinga	Vocational Training Centre for Dairy Husbandry and Grassland Management
ir. A.T.J. van Scheppingen	PR
L. Timmermans	Dairy farmer
H.A.A. Versmissen	Dairy farmer
prof.dr. P.R. Wiepkema	Department of Animal Husbandry, Agricultural University
prof.dr. L.C. Zachariasse	LEI-DLO.

The research report was written under the responsibility of this committee. Also two firms, developing milking robots, have positively contributed to the discussions. Colleagues from other countries were so kind to provide us with impressions about the perspectives of automatic milking in different regions of the world.

A working group prepared the various chapters of this report. The working group was composed of:

ir. A.T.J. van Scheppingen	PR (chairman)
ir. P.B. de Boer	LEI-DLO, detached on PR
ir. A.H. Ipema	IMAG-DLO
ir. A.P. Subnel	PR
ing. J. Visch	PR

dr.ir. A. Kuipers
director
Research Institute
for Dairy Cattle, Sheep and
Horse Husbandry (PR)

INTRODUCTION

A Dutch study from 1989, named "Aspects of automation in dairy husbandry" (29) was used as starting point for this report. In the study the consequences of a further automation in the dairy sector were described in a global way. This research report concentrates on the concept of automatic milking and the effects for the dairy farm and the surrounding community. The majority of data used is from research performed in various countries since 1988.

In chapter 1 the consequences of an automatic milking system (milking robot/automat and management system) for the management of the farm are outlined. Because present milking automats are developed for use in loose housing systems, implementation of automatic milking in stanchion barns is not considered.

In chapter 2 and 3 the interaction between automatic milking systems and respectively the dairyman and the cow are analyzed. The prospects of automatic milking depend on the suitability of the system to fit in the farm operation, the effects on the welfare of the farmer and his family and on the welfare of the herd. However, economical aspects will also play an important role in the prospects of the system.

In chapter 4 factors influencing the rentability of automatic milking are explained. Environmental and energy aspects receive more and more attention in the dairy sector.

In chapter 5 possible relations between automatic milking, production level and environmental issues and energy use are outlined. Automatic milking will also have consequences for the service organizations in the sector, like the dairy cattle improvement organizations and the dairy industry. This is described in chapter 6.

In chapter 7 the interest of dairy farmers for automatic milking is estimated. Types of farms and conditions that are likely to favour the introduction of milking automats on dairy farms are mentioned. Aside of economical aspects social factors will be very important. The analyses is based on the situation in the Netherlands. In chapter 8 some impressions from other countries about the prospects of automatic milking are presented.

Finally, in chapter 9 an overview of research questions is listed.

1. INTEGRATION INTO FARM MANAGEMENT AND FARM STRUCTURE

For proper farm management it is essential to know whether an automatic milking system needs permanent or periodic monitoring. This study is based on the assumption that in the end a few personal inspections per day will suffice for monitoring. This means that besides the automatic milker as such, a management system should be developed which can take over the farmer's supervision duties during the milking process. The system will be developed to realize this aim and consequently to create a fully automatic milking system.

The performance of the system to a large extent depends on the readiness of cows to call at the milking robot spontaneously or, otherwise, the presence of a system to bring the cows to the milking system. The desired frequency of milking also determines whether the system can be integrated into the farm operations. When the cows are to be milked more often than twice a day, they will have to stay permanently near the milking facilities. This has an effect on e.g. grassland utilization. Cows will have to enter the milking unit as clean as possible. Much attention will have to be paid to the detection and treatment of problem cows. As it is assumed that the farmer will supervise the herd periodically only, he will have to rely on a management information system to monitor the milking of the cows. Problem cows will have to be detected with sensors. Below, the various aspects are dealt with.

1.1 Housing

For fully automatic milking it is desirable that the cows spontaneously visit the milking automat several times daily. This could be achieved by combining the milking process with the supply of concentrates, for which purpose a milking point can be combined with a feeding station. If concentrates are given during milking, many cows will be prepared to call at the milking automat several times a day. But the question is how many cows under different conditions will visit the unit too infrequently. Cows will also experience a certain pressure to give off the milk several times a day. Especially with mixed feeding, where often a considerable part of concentrates are provided at the feeding rack, it is most questionable whether the animals will enter the milking automat of their own accord. It is anticipated that the problems will be greater the more often the cows are expected to be milked (e.g. 4 - 5 times daily compared with 2 - 3 times).

If a cow refuses to call at the milking automat at the required frequency, compulsory walking routes should be laid out in the house, for which various options are conceivable. For instance, the cow is identified in a selection gate on the route and then sent to the milking robot. When leaving the milking automat, she is selected again. Animals showing deviations in health or behaviour are sent to a holding pen.

The most rigid controlling system is the presently used milking procedure: the cows are brought to the waiting area, where they are gradually forced towards the parlour. As a matter of fact, a system which controls animal flow will set higher requirements on the layout of the livestock house than a system in which cows come to the milking automat freely.

It is evident that a milking system which allows the cows to come by themselves, can result in delays in the milking process. At various stages of the automatic milking process the cows are not likely to hurry. In case of slow movement through the milking process, less cows can be milked in a certain time. The speed at which a cow moves through the system may be influenced by both the feed supply and technical measures (driving bar). In research at 'De Vijf Roeden' Experimental Farm (IMAG-DLO) Duiven, attention is being paid to this aspect. Initial research results reveal that cows are milked voluntarily 3 - 4 times per day (1,2,3,4) when use is made of a certain degree of presence control (e.g. collecting the last few cows still to be milked). The location of the milking automat inside the house and the layout of the house can also influence the frequency of visiting the milking unit. Consequently, quite some variation has been found, depending on how the experiments have been set up.

When a new livestock house is to be built, the automatic milking system can be installed right away on the ideal spot. There is no need to install a milking parlour then. If the automatic milking system is to be installed in an existing building, it is necessary to examine whether the place of the present milking parlour is also the right place for the new system. For a system to be visited by the cows voluntarily, they will have to be housed around the automatic milking system as much as possible. This is less strict for a cow driving system, which can also be used in combination with the present setup of the building.

1.2 Nutrition

Concentrates can be provided in the automatic milking system and/or in special feed stations. Forage will continue to be given at the feeding rack. Mixed feeding systems have the disadvantage that providing concentrates in the automatic milking automat is hardly necessary, so that the enticing effect on the cow is practically lost. When cows are housed throughout the summer, conserved forage or freshly mown grass can be fed. Providing the same type of conserved forage throughout the year can have a favourable effect on the stability of the cow's rumen flora and fauna. This can result in smaller fluctuations in the fat content in milk. The system implies, however, that more concentrates have to be given. It is also possible to apply zero grazing, with fresh grass being fed to cows housed in summer.

Changing over to more frequent milking will cause the milk yield to rise, and consequently urge the need to adapt the rations accordingly. It is anticipated that the cows will be fed more evenly distributed over the day. Whether yield-based group accommodation is practicable or desirable together with automatic milking, cannot be judged yet.

1.3 Grassland management

With frequent milking, cows are kept near the milking system. This will certainly apply when there are no longer fixed milking times. In that case, three options of grassland utilization remain:

- limited grazing,
- zero grazing, with fresh grass being fed in summer to housed cows,
- summer feeding, with conserved forage being provided throughout the year.

Limited grazing or providing an outside exercise area seem to have convincing disadvantages as they cause quite some organizational problems. If the cows are allowed to graze for a few hours per day, the farmer will have to release and later to collect them. If it is entirely left up to the cows whether to go outside or not, they should return to the building spontaneously after a certain period of time, which in practice they are not likely to do. Furthermore, grazing conflicts with an efficient automatic milking practice. It is not possible for an automatic milking system to be evenly occupied throughout the day if the cows are allowed out to graze.

In combination with automatic milking, zero grazing and summer feeding will be the most suitable options. There are still uncertainties, though, as regards animal welfare and health. It is known of some farms using these feeding systems that the cows have more foot problems. But this does not apply to all farms. Providing an outside exercise area might have advantages after all.

Forage production for zero grazing and summer feeding is more expensive. The costs of contract work are higher or more has to be invested in machinery. Summer feeding simplifies grassland management, and the cows' diet is more constant over the year. Zero grazing entails certain operations having to be carried out during the day so that the stockman is more tied to the farm. Providing conserved forage is somewhat easier to automate, but it is also more laborious than grazing systems. Therefore, for several reasons, it remains desirable to find ways to include a few hours of grazing (e.g. 4 - 6 h a day).

In traditional grassland management, mowing is subordinate to grazing. In cases where the grass is harvested only by mowing, the question will arise what grass dm yield levels are optimal on the farm. If forage is only provided to housed cows, the options of mechanized forage feeding have to be considered.

If grazing is abandoned, the options for land use are widened, as concentrate replacers can be grown in addition to grass.

Zero grazing and summer feeding, with dairy cows being concealed from sight, will to a large extent effect the landscape, which would then be decorated with young stock, dried-off cows and beef cattle only.

1.4 Hygiene

Requirements on the quality of milk will become even more strict in the future. Therefore, it is an absolute must for cows visiting the automatic milking system that their udders and teats are clean. Proper udder and teat hygiene is to be achieved with the smallest possible amount of water in order to minimize the risk of mastitis and reduce inconvenience to the environment due to the discharge of rinsing water. How to materialize this, is a question to be dealt with by research institutes. A solution might be a pre-treatment cubicle where udder and teats are cleaned automatically before the cow is allowed to enter the milking system. The requirement of hygienic conditions in the house is also likely to be tightened when milking is done automatically.

A consequence of automatic milking is that cows have to be kept inside or near the livestock house.

1.5 Management

Traditionally twice a day, the contact between herdsman and cow will become less when cows are milked in an automatic system. Farmers will perform their supervisory task in a different way. Detecting mastitis in cows is most essential for automatic milking to succeed. Heat and disease detection will also require attention. The latter can also be catered for by the farmer making time for this purpose at other moments of the day (2 or 3 times). In addition, detailed information on the individual cow can draw the farmer's attention to any deviations or problems. Such detailed information can be provided for by sensors for mastitis, heat and disease. This 'management-by-exception' (recording of deviations) will have to be highly sophisticated in order to be able to keep "an eye on the herd".

At the milking point there should be a separation facility where cows, if necessary, can receive special treatment and be milked individually. This applies to cows infected with mastitis in particular. This should be taken into account in the livestock house layout and the control techniques.

1.6 Research aspects

Research on farm management will especially deal with the desired milking frequency in relation to yield level and stage of lactation. This to a large extent determines the consequences of automatic milking for the farm layout, the capacity of the automatic milking system and the farm management (grazing compared with housing throughout the year). Furthermore, more detailed information should be collected on the readiness of cows to voluntarily enter the automatic milking system at various milking frequencies. Subsequently, the location of the system in the house and the presence of any cow driving systems need to be investigated. Attention will also be paid to the effects of more frequent milking and of limited or no grazing at all on feeding. In combination with an automatic milking system, the hygienic standards in the house must be very high. To achieve this, existing techniques may be combined. It is conceivable that new systems will be developed to optimize farm management and structure. Management-by-exception (recording of deviations) will be essential with automatic milking. To detect deviations in cows, sensors will have to be tested and introduced on farms. Methods for the automatic separation of cows (or their milk) will have to be further developed and adapted to the farming practice. Especially cows with mastitis will have to be automatically separated from the normal milking process.

2. EFFECTS ON THE FARMER

Despite all innovations, the average farmer still has a seven-day working week and working hours which are above standards generally accepted in society. In addition, he has to deal with an ever-increasing complexity of the production process, which is partly caused by the demands of society as regards his farm management. For that reason it shall be estimated what the effects will be of automatic milking on the physical workload and on the degree to which farmers are tied down by their business.

With automatic milking goes an extensive management system which takes over the farmer's supervision during the milking process. It is important to stress how important this management system is to the farmer and his family.

2.1 Labour demand and workload

Once it has been developed to maturity, the automatic milking system, in combination with sophisticated process automation (sensors), is expected to bring about a considerable economy of labour (5), the degree of which, however, can hardly be estimated. Automatic milking will result in a lower physical workload. The stockman's function will shift to more general supervisory work. Only in case of failure he will have to take action.

For the near future, there will be no mature comprehensive system as yet. The first milking automats to be introduced on farms, the herdsman will likely have to stay near the unit to provide assistance for attaching the cluster to some of the cows. At first it will appear to be difficult that supervisory duties are taken over by a management program. Probably, the stockman will still have to be present for separating any problem cows. Later, on-going technical optimization will probably result in a system which has the farmer on call with an ample time interval.

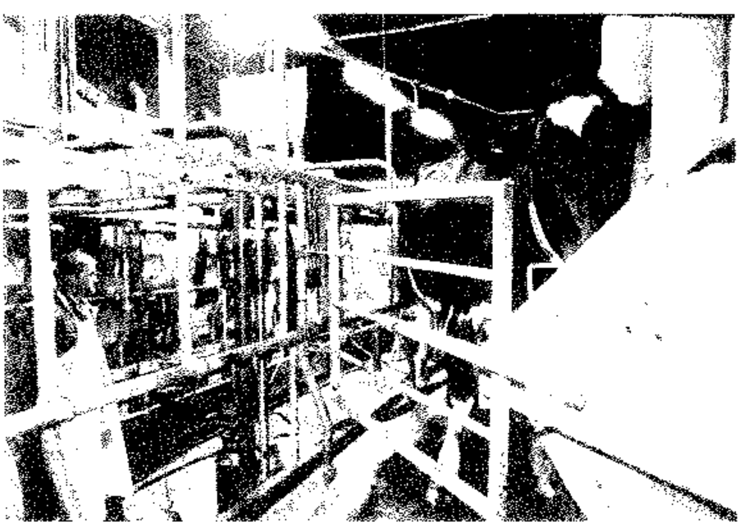
2.2 Restraint on the farmer's freedom

As stated before, there is strong doubt whether at short notice farmers will be less tied down by their business, with a simultaneous economy of labour. To some farmers the system may even make their work more stressful. For, if a farmer is continuously on call with a small time interval, this could be experienced as worse than the usual milking process. This will certainly be the case if the level of automation has not been adequately tuned to the farmer.

In the long term, with increasing reliability of the system, the farmer will clearly be tied down less by his farm. He will then be able to plan his own time as he no longer depends on fixed milking hours. To the farmer and his family this offers opportunities to have a life-style which is more in line with that of people working in other sectors. Major factors in the introduction of any type of automation on the farm, and in particular where automatic milking is concerned, are the farmer's attitude towards changes in the nature of his work, the knowledge required and the binding to his business. At this point of time, however, this might not be the most important point. Pioneers may be expected to cope with bigger burdens (if they face some initial disappointments), have a more profound knowledge and have a more flexible attitude.

2.3 Management support

The emphasis in farm management of the last few years has been more on the qualitative improvement of production than on greater quantities, which is mainly due to the introduction of milk quotas. When the daily check during milking is omitted, the interchange between farmer and cow, the farmer's observations will to a large extent have to be taken over by the automatic milking system. The farmer can, indeed, use part of the labour saved on actual milking for a number of observation rounds of the herd during the day. This can be done very effectively, especially if performed on the basis of attention lists as produced by the management system.

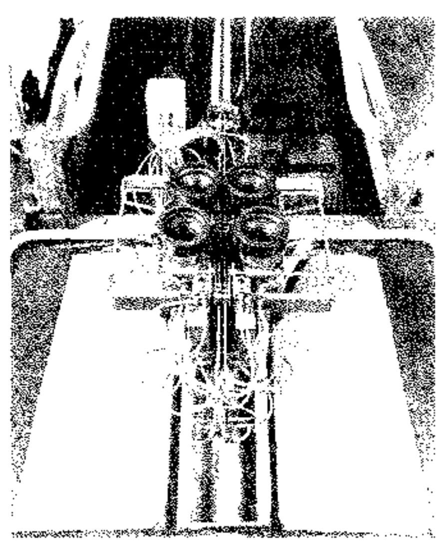


Automatic milking requires less physical labour.
Supervision remains necessary.

By combining information obtained from various sensor types (milk yield, concentrate rations, conductivity of milk, temperature and animal activity) the automatic milking system can offer this option. By means of these sensors, the farmer receives information on (udder) health and fertility (6). The practical success of the automatic milking system will largely depend on the reliability of information which the Management Information System (MIS) can offer the farmer. On the basis of this information animals shall be separated (isolation boxes) and/or prevented access to the automatic milking system. In this way the milk quality can partly be monitored (separate collection of types of milk). A sensor for milk composition will also be desired. Especially on large farms the automatic recording of process data can reduce the mental load on the farmer. For this it is necessary for the data to be expressed in simple management figures. The future farmer is assumed to have the knowledge required for interpreting the data. A different type of knowledge and insight will be demanded of the farmer. Not every dairy farmer will be interested in this.

2.4 Research aspects

There should be more insight into the potential labour economy achieved by automatic milking. Insight into the work pattern can be obtained by means of time studies on farms where cows are milked automatically. This applies even more to a well-functioning complete automatic milking system (i.e. including a management program), once it should become operational. In such a system the management-by-exception concept should make decisions during the milking process, e.g. separating cows or their milk. Research is required into the combining of attention items to useful practical information. Furthermore, research will have to work out the presentation of data to the farmer. It is important that data are converted into unambiguous management figures.



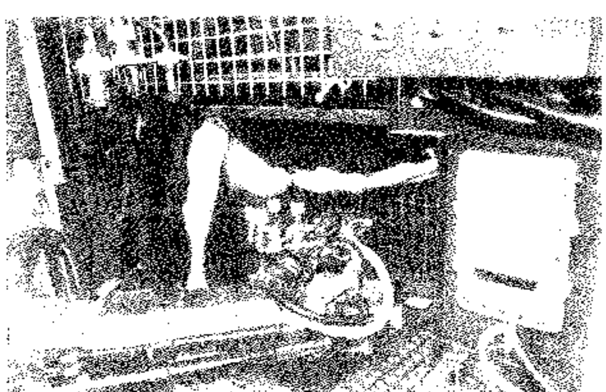
Milking frequency and milking technology are aspects of automatic milking which require further research.

3. EFFECTS FOR THE COW

Higher yields and milking frequencies must result in a longer total time that the teat cups are attached to the cow. This is an additional load on the cow which has to be minimized by adequate milking technology. Consequently, automatic milking will increase the need for technology geared more to the (individual) animal. This implies that it has to be formulated more accurately what the needs of the animal are. In addition, an inventory has to be made of effects of a new or improved milking technology and of changes in milking frequency on milk yield, milk composition, milk quality, teat quality, animal health and animal behaviour. Milking without direct human supervision also requires safeguards to prevent unfavourable effects on animal health and milk quality.

3.1 Milking technique

The better the milking technology has been adapted to the cow, the longer she can stand being milked. When cows are milked more often a day, matters such as optimum pulsation control and vacuum level become highly important. As to teat quality, research results have to some extent been ambiguous, but there are indications that a very high milking frequency (more than four times a day), has undesirable effects. It is known from experience that an adequate layout and adjustment of the milking machine allows cows to be milked three times a day. Research will have to be performed to find out when the present milking technology is less suitable for higher milking frequencies with the consequently longer total milking times. In addition to well known items such as milk transfer height and vacuum, research is also needed into improvements in milking technology which are made possible specifically by automatic milking.



A proper hygiene of cows is necessary for automatic milking.

3.2 Milking frequency

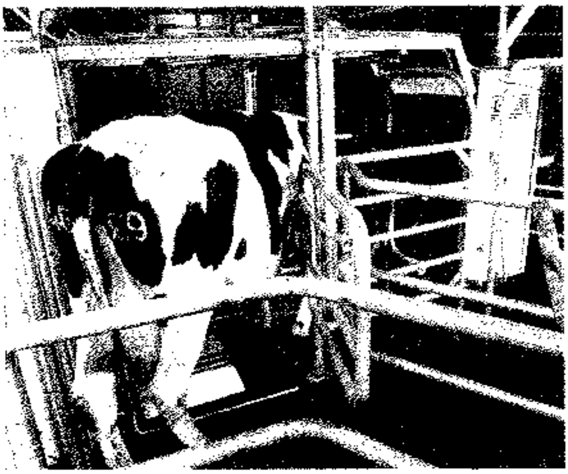
The number of cows to be milked in an automatic system in particular depends on whether the equipment is used efficiently and on the frequency of milking. Research has shown that cows are prepared to be milked voluntarily 3 - 4 times a day (1,2,3,4). At De Waiboerhoeve Experimental Farm it was found in experiments with an automatic milker that there is some hesitation among cows to come voluntarily to be milked more often. What the optimum milking frequency is exactly, has yet to be found, but it is clear that it is in between 2 and 4 times a day. In that case a number of 25 - 40 cows (including dry ones) per milking automat or robotarm is considered. For most farms this would imply that they need two or three units. The number of milking automats, the preferred milking frequency and the degree of freedom for the animal in the system will have to be balanced against each other.

The question also arises whether it is permissible with more frequent milking to milk sometimes three or two teats instead of all four. From the technical point of view it is not easy to realize and perhaps even inefficient if all teats must be spotted each time. If first location runs are only partly successful and a new location run has to be started to find teats still undetected, the animal will have to stay in the milking system longer. If the herdsman is to be called in such cases, this also takes time and is inconvenient.

3.3 Production level

Both experimental and practical results have shown that higher milk yields are a consequence of a raised milking frequency. The effects of more frequent milking on milk yield have been studied in a number of research projects in the Netherlands in the last few years (1,2,3,7,8). The increase in milk yield appeared to vary between 10 and 15 %. It was also found that this increase was linked to a reduction in fat content. Because the effect on protein content was less apparent, the fat to protein ratio became narrower. The effects of various milking frequencies appear also to be related to the stages of lactation. It seems that the greatest effects on production need necessarily become apparent in early lactation. This publication further assumes a 10 - 15 % increase in milk yield and a slight decrease in milk and protein contents of the milk.

Automatic milking can only succeed if cows visit the milking unit voluntarily



3.4 Milk quality

The milking interval also affects milk quality. According to foreign literature the somatic cell count (SCC) is lowered when the milking frequency is raised (4). Research carried out at IMAG-DLO rechearch farm showed the SCC for both test and reference groups to be on the same low level of an average of 150 000 per ml milk (3). It has also been observed, however, that a slightly raised milking frequency is accompanied by a lower cell count (7).

A real risk of stepping up the milking frequency is that of a raised free fatty acid content (9), as was confirmed in other research (7). It is generally known that there can be wide variations among individual animals. For some cows a raised lipolysis is already found when they are milked three times a day. There are indications (10) that the risk is greater when the quantities of milk are small. It has to be found in research which animals can be milked three or four times a day without problems with lipolysis occurring.

The total bacterial count, a major quality indicator, is hardly affected by the frequency of milking but all the more so by the frequency of cleaning. Research by the CMMB, the (former) Research and Extension Centre for Milking, Milk Hygiene and Farm Dairying in the Netherlands, have shown that the bacteriostatic action of fresh milk has a favourable effect on the bacterial count. These studies were based on as well model situation (11) as practical experiments. These studies were based on as well model situation (11) as practical experiments. The required cleaning frequency depends on the ambient temperature. Under favourable conditions, twice cleaning daily is likely to suffice. It has to be remarked that the cleaning circuit in an automatic milking system can be much smaller than in a usual system, so that the water consumption per cleaning can be reduced.

In addition to the quality aspects in relation to a raised milking frequency, the absence of supervision has other consequences for the milk quality. Cleaning of the udder should ensure that the teats are really clean. Research has shown (12,13) that technical solutions for the cleaning of teats are promising. But this does not solve the whole problem. Milk of poor quality can also be due to the fact that udders are dirty. So far, automatic detection of dirty udders could not be realized. Therefore, automatic milking will require the hygienic conditions in the house to be optimal to ensure that each cow is milked with her udder being fairly clean. Under such conditions, a dry cleaning procedure of the udder will be preferred.

Cleaning the udder should also stimulate the let-down of milk. Research has shown that no problems are to be expected here (14).

3.5 Health and breeding

A PR/CMMB literature study (15) has shown that higher yields are generally accompanied by healthier udders and consequently a lower cell count. Also, despite level of production, the total number of cells excreted in healthy cows was found to be constant throughout the lactation period. This implies, as a matter of fact, that the scc per ml of milk is not constant. Other PR research (8) has shown that stepping up the milking frequency to three times a day does not affect udder health. Research in the USA (16,17) indicates that three times milking helps to prevent mastitis. Furthermore, wearing off of the udder was reported to be less (18,19). But raising the milking frequency to three times a day causes the risk of cross-infection through the milking machine to increase by 50 % (16,17).

In general, the higher milk yield will require a better health and fertility management. How to realize this, remains an item of research. A system in which the animals are housed all-year-around or are only allowed a limited outside exercise area, will have to deal with more foot and leg problems. Possibly, animal breeding programs might help here in that the animals are selected for their resistance to such problems.

Something similar will apply as regards the uniformity of the udder shape. This aspect will certainly become more important than it already is. A number of animals will have to be culled because of these characteristics. Developments such as embryo cloning and embryo transfer can help increase the uniformity of the herd. More detailed research is needed to find out which characteristics ongoing automation will require as regards the exterior traits of animals. The present breeding programmes have only limited scope for selection on exterior traits. With a value of about 0.3, the heritability of these traits, however, is fairly high (20). This means that udder characteristics in a herd can be adequately corrected within two generations, if desired (21).

3.6 Animal behaviour and welfare

When high yielders are milked at intervals of 9 and 15 hours, they appear to lie down less during the last few hours before milking because of the greater pressure in the udder, especially during the long interval at night. From raising the milking frequency it may be expected that this inconvenience is ended. Indications for this have been found in actual research (22,23).

So far, not much is known about the behaviour of the animals in a voluntarily milking system (both in and outside the milk automat). Their behaviour is indeed a determining factor for the success of a system for automatic milking.

3.7 Research aspects

Above all, research will have to deal with the milking frequency that creates the optimum situation for an efficient production, for animal health and welfare as well as for milk quality. Animal behaviour is also of great importance with regard to cows spontaneously visiting the milking automat. The milk quality must be closely monitored, especially the formation of free fatty acids. The technology of a milking system with three to five times milking a day needs further research. To the cow, the milking process should be an agreeable experience. Attention should be paid to finding the optimum udder form and teat placement for automatic milking.

4. PROFITABILITY

An automatic milking system will require a substantial capital investment in machinery, management program and housing equipment. The decision whether an investment will be made in automatic milking will in most cases arise when the old milking parlour has to be replaced or renovated. Investments in adaptations of the old parlour will then be balanced against investments in an automatic milking system and the adaptations required for integrating the system into the existing dairy house.

Because automatic milking demands various modifications in farm management, there will not only be changes in investment costs but also in a number of yields and costs. Raising the milking frequency entails an increase in milk yield by about 10 to 15 %. Under the constraints of the quota system this must result in a smaller herd and consequently in a smaller amount of forage needed. If the raised milking frequency requires the cows to be housed all year round, the costs of forage production and feed supply will increase. The shrinking herd size will result in a lower figure for annual replacement costs. In the long term, depending on the structure of the labour capacity, (external) labour may become redundant and discharged or deployed in a different way.

By making calculations for the farm, various of these effects can be determined. These calculations have been made with the PR-dairy farm-model (34).

To be able to calculate the profitability of an automatic milking system, three major items have been considered which determine the maximum acquisition value. The first item is the outside grazing or indoor-feeding-system. Secondly, attention is paid to milk yield and composition, and the third item concerns the investments in a usual milking parlour with desired automation of cow data as an alternative to an automatic milking system. In addition, attention is briefly paid to the labour factor.

4.1 Grazing or feeding system

In cases where no grazing at all or only very limited grazing is possible, a transition will have to be made from the present grazing system to zero grazing (feeding fresh grass in summer) or summer feeding (feeding conserved forage throughout the year). Calculations show that, at unchanged level of milk quotas, the transition from an extensive grazing system, e.g. day and night grazing (unlimited grazing, O4 system) to overnight housing with supplementary feeding of 3 kg DM forage maize (limited grazing, B4 +3 system) will generally incur higher costs. A transition to indoor feeding, e.g. zero grazing (Z) or summer feeding (S) will cause even higher costs. Where profitability is concerned, the system which causes the cow to do most herself, is the most attractive one.

Table 1 shows the average decrease in gross margin of output minus variable costs due to changing over to other grazing or indoor feeding systems, expressed in guilders per hectare. These results are worked out in more detail in Appendix 1.

Table 1: Average decrease in gross margin (Hfl/hectare) when changing over to a different grazing system or summer feeding (S) based on unlimited grazing (O4), limited grazing with supplementary feeding 3 and 6 kg DM forage maize (B4 + 3 and B4 + 6)

From/to	B4 + 3	B4 + 6	S
O4	200	350	575
B4 + 3	.	150	375
B4 + 6	.	.	225

Table 1 shows that the costs of changing over from unlimited grazing (O4) to limited grazing and supplementary feeding of 3 kg DM forage maize (B4 + 3) average Hfl 200 per hectare. By stepping up the supplementary feeding (B4 + 6) the costs increase to an average Hfl 350. Changing from unlimited grazing to summer feeding costs an average of Hfl 575 per hectare. Changing from limited grazing to summer feeding costs Hfl 225 - 375. The major causes of the lower gross margins with limited grazing and summer feeding are the higher costs of forage production and land spreading of slurry.

4.2 Milk production and composition

Table 2 shows the average increase in gross margin per hectare expressed by a 1000 kg higher milk yield (from 7000 to 8000 kg), a 0.15 % lower fat content and a 0.05 % lower protein content. These effects are shown for two milk quota levels and for the different grazing systems and summer feeding. The effect on milk yield and composition in everyday practice will depend on a range of factors. Appendix 1 shows how the increase in gross margin is effected. Particularly effective here is a decrease in total costs. This is the combined effect of the smaller herd with lower cattle costs and (for the farm with milk quota of 15 000 kg per hectare) less forage to be purchased.

Table 2: Average increase in gross margin (Hfl/hectare) due to higher milk yield per cow from 7000 to 8000 kg and lower fat and protein contents by 0.15 % and 0.05 % respectively, at quota levels of 10 000 and 15 000 kg/hectare, unlimited grazing (O4), limited grazing with supplementary feeding 3 and 6 kg DM forage maize (B4 + 3 and B4 + 6) and summer feeding (S)

Grazing system	Milk quota levels	
	10 000	15 000
O4	70	190
B4 + 3	110	200
B4 + 6	.[1]	200
S	100	140

[1] No calculation has been made for this situation because it is not realistic

The calculations for Table 2 do not include any favourable or adverse effects as regards animal welfare, health and life expectancy. Apart from that, these effects have not yet been quantified either. In most cases, combining the increase in gross margin due to higher milk yields and the decrease in gross margin due to changing over to another grazing or indoor feeding system results in a lower gross margin. For changing over from unlimited grazing with a milk yield level of 7000 kg per cow to summer feeding with 8000 kg per cow, the average decrease in gross margin amounts to approx. Hfl 450 per hectare. For changing over from limited grazing (B4 + 3) with a milk yield level of 7000 kg per cow to summer feeding with 8000 kg per cow, the average decrease is approx. Hfl 250 per hectare.

4.3 Investment in traditional milking parlour

When the maximum acquisition value is calculated for an automatic milking system, the investment in and the annual costs of the alternative milking parlour have to be taken into account. Capital which would normally be invested in renovation or replacement of a traditional milking parlour can now be invested in an automatic milking system. In actual practice there are different levels of investment for furnishing milking parlours and the automation of cow data handling. These differences in investment level causes differences in the maximum acquisition value for the automatic milking system.

Table 3 gives an impression of three possible investment levels for equipping parlours and the automation of cow data handling. Details of the calculations are given in Appendix 2.

Table 3: Investments in milking parlour and related automation, together with annual costs involved at different herd sizes and different investment levels (Hfl/cow); investments rounded to Hfl 25, annual costs rounded to Hfl 10

Investment level	Dairy herd size 40-50		70-80		>100	
	Invest-ment	Annual costs	Invest-ment	Annual costs	Invest-ment	Annual costs
Low	975	210	900	200	875	200
Average	2100	490	2025	470	1800	420
High	3775	880	2800	650	2400	550

In table 3 large variations in investments in the milking parlour are shown. These are largely ascribable to the wishes of the farmer as regards layout and equipment of the parlour and related automation. In addition there is the effect caused by the larger scale, which is seen especially with the higher investment levels.

With a view to its functions, the automatic milking system can best be compared with a milking parlour which has a high level of investment.

4.4 Maximum acquisition value for automatic milking

Profitability of the automatic milking system is expressed in the 'maximum acquisition value'. This is the amount of capital which may be invested in the system to achieve the same net farm result as with a traditional milking parlour. If the investment exceeds the maximum acquisition value, net farm results will be smaller. And if the investment is lower, results will be higher. In the following equation the Maximum Acquisition Value (MAV) is calculated by accumulating the Returns from the increase in milk yield (R_{my}), the Costs of changing the grazing system (C_{gs}) and the savings in Annual Costs by not investing in a traditional parlour (AC_{tp}) and subsequently dividing this total by the estimated Annual Costs of the automatic milking system (AC_{am}).

$$MAV = \{(R_{my} - C_{gs} + AC_{tp})/AC_{am}\}.$$

In Appendix 3 the maximum acquisition value for the automatic milking system has been calculated for four different farm situations. The calculations were based on annual cost percentages of 20 - 30 % (interest, maintenance and depreciation) and on the various investment levels for the traditional milking parlour.

The capital outlays are given in Table 4, together with the investment levels needed, depending on prices and capacities applying indicatively at the time.

Table 4: Maximum acquisition value (x Hfl 1000) per farm for automatic milking system at 2 investment levels for traditional milking parlour, 2 annual cost percentages for the automatic system (20 & 30) and 3 herd sizes; 4 farm situations are characterized by changing over to other grazing system and area-related milk quotas (10 000 and 15 000 kg/hectare); estimated investment requirement (x Hfl 1000) per farm

Grazing system		Milk quota	Investment level	Dairy herd size					
				40-50		70-80		> 100	
from	to			30	20	30	20	30	20
O4	B4+6	10 000	high	95	143	101	152	108	162
			average	37	56	56	84	61	91
O4	S	10 000	high	82	123	79	119	78	116
			average	24	36	34	51	30	45
B4+3	B4+6	15 000	high	121	182	145	217	169	254
			average	63	95	100	150	122	183
B4+3	S	15 000	high	115	173	135	202	156	233
			average	58	86	90	135	108	162
Estimated required investment				200 - 275		275 - 400		300 - 550	

Notes: 1. O4 = unlimited grazing
B4+3 = limited grazing, supplementary feeding 3 kg DM forage maize
B4+6 = limited grazing, supplementary feeding 6 kg DM forage maize
S = summer feeding

2. When changing over to B4+6 system, no higher milk yield was taken into account; when changing over to summer feeding, it was.

Table 4 provides a variation in the maximum acquisition value for each situation. This variation depends on estimated values for total costs of the automatic milking system and the layout of the milking parlour selected if no automatic milking system would be installed. The annual costs of the automatic milking system are based on cost percentages of 30 % (depreciation in 5 years) of the replacement value and of 20 % (depreciation in 10 years). The actual level of this percentage is presently not known but it is more likely to tend towards 30 % rather than 20 %. In addition to this percentage, the layout of the milking parlour which would be selected alternatively plays an important role. The principles have been included in Appendix 2 and Table 3.

Transition from unlimited grazing to summer feeding involves high area-related transition costs (see Table 1). The larger the farm, the higher these costs, without being adequately compensated for by non-investment in an alternative milking parlour. The consequence is that for this situation the maximum acquisition value becomes less when the farm size increases. For a transition to limited grazing (B4 + 6) the costs of transition will be less. In this situation, however, no increase in milk yield per cow has been assumed because, even with limited grazing with supplementary feeding of 6 kg DM forage maize, it is not deemed possible that the cows are milked often enough to realize such yield increases. In the end, the maximum acquisition value increases with the farm size.

Changing from limited grazing with supplementary feeding of 3 kg DM forage maize (B4 + 3) to limited grazing with supplementary feeding of 6 kg DM forage maize (B4 + 6) entails relatively low transition costs. As a result, the annual costs made available due to non-investment in a milking parlour, can to an almost full extent contribute to the maximum acquisition value for the automatic milking system. Consequently, this maximum acquisition value is higher than in a situation based on unlimited grazing (O4). If, with limited grazing with supplementary feeding of 6 kg DM forage maize, a higher milk yield per cow would nevertheless be possible, e.g. because of more frequent milking during the winter, a slightly higher maximum acquisition value is achieved than Table 4 gives for the system.

It appears clearly that with a decision in favour of a lower investment level for the milking parlour (average level) the maximum acquisition value for the automatic milking system becomes lower. With a low investment level for the milking parlour there is no leeway for an investment in automatic milking. As a consequence, individual wishes as to the layout of the milking parlour play an important role in the profitability of the automatic milking system.

In all cases the calculated maximum acquisition value is lower than the prices referred to for the automatic milking system at the time. It has to be stated here that price levels and capacities of automatic milking systems are provisional values.

The various suppliers give indications for the required investments for a herd of 40 - 50 cows of Hfl 200 000 - 275 000. The latter amount applies to a system which can handle more than 50 cows. This implies that the system might work below capacity on the farm with 40 - 50 cows. It is evident that this must adversely affect the profitability of the system.

4.5 Labour economy and reduction of physical workload

Another important point is the labour economy which could be achieved with a fully autonomously operating system. For the immediate future it is assumed that no real labour economy can be achieved. But it could be possible to reduce the workload as the automatic milking system can take over a great deal of the physical efforts. In this period the farmer's task will shift more towards supervision. For that reason no cost reduction due to actual labour economy has been taken into account. When the system has established itself, a real labour economy seems to be feasible, with the farmer having to attend the milking process only from time to time.

Economy in labour can be effectuated by enlarging the farm by acquiring quotas for more milk, by expanding business into other sectors, by becoming a part-time farmer, or by discharging a redundant worker. Discharging labour will only be possible for large farms. In Table 4 this refers in most cases to farms with over 100 dairy cows. Then the maximum acquisition value will increase more. If a farm with more than 100 dairy cows can reduce its labour force by 0.5 - 1 full-time worker, this means an economy in annual labour costs of Hfl 32 500 - 65 000. As a result, at a 30 % annual cost level the maximum acquisition value will increase by an amount of Hfl 108 000 - 217 000 (see Appendix 3 for calculation).

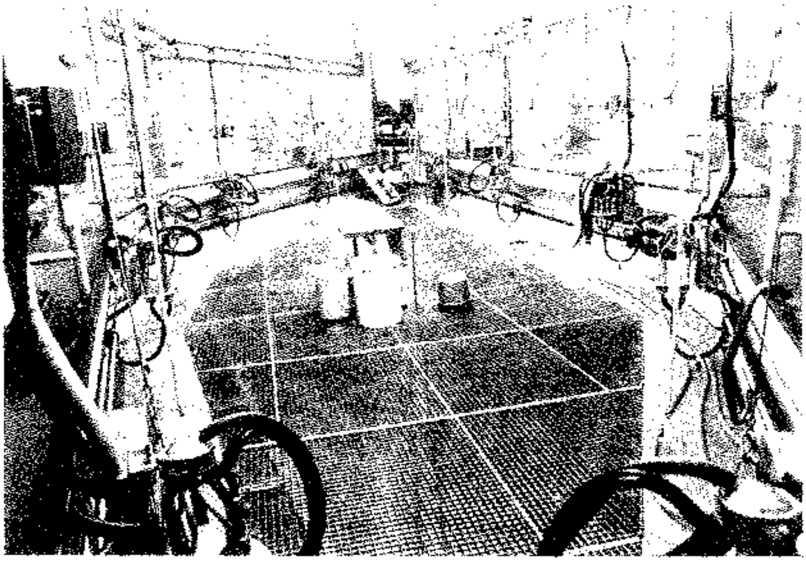
4.6 Conclusions

It can be concluded from the tables and figures in this chapter that the maximum acquisition value highly depends on the alternative for automatic milking. Large herds will require lower investments to be made per cow because of the effect of the larger numbers; furthermore, the surplus capacity for the automatic milking system may be smaller.

Transition to a more intensive grazing or indoor feeding system will render a considerable decrease in gross margin per hectare, whereas the yield increase will produce a gross margin increase. Furthermore, very decisive for the profitability will be the type of parlour and the degree of automation chosen by the farmer, if he is not to invest in an automatic milking system. For the time being, the factor of economy of labour will not raise the maximum acquisition value substantially.

Prices now stated for an automatic milking system will decline in the long run, when the system is introduced on a larger scale.

In short it can be stated that it may become an alternative to invest in an automatic milking system for farms where the milking parlour has to be renovated and for those farmers who are open-minded towards innovations and seek to achieve a high level of automation and data processing. The profitability of automatic milking will depend on price levels in combination with the capacity per milking unit, the capacity utilization of the milking system and the economy of labour to be expected in the end.



The investment a farmer is prepared to make in a traditional milking parlour to a large extent determines the capital available to be invested in automatic milking.

5. EFFECTS ON ENERGY AND THE ENVIRONMENT

Far-reaching limiting regulations which concern the environment are being drafted for farms. For that reason the effects on the environment of innovations must be properly inventorized. Of special importance are the utilization of nutrients (N, P and K), the volatization of ammonia into the atmosphere and the run-off and leaching of nitrate into surface water and groundwater.

5.1 Utilization of nutrients/minerals

As stated in Chapter 3, a higher milking frequency will cause the milk yield to increase. A well-functioning automatic system which milks the animals three or four times a day, will raise the yield by 10 - 15 % (approx. 500 - 1000 kg fat and protein-corrected milk per cow). Higher yields imply that less cows are needed on a farm to reach the milk quota. This will bring down the total forage requirement of the herd, if the productive capacity (forage, labour, accommodation) is not used for additional young stock or beef cattle. On self-sufficient farms, this lowered requirement will result in a forage surplus. If less nitrogen is applied to the land, the surplus can be prevented.

Considering the present average milk yield level of 7000 kg and an N application of 350 kg/hectare on self-sufficient farms, a forage surplus due to a rise in milk yield by 500 - 1000 kg, can be prevented if the N application is lowered by 50 - 100 kg N. Model studies at PR (24) have shown that lowering the N application together with a milk yield increase per cow can result in a substantial reduction in ammonia emission and nitrate leaching. These results apply to quota ranges of 7 500 to 17 500 kg milk per hectare. Table 5 shows the eventual effect of higher yields on ammonia emission and nitrate leaching, together with the effect of lower N application.

Table 5: Effect on ammonia emission and nitrate leaching of higher milk yields per cow (kg milk) and of lower N application on grassland (kg/hectare)

	Reduction in ammonia emission (%)	Reduction in nitrate leaching (%)
1. Higher milk yield by 500 - 1000 kg	5 - 10	2 - 5
2. Lower N application by 50 - 100 kg	5 - 10	17 - 35
3. Combination of 1 and 2	10 - 20	>20 - 40

At a yield increase by 500 - 1000 kg milk the ammonia emission is reduced by on average 5 - 10 %. This is especially caused by a more favourable ratio between feed for maintenance and feed for lactation in the ration. A decrease in N application from 400 kg/hectare to 350 or 300 kg/hectare will reduce the ammonia emission by about 5 - 10 %. Combining a 1000 kg milk yield increase with 100 kg less N being applied per hectare will result in a decrease in ammonia emission by more than 20 %. And nitrate leaching, as a result of combining the higher milk yield with a lower N application will be less by 20 - 40 %.

If nitrate leaching is to be reduced even more, the cows should be housed year-round, as this measurement reduces the occurrence of urine patches (except for young stock) and allows for proper management of nutrient supply and a suitable timing of manuring operations. When the cows are housed year-round, the ammonia emission can only be lowered in combination with adapted housing facilities (with corresponding investments).

5.2 Energy

Supported by the strongly developing environmental awareness, largely based on the CO_2 issue, it is the policy of the Netherlands government to encourage energy saving and the use of renewable energy. The policy is laid down in the National Policy Plan (NMP Plus). The general target is that in 1994/1995 the CO_2 emission shall not exceed that in 1990 (25). This requires an annual reduction rate which is equal to that for the period 1973-1985, or rather more than 2 %.

Table 6 shows that the direct and indirect energy consumption per litre of milk on the average dairy farm mainly depends on the extent to which concentrates and fertilizer are applied.

Concentrates are the major energy consumer in dairy farming, followed by fertilizers.

Table 6: Percentages of energy consumption on a dairy farm (26)

	Model[1]) farm	LEI[2]) random sample of farms
Concentrates	48	58
Fertilizer	24	18
Electricity	9	7
Diesel oil	6	5
Machinery	5	4
Buildings	5	4
Services	3	3
Forage storage	1	1

[1]) Energy consumption expressed in percent of total of model farm (Snijders, 1981)

[2]) Calculated average energy consumption expressed in percent of total of LEI random sample of farms on sandy soil (1983 - 1986)

Concentrates and fertilizer are responsible for more than 70 % of the farm energy consumption. When the milk yield increases and the milk quota remains the same, the forage requirement of the herd will be less, so that less N has to be applied. A reduction in N application results in a lower energy consumption. Considered per individual cow, the higher milk yield does cause a higher concentrate requirement, but the concentrate requirement per quantity of milk remains the same at the present production levels.

The energy consumption can further substantially be reduced by growing concentrate crops on the dairy farm. This is easier to realize if the dairy herd is housed year-round. Preliminary calculations (26) carried out for the experimental farm 'De Marke', devoted to environmental research in dairy farming, have shown that the energy consumption can be reduced by nearly 60 % as a combined effect of applying less N fertilizer and growing a substantial part of concentrates for the own herd, when comparing the figures with those of conventional farms of about the same size. This reduction especially refers to the indirect energy consumption. It has to be remarked, however, that the present price situation in the Netherlands makes concentrate growing on the farm less attractive.

6. CONSEQUENCES FOR ORGANIZATIONS OFF THE FARM

Introduction of automatic milking will cause organizations affiliated with the dairy farm, to make adaptations. How and to what extent this is to be done, will depend on the scope of the interface. An essential element is the future level of knowledge required of the farmer. Research, advisory services and education shall ensure a proper supply of knowledge to prepare the present and future farmer for the handling of large management information systems. This chapter, however, will be restricted to the effects for the dairy industry and for cattle dairy herd improvement organizations.

6.1 Dairy industry

Milk quality monitoring as is to be practised with fully automatic milking might require the presence of two milk tanks, so that one can be used for collecting abnormal (e.g. mastitis) milk. Adequate cooling is a requirement to maintain the milk quality. As a result of the continuous influx of warm milk into the tank the milk temperature in the tank may tend to be higher than is the case now. This may imply that the cooling system has to be adapted. Furthermore, the milk quality aspects involved in automatic milking (cell count, bacterial count, lipolysis, frequency of equipment cleaning, cleaning of teats etc.) have to be examined more specifically.

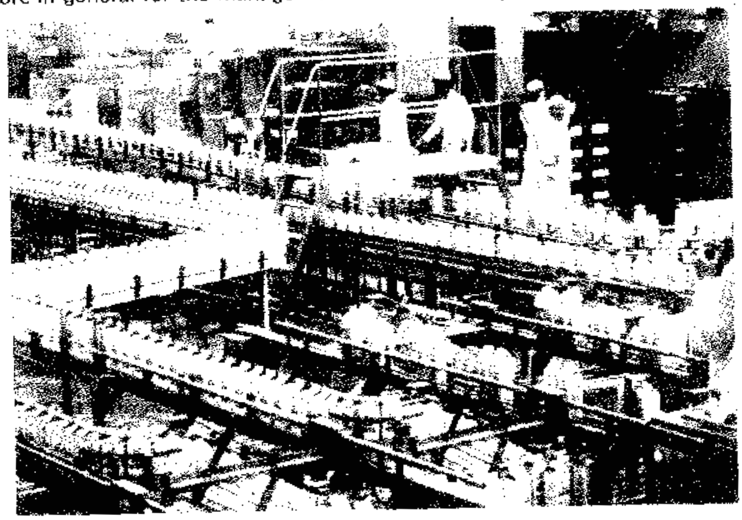
Dairy factories collect farm milk at regular intervals. This can be done throughout the day and even at night. If we assume that automatic milking is performed continuously, the milking process will have to be interrupted from time to time to allow for the emptying and cleaning of the milk tank. An alternative can be a second tank to which the influx of fresh milk can be switched over when the other tank is being emptied. Adequate arrangements shall be made between farmer and dairy factory. It might be possible to combine milk collecting and thorough cleaning of the installation as a whole (including clusters and pipelines) to a single operation.

6.2 Dairy herd improvement organizations

The official milk recording will have to undergo certain modifications if the cows are milked at various moments and more often than twice in a day. Sampling for fat and protein contents will become complicated. The development of sensors for measuring the solids in milk is desirable.

It will also be necessary to modify the calculation routine for progressive total production, milk yield prognosis etc. This intervention on management level is certain to affect the lactation production figures and the derived breeding value prdictions for cows and bulls. Cattle breeding probably will have to be based on the data and/or calculating procedures of the management program that is connected with the automatic milking system.

Automatic milking has far-reaching consequences for milk recording and breeding value assessments, and more in general for the management service of the professional organizations.



More emphasis requires the delivery of quality milk (photo: Zuivelzicht).

7. PROSPECTS FOR PRACTICAL INTRODUCTION

7.1 Introduction

Priority and setup of the applied research on automatic milking partly depend on the number and type of farms which could use such a system. The prospects for the practical introduction of systems for automatic milking depend on:

- milk quality
- quality of equipment
- integration of the system into production process and farm strategy
- effects on profitability of farms (price level of equipment)
- effects on labour conditions
- structure of the dairy farming sector
- future developments expected as to above points.

Within a few years the equipment is assumed to be able to perform well under practical conditions. The need for someone to be present for immediate intervention in case of trouble will gradually become less.

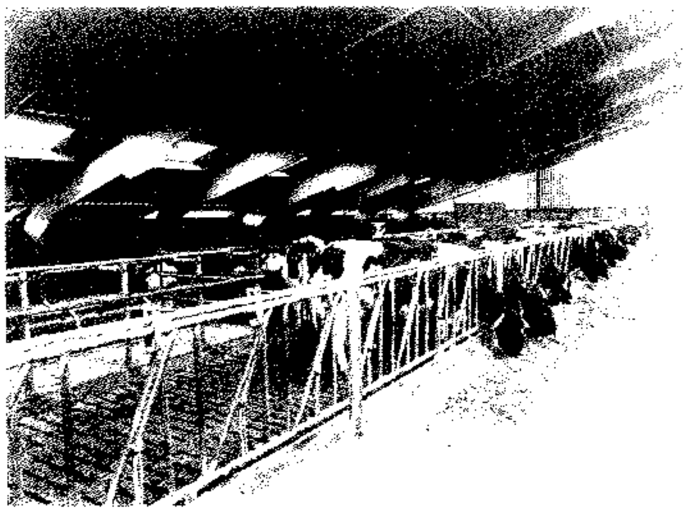
A prognosis of the number of farms adopting automatic milking in the course of years cannot be accurate. At the moment the questions are more relevant whether automatic milking will be suitable for a substantial number of farms and what type of farms these are. This issue will be discussed against the background of Dutch dairy farming, its conditions and developments as expected. This discussion will be supported by a comparison with some other technical developments.

7.2 Present situation in Dutch dairy farming

7.2.1 Herd sizes

Under present conditions, 25 - 40 cows can be handled per milking automat or robot arm. An automatic milking system contains one or two milking points. For that reason the minimum herd size for automatic milking can be set at approx. 30 cows. The larger the herd, the higher the maximum acquisition value (see chapter 4).

The prototypes of present-day automatic milking systems can be applied in combination with cubicle houses only.



In 1990 there were 28 700 farms with 30 or more cows in the Netherlands, which is 61 % of farms with dairy cattle (27). These farms had a total of 1.6 million dairy cows, which is 85 % of the national dairy cattle population. About 4200 farms had 70 to 100 dairy cows, and 1500 had 100 and more dairy cows.

Since 1984 herd development has strongly been influenced by the milk quota system. Recently, the former pattern seems to be appearing again, with the number of smaller herds becoming less and that of larger herds increasing. The boundary between decrease and increase in the number of herds now seems to be at approx. 70 cows per farm.

7.2.2 Housing type

The present types of automatic milking system are only suitable for cows which are not tied, consequently with cubicle houses loose housing only.

In 1987 there were over 23 000 cubicle houses in the Netherlands. Despite the milk quota system, these were 6 % more than in 1984 (27). If this trend continues, the number of cubicle houses may be expected to be more than 24 000 in 1990. This figure covers more than half the farms with dairy cattle. No data are available of the number of dairy cows housed in a cubicle house, but it is likely to be 70 - 80 % of the total number of dairy cows.

By far the major part of the cubicle houses in the Netherlands, or rather 94 %, can contain dairy herds of 40 or more. Herds under 30 dairy cows will hardly be found in cubicle houses. So, for practically all herds housed in cubicle houses there can be a good or fairly good utilization of the capacity of an automatic milking system.

7.2.3 Milk yield per cow

With an automatic milking system the cows can be milked more often than twice a day. As a consequence they produce more milk. Milking more than twice a day is especially found in high-yielding herds. In the USA milking three times a day occurs quite often with production levels of 10 000 kg and more. In a conventional parlour, milking more than twice a day is a high burden on the labour organization.

In 1990, the milk yield in the Netherlands per cow averaged more than 6 000 kg (27). On the grassland and mixed farms with more than 157 Standard Farm Units, (equal to more than 30 - 35 dairy cows) in the LEI random sample of farms, the annual yield even averaged 6 665 kg in 1998/1990. Variation among farms is fairly wide. In the last few years the average milk yield has risen substantially. Therefore, more frequent milking may become an important option for more and more farms.

7.2.4 Milk quotas and feed supply

Milking being more frequent, an automatic milking system will result in a higher yield per cow. With unchanged milk quotas this means the number of cows per herd and per unit of area will have to be reduced. Furthermore, automatic milking implies a transition to limited grazing, zero grazing or summer feeding and consequently lower feed losses and/or a lower forage intake per animal.

The milk quota system has generally resulted in the forage supply situation becoming less tight. Consequently, at the time there does not seem to be a great stimulus to get in on automatic milking to economize the forage situation. This might be different for individual cases where the cattle density is still high or the farmer has bought or leased milk quotas to optimize the capacity of his buildings and equipment. Furthermore, it should be taken into consideration that reductions in fertilizer and feed purchases and in cattle density not only allow for direct costs savings to be realized but also for the ever stricter environmental requirements to be met with less difficulty. Moreover, as automatic milking furthers grass being grown more or less as an arable crop, it can also stimulate other (forage and cash) crops being included in the farming plan.

7.2.5 Labour

Automatic milking brings about a shift as to the labour requirement, away from the milking process towards feeding and forage production. On balance, that is after some time, an economy in labour may be expected (5,29). This economy can be materialized by discharging labour force, alternative employment on the farm or more spare time.

The option to find alternative employment on the farm seems to be scarce, as this will already have been done in past years when the herd size had to be reduced. It would be possible, however, that the introduction of automatic milking stimulates the acquisition or leasing of additional milk quotas or the introduction or expansion of additional activities (see also 7.2.4).

The possibilities to discharge labour force are also limited. This is least difficult where hired labour is involved. But the share of hired labour in dairy farming is very small in the Netherlands. In 1989/1990 nearly 26 000 farms were counted with dairy farming as their sole or main business and more than 157 Standard Farm Units (30 - 35 dairy cows), and where the contribution by hired labour averaged only 5 - 6 % (30). Only on farms with more than 300 - 350 SFU (on grassland farms corresponding with about 70 dairy cows) hired labour was found to have some significance (average about 0.2 full-time worker for 70 - 100 cows and 0.4 - 0.5 full-time worker for more than 100 cows; here, the total labour supply averages 2 and almost 3 full-time workers respectively.) The readiness to reduce the regular labour force will not only depend on labour economy due to automatic milking but also on the suitability of the system to work fully autonomously (otherwise the farmer would become even more tied to his enterprise).

On family farms (farmer assisted by family members) it is hardly possible to employ labour force which has come available elsewhere. Especially for large family businesses the reduction of the physical workload due to automatic milking may be important. It also applies to family businesses that automatic milking may (eventually) result in being tied down to the farm to a lesser extent. Labour economy can also result in more spare time.

A remark to be made when dealing with the labour issue is, that automatic milking results in less direct contact with the animals. Some farmers may consider this to be a loss of a major element in their stockmanship and incompatible with the direction they want to develop their farm.

7.2.6 Financial aspects

An automatic milking system requires substantial investments. Not only do the relevant annual costs have to be recovered (or compensated by a desired reduction in physical workload), but the financial resources also have to be available.

The financial situation tends to vary strongly from farm to farm. On average, the grassland and mixed farms with mainly cattle in the LEI random sample of farms had in 1990 75 - 80 % of own capital (31). Only 5 - 10 % of the farms had less than 50 % of own capital. Consequently, financing an automatic milking system will normally not cause insurmountable problems.

Other factors in the readiness to invest are the presence of financial reservations. These in turn strongly depend on the farming results. After the fairly prosperous years 1987-1990 the lower prices of outputs on of dairy farms of 1990/91 strongly lowered the financial reservations. On the larger grassland farms in the LEI random sample of farms the financial reservations in the years 1976-1987 averaged Hfl 9 000, whereas in the years 1987-1990 their average was Hfl 43 000 (28). For the years 1990-1992 they are provisionally estimated to average Hfl 7 000 (32). A prolonged unfavourable ratio between revenue and costs can be a major impediment to technical developments in dairy farming. This can be observed at this time, e.g. in New Zealand (33).

7.3 Favourable and adverse factors

The prospects for introducing automatic milking will be determined by both favourable and adverse factors. A distinction can be made between the present situation in the dairy farming sector and future developments. The present situation is determinant for the short-term prospects, whereas the future developments do affect the long-term ones.

As favourable short-term factors for the introduction of automatic milking can be regarded the following:

- the size of dairy herds in the Netherlands,
- the large number of cubicle houses,
- the high milk yield per cow,
- the generally favourable financial situation of dairy farms,
- the high level of labour costs,
- the reduction in physical workload possible by automatic milking and, in case of a complete system, more freedom from his business.

As adverse short-term factors the following can be regarded:

- the ample availability of forage on farms,
- the limited maximum acquisition value due to potential economies as regards other cost items,
- the less intensive contact with the animals,
- the limited possibilities to use labour force becoming available elsewhere on the farm or to discharge it.

There are a number of factors which may enlarge the interest in automatic milking. Among these are:

- the (resumed) increase in the number of larger herds,
- the ongoing erection of new cubicles houses,
- a further increase in milk production of cows,
- the ongoing possibilities to connect the system with other types of automation and management systems,
- an increasing appreciation of more freedom from work,
- the usual (relative) decreases in prices of technological innovations in the course of years,
- an improved level of education among young farmers.

Opposed to this, there is one special factor which could considerably slow down the introduction of automatic milking - the ongoing deterioration of the profitability in dairy farming, especially due to further price cuts for milk. This could severely affect the financial reservations as well as the readiness to invest. Whether this is going to happen and to what extent, will greatly depend on political decision-making in the EC and GATT-negotiations.

From the point of view of animal welfare and/or landscape the general public will appreciate more frequent milking in a positive way, whereas the reduced appearance of grazing cattle will be rated negative. The image of the dairy farm might become somewhat more that of a high-tech enterprise.

Automatic milking requires a considerable investment.

7.4 Categories of farms

There are two types of farms which seem likely to be eligible for automatic milking, viz.:

1. Large dairy farms which are willing and able to discharge labour force. For farms which employ three or more people this will in general be easier than for those employing two. Besides, for larger ones it would be easier to make automatic milking profitable.

2. Large family farms where only one person is available to do the milking. Here the reduction in physical workload and/or the increased freedom may play a decisive role. In a number of cases the farmer will be ready and able to be content with a slightly lower profitability of the farm. It must be taken into account that the interest amongst these farmers will depend strongly on to what extent the system can act autonomously.

There are several conditions which can stimulate the interest in automatic milking among individual farmers. Examples are:

- A reduction in labour supply due to other causes, e.g. full or partial retirement of the father from a partnership between father and son.
- Renovation and/or new building of cubicle houses (in which case it will be easier to make automatic milking profitable; moreover the risk is less that building layout and equipment would be object to rapid depreciation owing to economic obsolescence).
- The objective of very high yields per cow.
- Acquisition or leasing of milk quotas (without concurring extension of land and labour).
- A tight forage situation and/or problems with compliance with environmental requirements due to (too) dense a cattle population.
- Introduction or expansion of other sectors of business.

But it is also possible that farmers have motives or that there are developments in society which check the introduction of automatic milking. For instance, not all farmers have the ambition to achieve ultra-high yields from their animals; some are more attracted by a more extensive type of farming or by not 'boosting' the production too much, and some other farmers have the desire (or are confronted with the obligation) to integrate dairy farming into a system of nature management or nature development.

7.5 Number of farms

By analysing favourable and adverse factors and categories of farms which are potential candidates for the system, nothing has been said about the rate at which automatic milking is to be actually introduced. To gain some insight into what is thinkable in this respect, one could consider more or less comparable developments which took place in the past. Suitable examples are the introduction of the cubicle house and that of the automatic feed dispensing station.

Perhaps one could say that the introduction of the cubicle house with milking parlour was a still more radical change than that of automatic milking. In the Netherlands the first cubicle houses were built in the early 60s. It was not before 1968 that more than 100 of them were delivered each year. In 1970, which is about nine years from the start, there were slightly over 800 (27). These figures show that the development of a prototype to a mature concept for practical farming takes quite a few years. The breakthrough was from 1971 to 1981, with numbers of 1.500 - 2.000 built a year. The way the introduction went on, will not only have to be ascribed to actual development problems but also to initial unfamiliarity and the radical nature of the decision.

The introduction of the automatic feed station was much less radical as regards farm structure and management than that of the cubicle house. The first feed stations were installed on practical farms in 1976. In 1985 more than 2 600 farms had these feed stations, whereas the figure had risen to nearly 8 000 in 1990 (27). In the first ten years, 3 000 - 3 500 farms bought a feed dispensing station.

Initially, the introduction of the feed station went off faster than that of the cubicle house. Later, the increase in number of cubicle houses was faster. To have an idea of the potential for introducing automatic milking, it is assumed that in the initial phase its success will be somewhere in between that of cubicle houses and feed stations and that it will to some extent be slowed down later, as automatic milking can only be practised on farms already equipped with cubicle houses (like with the feed station). Figures on the basis of these assumptions would then be that there can be some 500 milk automats in 5 years, 2 000 - 2 500 in 10 years and some 5 000 - 10 000 in 15 years. But these are mere assumptions. What seems certain anyway, is that the introduction will be very gradual in the initial 5 - 10 years.

In 1990 there were 8 600 farms with 50 - 70 dairy cows each, 4 200 with 70 - 100 dairy cows and 1 500 with 100 and more dairy cows. These size categories could (very roughly!) be related to large family farms, two-man farms and farms employing more than two man, respectively. A number of 2.000 - 2.500 farms applying automatic milking in about 10 years after its first introduction on an (experimental) farm, might be realized, e.g. by installing milk automats on 10, 20 and 40 %, respectively, of the numbers of farms stated. This rate of introduction would seem possible. As a matter of fact, the introduction could very well go slower or faster, depending on technical and economic developments in the years to come.

7.6 Conclusions

The structure of dairy farming in the Netherlands is such that automatic milking could be integrated on many farms. Automatic milking can reduce the physical workload and in the long term increase the freedom on the farm. In most cases, however, it will not be profitable right from the start. This may lead to the expectation that in the short term the interest in automatic milking will be substantial but not massive. The interest is especially to be found among (very) large farms which can make labour redundant and among large family farms anxious to reduce the workload and ties to the farm. An extra stimulus might be an intensive farming type (high cattle density, high individual milk yield). In the course of years the group of farmers interested will expand due to changes in conditions, such as succession and renovation or construction of new cubicle houses. Automatic milking can be a stimulus for farm enlargement through acquiring or leasing milk quotas. The degree to which a system is actually installed, seems to depend in particular on:

- The quality of product and equipment and whether the system can work fully on its own.
- The price of the equipment and how it will develop.
- Financial reservations in dairy farming which most of all rely on developments in prices of outputs.
- The acceptance in sympathy with this type of farm management system.

Effects of these factors on whether an automatic milking system will be purchased will be stronger for (large) family farms than for large farms with more than two workers.

The introduction of automatic milking may be assumed to occur very gradually in the first years, which assumption is also based on similar developments in the past. As a matter of fact, this would seem to have certain advantages in that adequate experience can be gathered as to the integration of the system into the farm and daily practice. The way in which the cubicle house and the feed station were introduced and how this developed shows that such a gradual start need not at all be an obstacle to an eventual massive adoption of the system.

No inventory has been made among different types of farm management. It would be interesting to study the acceptance of automatic milking in the daily practice and the structural effects on the sector.

8. Impressions from other countries

8.1 Germany

H.O. Gravert, Institut für Milcherzeugung, Kiel.

In Germany, in recent years an intensive discussion has taken place about the ethical aspects of cattle husbandry. Questions concerning the pigs and poultry husbandry have been the major issue, but there are also reasons to give more attention to the concept of cows in relation to the way the animals are housed and managed. First, some remarks are made in this context about automatic milking, next the interest for the system of automatic milking is estimated.

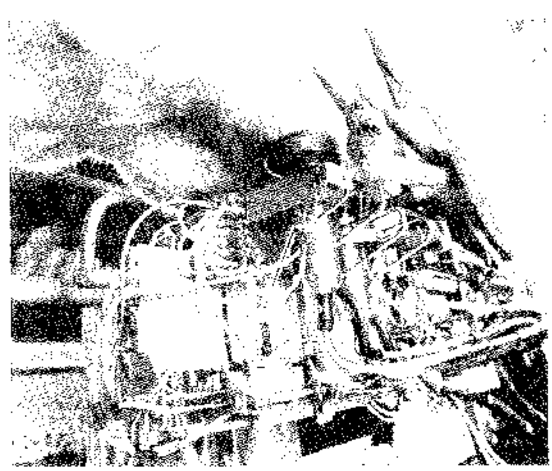
Behavioural studies with cows learn that the housing systems are not optimally used, because the cows are kept twice a day for 1 à 2 hours in a collection yard
before milking. Also, the cows are not able to utilize during these hours the facilities for feeding and concentrate intake, as well as the cubicles and the water reservoirs.
With automatic milking and free access of the cows to the robot, all facilities in the housing system can be utilised nearly continuously. The milking machine is almost all the time in operation with exception of the cleaning time. Therefore, when new housing is built less cubicles are needed than with a traditional milking parlour.
New techniques in cattle husbandry are meaningful, when the system allows a more natural behaviour of the animal. For raising a calf, a maximum of 20 kg of milk per day is needed. This means a milk amount of ca 5 kg or less per time of suckling. On the opposite, high productive cows yield more than 40 kg milk per day, which amount is delivered in two milkings a day. At this point the present milking routine is not in harmony with the behaviour and needs of the animal. For these high yielding cows the swelling of the udder before milking indicates a kind of stress, resulting in less laying down of these cows. Too big udders are not favourable for the ease of walking of the animals, for instance when grazing. More frequent milking will benefit the welfare of the cow.

For the introduction of the milking robot in Germany, farms with 40 to 60 dairy cows are most suited. On these farms labour is usually provided by farm members (father and son, two brothers, farmer and wife). Therefore labour income is equivalent to the income of the farm family. However, the investment in a milking robot will not exclusively be based on economic calculations, but also interest in the technique, prestige and the expectation of less strict working hours will surely count in the decision making.
In the future, Western Germany will count approximately 30000 dairy farms with the size of 40-100 cows. In Eastern Germany, the number of farms of this size is estimated at about

5000. For large farms with hired personel the purchase of a milking robot is not likely because the hired labour is usually not fitted for the acquired technical knowledge. Also the insufficient use of the technical equipment and milking facilities on the farm can be avoided by use of labour shifts.

For farms with less than 40 cows, a very limited perpective for the introduction of the milking robot is expected. On these farms, the cows are usualy housed in stanchian barns. The majority of these farms will also be exploited in an extensive way as a second profession. The investments will be very limited. But even on these farms, provided loose-housing is available, some farms will implement a milking robot as experiences with other machines like tractors and harvesters have shown in the past.

When the milking robot is well functioning, it is estimated that 10 % of the mentioned 35.000 farms in Germany will implement such a system. Within a 10 year period, this proportion may increase to 30 % of these farms. Assuming a replacement rate of the equipment of 10 years, the demand for robots can be predicted at a 1000 a year.



The interest in automatic milking in other countries strongly depends on the circumstances.

8.2 England

A.R. Frost, Silsoe Research Institute, England

From the point of view of research it is expected that automatic milking will bring benefits in terms of economics and cow health and welfare. The cow health and welfare benefits will mainly come from the increased time the cowman will have to look after his cows. The cows will be free to adopt their own patterns of behaviour. The problems that remain include devising farming systems that can take advantage of an automatic milking robot. It is not yet decided how a dairy farm should be structured around a robot. Another major concern is that standards of hygiene must be maintained.

A survey of the attitudes of farmers to automatic milking has been carried out in England. Their views are summarised below:

- All of the farmers that were questioned appeared to be aware of the research into automatic milking, though detailed knowledge was limited. Confusion is apparent over the various projects that are under way. The high level of awareness indicates that there is much interest in the concept of automatic milking amongst UK farmers.
- The concerns expressed by farmers include: reliability, milking performance, cow participation (there are strong doubts about the idea of voluntary attendance), cleaning of the machine, and cow preparation (teat cleaning, etc.).
- The benefits expected by farmers include: a reduction in the length of the working day, an improvement in working conditions, improvement in cow health due to increased milking frequency and increased yield.
- There was a general agreement that automatic milking was inevitable. There was overriding support for the concept. It has caught the imagination of the vast majority of dairy farmers as it represents the most revolutionary step in milking technology since the introduction of parlours.
- The likely reaction of the public to zero-grazing does worry dairy farmers. Nevertheless there is no reason why fields directly adjacent to the farmstead could not be used in the summer for grazing and exercising. Alternatively some farmers felt that they could utilise the full potential of the automated system in the winter, when the herd is housed conventionally, and could revert to field grazing in the summer, bringing the herd back to the automated station for milking.

As regards the type of dairy farmer most likely to pioneer automatic milking, it was found that no one group predominated. It was apparent that small and large dairy farmers alike have reason to be attracted by the concept. Small specialist dairy farmers are often single man operations, reliant on family and casual labour for relief. Such labour is becoming increasingly difficult to find. Automatic milking would take the chore out of the small farmer's work, enabling him to make better use of his time. The attraction for the larger specialist farmer would principally be one of labour saving. In many cases where two men are now employed there would only be the need for one. Furthermore it is the large farms that have the most diffilculty in retaining regular labour. Cowmen frequently leave after a year. Automatic milking would increase the appeal of the cowman's job.

8.3 France

P. Billon, Service Bâtiments, Equipements, Travail, Institut de l'Elevage, Monsoisin.

From point of view of the research institute, it is believed that the automatical attachment of the teat cups, although technically a very complicated procedure, is nevertheless easier to realize than the needed control of mastitis cows, abnormal cows, cows in heat, the control of milk quality, etc.

As positive factors for introduction of the milking robot in France can be mentioned:

- less physical and mental labour for the milker,
- more and direct information, so the farmer can take a decision shortly after the detection of the problem.
- no more fixed times and fixed hours for milking,
- more time to do others things in the farm and in particular for the management,
- curiosity and interest of many dairy farmers for something new and revolutionary,
- simplification of the machine milking itself: no longer problems of pipe diameter, of size of vacuum pump. Less liner to change every year.

As negative factors are mentioned:

- the cost of the robot.
- in France, dairy herds are very small and most of them are still located in stanchion barns.
- the average number of cows per herd in loose housing systems is about 30-40 cows. Perhaps it will be to small to utilise a machine with a very expensive price.
- in economic context, perspectives at the moment are not so favourable for big investments.
- technical problems of herd management in particular: most of the herds are in the pastures during summer. What about the milking robot during the time of pasture? Many farmers have had difficulties to adapt cows to the automatic feed stations during this time and are obliged to keep the herd in the house during several hours; this time will automatically increase with

a milking robot; so, severe problems appear and will finally result in more work for the farmer for feeding, management of the herd, etc.
- many interrogations about the salesman and especially the after sales service.

Some questions still to answer are:
- a farm building with a robot will be certainly different than a classical one with a milking parlour. What is the best position of the robot in the housing system?
- there is very few information about the behaviour of the cows when in good health, when sick, when at the end of their lactation.
- what about the milk quality; the frequency of milking, three or four times a day; the frequency of cleaning of the milking equipment?
- what about milk recording and genetic selection?

Categories of farms interested in automatic milking:
In France the big majority of farms have family workers: 48 % of the farms have less than 20 cows and only 13 % more than forty cows. A milking automat will probably interest this last group the most, but only 60 % of them (near 8 % of the total which represent about 16.000-17.000 farms) have loose housing systems. On most of these farms, the price of the robot may be considered as prohibitive to purchase such a system.
There are not many large herds with 80-150 cows and more: less than 1 % of the dairy farms (about 2.000). On these farms two or more persons are employed. A milking automat should be interesting, when the farmer has the possibility of decreasing the number of workers.
The expectations are that not exclusively farmers with large herds will buy automats in future. But before introduction of the milking robot in the field, technical problems have to be solved, otherwise this automat will not have much perspective on French dairy farms.

8.4 United States of America

A. *B. Johnson, Experimental Station, University of Maryland.*

On the experimental Station of the University of Maryland a milking automat is installed. The automat is imported from Europe. There is only very limited interest for this new milking device. This may be also caused by the fact that the information flow to the outside world is kept restricted.

It is noticed that techniques, like cow identification and automatic feed stations have not been introduced widely on dairy farms in the U.S.A. In the Eastern States of the U.S.A. dairy cows are often housed in tie-stalls. Also feeding of complete rations (mixed feeding)

is popular. In such management systems, individual cow identification devices, individual feeding of concentrates and automatic milking do not (easily) fit.
More interest for automatic milking is relatively expected from the larger specialised dairy herds in the U.S.A. In the Eastern States, small farms are often kept as second profession.

B. *D.V. Armstrong, Department of Animel Sciences, University of Arizona*

To evaluate any new dairy equipment or technology impact on the U.S. dairy industry, one must be aware of the wide range of herd size and dairy cattle housing which is presently used on U.S. dairy farms. Herd size varies from an average of 50-60 cows predominantly housed in stanchion barns in the upper midwest to the 150-3000 cow herds housed in open corrals in the western states and open corral and free stall barns in the south-east. In all areas the trend is to larger herds in loose housing systems.
Many present management systems must also be taken into consideration when considering the future effect of robotic milking systems.

- year round calving is the normal situation on U.S. dairy farms with one third of the animals each year being first lactation animals which will require an extensive adaption period.
- in the majority of large dairy farms, dairy cows are grouped according to milk production level, stage of lactation or reproductive status with first lactation in a separate group.
- dairy cattle feeding trends are to use total mixed rations with little or no grain feed in the milking parlour.
- federal interstate milk shipping regulations require that the cows'teats be sanitized and dryed before the attachement of the milking unit.
- milking cows 2 times a day and even 3 and 4 times a day on a twenty four hour basis is presently being done on large dairy farms and is not considered to be an unsocial occupation as many U.S. factories, stores, restaurants and service stations operate on a 24 hour basis.

Factors that may limit the usage of automatic milking systems in the U.S. would include the following:

- the automatic milking system will require new facilities
- can 95 % of the cows be trained to use the robotic system?
- will fresh cows and hospital cows be milked by the robotic system or will a second milk system be necessary for this group of cows?
- if all the concentrate is not fed in the robotic system to encourage cow entry is the normal 22-26 kg of dry matter intake possible which is necessary for high producing cows?

The major question on when and if an automatic milking system will be used on U.S. dairy farms is, will it be economically attractive to the dairy owners? From past history of the adaption of new milking equipement technology by the U.S. dairy industry several assumptions can be made:

- new equipment and technology is adapted more rapidly in greater numbers when it can be used on existing facilities.
- large dairy farms tend to be early adapters because they have the capital resources available for expansion or equipment purchase.
- it must be cost effective and reduce labour cost or improve milk production and milk quality.

Presently total labour cost on the majority of U.S. dairy farms is 8-15 % of gross income with about 50 % of these labour cost being for milking. Dairy farm labour costs have decreased during the last thirty years because of new technology, equipment and higher milk production per cow.
An increase in milk production of 15 % is expected due to 3 times milking a day. This system of milking is quite commonly applied in Arizona and California. Because of high temperatures, cows in Arizona are sometimes milked 4 times a day (the milking parlour appears to be a relatively cool place of the dairy operation). Data from 16 herds milking 4x indicate that an additional 6-8 % increase in production over 3x is possible.

In summary it can be said that the milking robot will only have an impact if it is cost effective in reducing labour, or improving milk production and milk quality over a present three times a day milking system.
The automatic milking system may be cost effective on small dairy herds that are housed in loose housing and milking 2 x a day by reducing labour cost and increasing milk production to the 3 x level. The system may be used on large U.S. farms if they are developed for use in existing milking facilities and when labour would be reduced from for instance 3-4 personal parlours to one person parlours.

9. RESEARCH TOPICS

In chapters 1, 2 and 3 most questions for research have already been formulated. Further research is needed in optimizing the technical functioning of the milking automats.
Aspects mentioned are:

* the reliability of the milking automat.
  Further development and perfection of
  - attachment of milking machine
  - position of cow in automat
  - cleaning of udder and teats
  - use of water
* adaptation in milk technique
* development of process automation and sensors
* separation of mastitis cows from milking process.

Also research is needed to implement automatic milking in a total farm management system.
Research topics are:

* the volontary entrance of the cow in the automat.
  Aspects of interest:
  - division and outlay of house to realize an efficient cow traffic.
    It is possible that the development of a new outlay of loose housing is needed.
  - welfare and behaviour of the cow and herd in an automatic system
  - implementation of (limited) grazing in system
* the milking frequency
  Aspect of interest:
  - which frequency of milking is optimal in relation to milk production, health, fertility, behaviour and well-being of the animal
  - (fysiological) animal aspects at very high productions
  - linkage between milk frequency, capacity of automat and economy of farm
* the milk quality
  - development of methods to clean udder and teats
  - to maximize the cleanliness of cows by adaptations in outlay of house and bedding of cubicles
  - effect of feeding on cleanliness of cows
  - cooling of milk with frequent milking

* a supporting management program for transferring information about cows to farmer
  Aspects of interest:
  - which signal functions per cow and per sensor and in which combination are optimal
  - development of uniform management criteria
  - development of an information stream concerning milk quality and composition
* the labour requirements
  - assesment of labour needs quantitatively
  - assesment of labour qualitatively: mental pressure and degree of attachment to farm
* the grassland management
  - when cows are all year indoors a choice has to be made concerning feeding routine. The wish to realize limited grazing as part of system requires further exploration

In general the following aspects of an automatic milking system ask attention:

* the rentability
  Aspects of importance are
  - change in return and cost factors
  - required investments
  - annual costs
* the criteria on uniformity and conformation of the cow herd
* the use of water and energy and the effect on efficiency of mineral inputs

To estimate the acceptance of an automatic milking system in practice, a technology assesment study would be of interest. Also effects on the structural development of the sector are of importance.

Some of the above mentioned topics of research are already part of existing research programs. Other topics still need to be incorporated in programs. Especially the development of an automatic milking system as an integrated part of a larger family farm ought to be an important research goal.

10. SUMMARY

At the experimental farms the Waiboerhoeve in Lelystad and De Vijf Roeden in Duiven, experiences are obtained with two types of milking robots (automats). Also in some other European countries, experiences are gathered. The goal of automatic milking is to make the continuous presence of the dairyman in the milking parlour not needed any more. Realisation of this goal will be a very important achievement in automation of the dairy farm. It will have a large impact on management of the dairy farm, on the farmer, the cow and on the farm family as part of society. However, many technical, economical and social questions still remain. Therefore, a working group composed of representatives from various organizations in the Netherlands studied current experiences with automatic milking systems and its prospects. Also research topics were considered.

A number of technical and management factors concerning the use of the milking automat emerged from the study as being important. To be mentioned are:

- speed and accuracy of robot arm to find teats; different systems are developed to find teats. Reliability of the system and time needed for attachment of teat cups are important factors. Improvement is still needed concerning both aspects.
- behaviour of cows and voluntarily entering of milking automat; cows must feel at ease in the system. That contributes positively to the willingness to enter the system and to a succesfull attachment of the teat cups. Data of the cow behaviour in a fully automated farm are of interest. Research results about number of cows entering the milking automat per unit of time differ.
- optimal frequency of milking; cows may be milked 2, 3 or 4 times a day. The frequency of milking of high and low yielding cows is one of the main factors determining the capacity of the automat. The production increase by 3 times milking is well documented. However, more data are required about cows milked 4 times a day or more. For economical reasons a possible chance in fat/protein ration with frequent milking is also of importance.
- capacity of milking automat; a wide variety in number of cows milked per automat or robot arm during the day is mentioned by the manufacturers of robots. The capacity depends on previous points listed and on the lay-out of the housing facilities. For management and economical purposes it is needed to determine more exactly the number of cows milked per unit of time in a whole farm set-up.
- cleanliness of cows and milk quality; detection methods are at this moment not available for selection of dirty cows or udders. Clean udders or teats can be

achieved by proper management in the loose housing system, by preparation-boxes and teat-cleaning as part of automatic milking. When the human presence in the milking parlour is eliminated, it is a must that cows enter the milking automat with clean udders and teats. One of the milk quality factors to be watched is for instance the fatty acids content of milk.

- separation of mastitis milk and management program; a self controlled system requires automatic separation of abnormal cows or milk from the system. After the automatic attachment of teat cups, detection and separation of abnormal cows (milk) is another large challenge of an automatic milking system. The conductivity of milk to detect mastitis cases can be measured. The procedure for removing cows from the system has still to be set up. Extensive management programs are needed as part of the automatic milking system, to take over control of the herd during milking.
- labour saving and labour ease; data should be collected under normal farm conditions about labour requirements and savings, when automatic milking is performed.
- change of grassland management; it is expected that cows will be centered around the automat to quarantee an efficient use of the system. Grazing becomes a difficult part of such a farm set-up. Grass has to be grown more as an areable crop, possibly stimulating also other forage crops to be included in the farming plan. Nevertheless, in several countries, like in the Netherlands, grazing of dairy cows is part of the dairy operation. Therefore, limited grazing in combination with automatic milking needs further exploration.

Up till now, much less emphasis is, in agricultural research, put on the economic and social factors influencing the implementation of the milking automat on the dairy farm. Therefore, model calculations were performed to estimate economical effects of implementation of automatic milking on the farm. Also social factors were studied.

An automatic milking system will require a substantial capital investment. The decision wether an investment will be made in automatic miking arises in most cases when the old milking parlour has to be replaced or renovated. Also changes in the anual yields and costs may occur when an automatic milking system is choosen. In most cases such a system may require adaptations in not only the housing system but in the whole farm set-up. Calculations were made to estimate the economic consequences of these adaptations. The main factors studied were:

- increase in milk yield per cow and change in milk composition;
- alteration in grazing and feeding strategy; and

- choice of traditional milking parlour

An increase in production per cow contributes positively to net returns of automatic milking. Transition from an unlimited grazing system to feeding cows all year round indoors affects returns in a strongly negative way. The investment levels for traditional parlours also significantly affect the acquisition values for the automat. With the choice of a lower investment level for the conventional milking parlour, the maximum acquisition value for the automatic milking system becomes lower. As a consequence, individual wishes as to the layout of the milking parlour play an important role in the profitability of the automatic milking system.

Also the level of the annual costs influence the perspectives considerably. However, maintenance costs of milking automats are not yet known, but will affect the final level of the annual costs.

It is assumed that the first years after introduction of the system, there will be no real labour savings on the farm. However, in the long run labour saving will be one of the main factors determining the profitability of automatic milking systems.

The following factors influencing the introduction of automatic milking systems in the field were mentioned by the working group:

- size of dairy herds. It may be less likely that smaller farms (below 40 cows) are interested in automatic milking systems, due to investment level and type of farms.
- housing system. Present milking automats require self entrance of the cow. Cows will also be allowed to enter the automat several times a day. This implies that a loose-housing is required.
- production level. High production levels are associated with more frequent milking. More frequent milking may contribute to the idea of animal welfare.
- labour costs. When an automatic milking system results in savings of labour hours, high labour costs will stimulate the introduction of the system.
- grassland management system. Automatic milking requires the cows to be near the automat. If cows are kept indoors all-year-round, the society may react in a negative way as to the animal welfare and landscape aspects.
- contact with animals. Less contact with the animals can be a negative factor in control of the herd. However, more experience is needed to determine in which degree a management program and sensors can take over this task of the farmer. Also some farmers may consider less direct contact with the animals not to be in line with their profession.

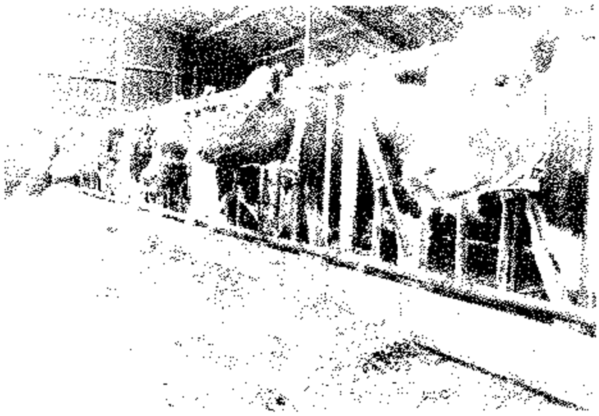
- ease of working. It is expected that automatic milking will reduce physical labour. The herdman's function will shift more to general supervisory work. This demands other skill's from the farmer.
- attachment to farm. In the long run it is expected that the farmer (and his family) is less tied down to the farm, because the milking process requires only incidental attendance. This may place the profession of dairy farmer more in line with general developments in society.
- capital position and income. The financial position of the dairy farm(s) is important when deciding upon such a considerable investment as required for automatic milking. The tendencies in levels of farm incomes will also influence the rate of introduction of automatic milking systems in practice.

Impressions from other countries vary considerably. Size of herds, housing systems, feeding methods and costs of the milking automat are main factors determining the interest in automatic milking. In some European countries, farmers prefer the possibility of grazing of cows as part of dairy farm management. Automatic milking will also effect the services of the dairy herd improvement organisations and the dairy industry.

The introduction of the milking automat on dairy farms can be pictured in two stages. In the first stage, use of a milking automat means a further automation of the milking process. The cows are milked without manual assistance of the farmer or milking personel. The presence of the farmer is regularly needed because of the selection of abnormal cows, especially cows with mastitis. Also some " difficult" cows need additional care in entering the automat and during the milking process. In this stage of introduction there is no labour saving to be expected.
In the second stage, a complete automatic milking system will be developed. A management program with various sensors is ment to take over most of the control tasks of the farmer in the traditional milking parlour. After the automatic attachment of teat cups, detection and separation of abnormal and dirty cows (milk) is another large challenge of an automatic milking system. However, to which degree this goal will be reached is presently difficult to assess.
In the long run, these developments may result in saving of labour which contributes under certain conditions significantly to the economic returns of automatic milking. But social aspects may be as important as economic factors. When the dairy farmer (and his family) will be less tied down to the milking process and therefore to the

farm, this development will be seen as a very important achievement for the profession of the dairy farmer.
Saving of labour is the easiest to capitalize in large herds with several employees. On family farms with usually 1-1½ family member employed, less attachement to the dairy operation will be appreciated most. Therefore, introduction of automatic milking systems seem to be most attractive for family farms with full labour input and large dairy farms with more than two employees.

Aside of technical and management aspects, research towards implementation of automatic milking in a whole farm operation is especially needed.



The integration of automatic milking on the farm is a major item for research.

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APPENDICES

Appendix 1. Calculation of gross margin minus variable costs in various farm situations and the derived effects on gross margin when changing to a different grassland utilization system and at an increase in milk yield of 1000 kg

Milk quota 10 000 kg per hectare

	7000 O4	8000 O4	7000 B4 + 3	8000 B4 + 3	7000 B4 + 3 maize	8000 B4 + 3 maize	7000 S	8000 S
TECHNICAL DATA								
Number of dairy cows	35.71	32.09	35.71	32.09	35.71	32.09	35.71	32.09
Number of dairy breed calves	12.33	11.08	12.33	11.08	12.33	11.08	12.33	11.08
Number of dairy breed heifers	11.10	9.98	11.10	9.98	11.10	9.98	11.10	9.98
Grass area, grazing/house feeding(ha)	25.00	25.00	20.00	20.00	15.00	15.00		
Grass area, cutting only (ha)				5.00	5.00		25.00	25.00
Forage maize area, farm-grown (ha)						10.00	10.00	
Forage maize, bought (ha)				1.69	1.51			
Milk yield (kg/cow)	7000	8000	7000	8000	7000	8000	7000	8000
Fat content in milk (%)	4.40	4.25	4.40	4.25	4.40	4.25	4.40	4.25
Protein content in milk (%)	3.40	3.35	3.40	3.35	3.40	3.35	3.40	3.35
Grassland utilization system	O4	O4	B4 + 3	B4 + 3	B4 + 3	B4 + 3	S	S
N level, grassland (kg/ha)	381	381	379	379	389	389	383	383
Cutting percentage, total	209	220	251	261	164	174	407	407
Slurry production, stored (m^3)	450	401	669	596	669	596	901	803
REVENUES								
Total	214292	214423	220513	219964	219837	221296	221340	221020
Milk	179004	179242	179004	179242	179004	179242	179004	179242
Annual replacement output and change in volume dairy cattle	27389	24613	27389	24613	27389	24613	27389	24613
Further revenues	7900	10569	14120	16720	13445	17441	14947	17165

VARIABLE COSTS								
Total	87277	85698	100257	97490	97453	95700	109408	106661
Concentrates	23392	23096	24473	24017	24271	24157	30305	29656
Forage			6001	5394				
Cattle	22859	20806	23074	20998	23074	20998	23234	21143
Grassland	21407	21902	21913	22501	10655	11265	20001	20705
Forage maize				475	433	11254	11229	
Energy	739	759	739	759	739	759	739	759
Variable contract work	18881	19136	23583	23388	27460	27252	35130	34399
Gross margin revenues-feed costs	190901	191328	190039	190563	195566	197139	191035	191364
Gross margin revenues- variable costs of own equipment	145896	147861	143839	145862	149844	152848	147061	148757
Gross margin revenues- variable costs of contract work	127015	128725	120256	122474	122385	125595	111932	114358
Gross margin in case of contract work per hectare	5081	5149	4810	4899	4895	5024	4477	4574
Effect on gross margin due to change in grazing system								
- from O4 to			-271	-250	-186	-125	-604	-575
- from B4 + 3 to					+85	+125	-333	-325
- from B4 + 3 with maize to							-418	-450
Effect on gross margin due to higher milk yield per cow		+68		+89		+129		+97

Appendix 1 (cont'd). *Calculation of gross margin minus variable costs in various farm situations and the derived effects on gross margin when changing to a different grassland utilization system and at an increase in milk yield of 1000 kg*

Milk quota 15 000 kg per hectare

	7000 O4	8000 O4	7000 B4 + 3	8000 B4 + 3	7000 B4 + 3 maize	8000 B4 + 3 maize	7000 B4 + 6 maize	8000 B4 + 6 maize	7000 S	8000 S
TECHNICAL DATA										
Number of dairy cows	53.57	48.14	53.57	48.14	53.57	48.14	53.57	48.14	53.57	48.14
Number of dairy breed calves	18.50	16.63	18.50	16.63	18.50	16.63	18.50	16.63	18.50	16.63
Number of dairy breed heifers	16.65	14.96	16.65	14.96	16.65	14.96	16.65	14.96	16.65	14.96
Grass area, grazing/house feeding (ha)	25.00	25.00	25.00	25.00	20.00	20.00	20.00	20.00		
Grass area, cutting only (ha)									25.00	25.00
Forage maize area, farm-grown (ha)					5.00	5.00	5.00	5.00		
Forage maize, bought (ha)	6.48	4.72	4.59	2.92	5.11	3.47	5.18	3.64		
Milk yield (kg/cow)	7000	8000	7000	8000	7000	8000	7000	8000	7000	8000
Fat content in milk (%)	4.40	4.25	4.40	4.25	4.40	4.25	4.40	4.25	4.40	4.25
Protein content in milk (%)	3.40	3.35	3.40	3.35	3.40	3.35	3.40	3.35	3.40	3.35
Grassland utilization system	O4	O4	B4 + 3	B4 + 3	B4 + 3	B4 + 3	B4 + 6	B4 + 6	S	S
N level, grassland (kg/ha)	384	384	384	383	384	383	385	383	383	383
Cutting percentage, total	125	141	185	194	137	149	175	181	407	407
Slurry production, stored (m^3)	675	601	1003	894	1003	894	1003	894	1352	1204
REVENUES										
Total	311755	307970	311755	307970	311755	307970	311755	307970	311755	308361
Milk	270668	271047	270668	271047	270668	271047	270668	271047	270668	271047
Annual replacement output and change in volume dairy cattle	41087	36923	41087	36923	41087	36923	41087	36923	41087	36923
Further revenues										391
VARIABLE COSTS										
Total	125723	117284	129440	120572	132055	123330	134725	125870	139800	132897
Concentrates	34048	33990	37024	36813	36247	35920	36245	35727	46724	46120
Forage	23035	16782	16318	10379	18159	12336	18402	12943	3017	
Cattle maintenance costs	32992	29911	33313	30200	33313	30200	33313	30200	33554	30417
Grassland	18430	19101	18937	19855	12996	13932	13433	14269	16661	17583
Forage maize	748	662	958	674	6300	6150	6327	6279		

Energy	1108	1138	1108	1138	1108	1138	1108	1138	1108	1138
Variable contract work	15363	15701	21781	21512	23933	23655	25896	25314	38735	37639
Gross margin revenues-feed costs	254673	257199	258413	260778	257350	259715	257108	259300	262014	262241
Gross margin revenues-variable costs of own equipment	201395	206387	204097	208910	203633	208295	202927	207414	210690	213103
Gross margin revenues-varirable costs in case of contract work	186032	190686	182316	187398	179700	184640	177030	182100	171955	175464
Balance of contract work per hectare	7441	7627	7293	7496	7188	7386	7081	7284	6878	7019
Effect on gross margin due to change in grazing system										
- from O4 to			-148	-131	-253	-241	-360	-343	-563	-608
- from B4+3 to					-105	-110	-212	-212	-415	-477
- from B4+3 with maize to							-107	-102	-310	-367
- from B4+6 to									-203	-265
Effect on gross margin due to higher milk yield per cow		186		203		198		203		141

Appendix 2. Calculation of automation levels

Low automation level

			40 - 50 cows					70 80 cows					100 - 110 cows				
	Dpr	Mnt	Type	Cap	Rpl.v	Tot rv	Costs	Type	Cap	Rpl v	Tot rv	Costs	Type	Cap	Rpl.v	Tot rv	Costs
Milking parlour	10	5	Herringb. 2x4	1	27700	27700	5526	Herringb. 2x6	1	35300	35300	7042	Herringb. 2x8	1	41900	41900	8359
Cluster removal equipment	15	5	None	0	0	0	0	Semi-autom.	12	800	9600	2395	Fully autom.	16	1300	20800	5190
Milk jars	15	5	Hand empt.	8	800	6400	1597	Hand empt.	12	800	9600	2395	Hand empt.	16	800	12800	3194
+Concentrates	15	5	Hand-oper.	8	500	4000	998	Hand-oper.	12	500	6000	1497	Hand-oper.	16	500	8000	1996
Cleaning	10	5	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499
Boiler	10	5	Electr. 120	2	1400	2800	559	Electr. 120	3	1400	4200	838	Electr. 120	4	1400	5600	1117
Concentrates trolley	10	5		1	750	750	150		1	750	750	150		1	750	750	150
Total						44150	9328				67950	14816				92350	20504
Per cow						981	207				906	198				880	195

Appendix 2 (cont'd). Calculation of automation levels

Average level of automation

			40 - 50 cows					70 - 80 cows					100 - 110 cows				
Costs	Dpr	Mnt		Type	Cap	Rpl.v	Tot rv	Costs	Type	Cap	Rpl.v	Tot rv	Costs	Type	Cap	Rpl.v	Tot rv
Milking parlour	10	5	Herringb. 2x4	1	27700	27700	5526	Herringb. 2x6	1	35300	35300	7042	Herringb. 2x8	1	41900	41900	8359
Cluster removal equipment	15	5	Semi-autom.	8	800	6400	1597	Fully autom.	12	1300	15600	3892	Fully autom.	16	1300	20800	5190
Milk jars	15	5	Autom. empt.	8	1200	9600	2395	Autom. empt.	12	1200	14400	3593	Autom. empt.	16	1200	19200	4790
Milk tube guide	15	5		8	250	2000	499		12	250	3000	749		16	250	4000	998
Concentrates	15	5	Electr.	8	900	7200	1796	Electr.	12	900	10800	2695	Electr.	16	900	14400	3593
Autom. feed. gate oper.*)	10	5							12	350	4200	838		16	350	5600	1117
Aut. oper. of exit gate	10	5	-					Automatic	4	1200	4800	958	Automatic	4	1200	4800	958
Compressor	10	5	-						1	3000	3000	599		1	3000	3000	599
Push-up fence	10	5	-						1	3500	3500	698		1	3500	3500	698
Cleaning	10	5	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499
Cleaning water protection	10	5	-						1	800	800	160		1	800	800	160
Boiler	10	5	Electr. 120	2	1400	2800	559	Electr. 120	3	1400	4200	838	Electr. 120	4	1400	5600	1117
Pre-cooler	10	5	-											1	3000	3000	599
Heat pump	12	3							1	4000	4000	798		1	4000	4000	798
Concentrates feed computer	15	5		1	5000	5000	1248		1	5000	5000	1248		1	5000	5000	1248
Feed stations	15	5		2	4000	8000	1996		3	4000	12000	2994		4	4000	16000	3992
Emitters	15	5		55	80	4400	1098		85	80	6800	1697		115	80	9200	2295
Auger	15	5	Length in m	30	250	7500	1871	Length in m	40	250	10000	2495	Length in m	50	250	12500	3119
Further material	15	5		1	1200	1200	299		1	1200	1200	299		1	1200	1200	299
Management computer	20	5		1	4000	4000	1198		1	5000	5000	1498		1	6000	6000	1797
Software	10	10	Basic package	1	6500	6500	1622	Basic package	1	6500	6500	1622	Basic package	1	6500	6500	1622
Total						94800	22203				152600	35209				189500	43845
Per cow						2107	493				2035	469				1805	418

Dpr Depreciation
Mnt Maintenance
Cap Capacity
Rpl.v Replacement value
Tot rv Total replacement value
*) to expel cow's head from feeding unit

Appendix 2 (cont'd). Calculation of automation levels

High level of automation

				40 - 50 cows				70 - 80 cows					100 - 110 cows				
Costs	Dpr	Mnt		Type	Cap	Rpl.v	Tot rv	Costs	Type	Cap	Rpl.v	Tot rv	Costs	Type	Cap	Rpl.v	Tot rv
Milking parlour	10	5	Open 2x3	1	40900	40900	8160	Open 2x4	1	52700	52700	10514	Open 2x5	1	66500	66500	13267
Cluster removal equipment	15	5	W. milk prod. m.	6	800	4800	1198	W. milk prod. m.	8	800	6400	1597	W. milk prod.m	10	800	8000	1996
Milk tube guide	15	5		6	250	1500	374		8	250	2000	499		10	250	2500	624
Milk production meters	15	5		6	2600	15600	3892		8	2600	20800	5190		10	2600	26000	6487
Computer connection	15	5		6	800	4800	1198		8	800	6400	1597		10	800	8000	1996
Milk yield recording	15	5	Comp. + acc	1	11000	11000	2745	Comp. + acc	1	11000	11000	2745	Comp. + acc	1	11000	11000	2745
Cow recognition	15	5	Per stall	6	900	5400	1347	Central	1	8000	8000	1996	Central	1	8000	8000	1996
Concentrates	15	5	Programmed	6	2000	12000	2994	Programmed	8	2000	16000	3992	Programmed	10	2000	20000	4990
Autom. feed. gate oper. *)	10	5		6	350	2100	419		8	350	2800	559		10	350	3500	698
Aut. oper. of exit gate	10	5	-					Automatic	4	1200	4800	958	Automatic	4	1200	4800	958
Compressor	10	5		1	3000	3000	599		1	3000	3000	599		1	3000	3000	599
Push-up fence	10	5		1	3500	3500	698		1	3500	3500	698		1	3500	3500	698
Teat disinfection spray	10	5	Automatic	1	1000	1000	200	Automatic	1	1000	1000	200	Automatic	1	1000	1000	200
Cleaning	10	5	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499	Automatic	1	2500	2500	499
Cleaning water protection	10	5		1	800	800	160		1	800	800	160		1	800	800	160
Cow transport	15	5	Fully autom.	1	20000	20000	4990	Fully autom.	1	20000	20000	4990	Fully autom.	1	20000	20000	4990
Boiler	10	5	Electr. 120	2	1400	2800	559	Electr. 120	3	1400	4200	838	Electr. 120	4	1400	5600	1117
Pre-cooler	10	5												1	3000	3000	599
Heat pump	12	3		1	4000	4000	798		1	4000	4000	798		1	4000	4000	798
Feed stations	15	5		2	4000	8000	1996		3	4000	12000	2994		4	4000	16000	3992
Emitters	15	5		55	80	4400	1098		85	80	6800	1697		115	80	9200	2295
Auger	15	5	Length in m	30	250	7500	1871	Length in m	40	250	10000	2495	Length in m	50	250	12500	3119
Further material	15	5		1	1200	1200	299		1	1200	1200	299		1	1200	1200	299
Management computer	20	5		1	4000	4000	1198		1	5000	5000	1498		1	6000	6000	1797
Software	10	10	Ext. package	1	9000	9000	2246	Ext. package	1	9000	9000	2246	Ext. package	1	9000	9000	2246
Total						169800	39535				209100	48695				250800	58205
Per cow						3773	879				2788	649				2389	554

Dpr Depreciation
Mnt Maintenance
Cap Capacity
Rpl.v Replacement value
Tot rv Total replacement value
*) to expel cow's head from feeding unit

Appendix 3. Calculation of maximum acquisition value for automatic milking system

Transition from unlimited grazing (O4) to limited grazing with supplementary feeding of 6 kg DM forage maize (B4 - 6) at a milk quota of 10 000 kg per hectare

Milk yield (kg/cow)			7000
Costs of transition from O4 to B4 - 6 (Hfl/ha)			350
Gross margin increase due to change in milk yield (Hfl/ha)			0
Number of cows	45	75	105
Area (ha)	32	53	74
<u>Low investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	207	198	195
Gross margin increase due to transition from O4 to B4 - 6 (Hfl/farm)	-11025	-18375	-25725
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	9315	14850	20475
Maximum annual costs of automatic milking system (Hfl/farm)	-1710	-3525	-5250
Maximum acquisition value at 20% annual costs (Hfl/farm)	-8850	-17625	-26250
Maximum acquisition value at 25% annual costs (Hfl/farm)	-6840	-14100	-21000
Maximum acquisition value at 30% annual costs (Hfl/farm)	-5700	-11750	-17500
<u>Average investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	493	469	418
Gross margin increase due to transition from O4 to B4 - 6 (Hfl/farm)	-11025	-18375	-25725
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	22185	35175	43890
Maximum annual costs of automatic milking system (Hfl/farm)	11160	16800	18165
Maximum acquisition value at 20% annual costs (Hfl/farm)	55800	84000	90825
Maximum acquisition value at 25% annual costs (Hfl/farm)	44640	67200	72660
Maximum acquisition value at 30% annual costs (Hfl/farm)	37200	56000	60550

<u>High investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	879	649	554
Gross margin increase due to transition from O4 to B4+6 (Hfl/farm)	-11025	-18375	-25725
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	39555	48675	58170
Maximum annual costs of automatic milking system (Hfl/farm)	28530	30300	32445
Maximum acquisition value at 20% annual costs (Hfl/farm)	142650	151500	162225
Maximum acquisition value at 25% annual costs (Hfl/farm)	114120	121200	129780
Maximum acquisition value at 30% annual costs (Hfl/farm)	95100	101000	108150
Labour economy 0,5 full-time worker (Hfl/farm)			32500
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			108333
Labour economy 1 full-time worker (Hfl/farm)			65000
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			216666

Appendix 3 (cont'd). Calculation of maximum acquisition value for automatic milking system

Transition from unlimited grazing (O4) to summer feeding (S) at a milk quota of 10 000 kg per hectare

Milk yield (kg/cow)			7000
Costs of transition from O4 to S (Hfl/ha)			575
Gross margin increase due to change in milk yield (Hfl/ha)			100
Number of cows	45	75	105
Area (ha)	32	53	74
<u>Low investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	207	198	195
Gross margin increase due to transition from O4 to S (Hfl/farm)	-18113	-30188	-42263
Gross margin increase due to change in milk yield (Hfl/farm)	3150	5250	7350
Annual costs of alternative milking parlour (Hfl/farm)	9315	14850	20475
Maximum annual costs of automatic milking system (Hfl/farm)	-5648	-10088	-14438
Maximum acquisition value at 20% annual costs (Hfl/farm)	-28238	-50438	-72188
Maximum acquisition value at 25% annual costs (Hfl/farm)	-22590	-40350	-57750
Maximum acquisition value at 30% annual costs (Hfl/farm)	-18825	-33625	-48125
<u>Average investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	493	469	418
Gross margin increase due to transition from O4 to S (Hfl/farm)	-18113	-30188	-42263
Gross margin increase due to change in milk yield (Hfl/farm)	3150	5250	7350
Annual costs of alternative milking parlour (Hfl/farm)	22185	35175	43890
Maximum annual costs of automatic milking system (Hfl/farm)	7223	10238	8978
Maximum acquisition value at 20% annual costs (Hfl/farm)	36113	51188	44888
Maximum acquisition value at 25% annual costs (Hfl/farm)	28890	40950	35910
Maximum acquisition value at 30% annual costs (Hfl/farm)	24075	34125	29925

<u>High investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	879	649	554
Gross margin increase due to transition from O4 to S (Hfl/farm)	-18113	-30188	-42263
Gross margin increase due to change in milk yield (Hfl/farm)	3150	5250	7350
Annual costs of alternative milking parlour (Hfl/farm)	39555	48675	58170
Maximum annual costs of automatic milking system (Hfl/farm)	24593	23738	23258
Maximum acquisition value at 20% annual costs (Hfl/farm)	122963	118688	116288
Maximum acquisition value at 25% annual costs (Hfl/farm)	98370	94950	93030
Maximum acquisition value at 30% annual costs (Hfl/farm)	81975	79125	77525
Labour economy 0,5 full-time worker (Hfl/farm)			32500
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			108333
Labour economy 1 full-time worker (Hfl/farm)			65000
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			216666

Appendix 3 (cont'd). Calculation of maximum acquisition value for automatic milking system

Transition from limited grazing with supplementary feeding of 3 kg DM forage maize (B4 + 3) to limited grazing with supplementary feeding of 6 kg DM forage maize (B4 + 6) at a milk quota of 15 000 kg per hectare

Milk yield (kg/cow)			7000
Costs of transition from B4 + 3 to B4 + 6 (Hfl/ha)			150
Gross margin increase due to change in milk yield (Hfl/ha)			0
Number of cows	45	75	105
Area (ha)	21	35	49
<u>Low investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	207	198	195
Gross margin increase due to transition from B4 + 3 to B4 + 6 (Hfl/farm)	-3150	-5250	-7350
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	9315	14850	20475
Maximum annual costs of automatic milking system (Hfl/farm)	6165	9600	13125
Maximum acquisition value at 20% annual costs (Hfl/farm)	30825	48000	65625
Maximum acquisition value at 25% annual costs (Hfl/farm)	24660	38400	52500
Maximum acquisition value at 30% annual costs (Hfl/farm)	20550	32000	43750
<u>Average investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	493	469	418
Gross margin increase due to transition from B4 + 3 to B4 + 6 (Hfl/farm)	-3150	-5250	-7350
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	22185	35175	43890
Maximum annual costs of automatic milking system (Hfl/farm)	19035	29925	36540
Maximum acquisition value at 20% annual costs (Hfl/farm)	95175	149625	182700
Maximum acquisition value at 25% annual costs (Hfl/farm)	76140	119700	146160
Maximum acquisition value at 30% annual costs (Hfl/farm)	63450	99750	121800

High investment level of milking parlour			
Annual costs of alternative milking parlour (Hfl/cow)	879	649	554
Gross margin increase due to transition from B4+3 to B4+6 (Hfl/farm)	-3150	-5250	-7350
Gross margin increase due to change in milk yield (Hfl/farm)	0	0	0
Annual costs of alternative milking parlour (Hfl/farm)	39555	48675	58170
Maximum annual costs of automatic milking system (Hfl/farm)	36405	43425	50820
Maximum acquisition value at 20% annual costs (Hfl/farm)	182025	217125	254100
Maximum acquisition value at 25% annual costs (Hfl/farm)	145620	173700	203280
Maximum acquisition value at 30% annual costs (Hfl/farm)	121350	144750	169400
Labour economy 0,5 full-time worker (Hfl/farm)			32500
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			108333
Labour economy 1 full-time worker (Hfl/farm)			65000
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			216666

Appendix 3 (cont'd). Calculation of maximum acquisition value for automatic milking system

Transition from limited grazing with supplementary feeding of 3 kg DM forage maize (B4 + 3) to summer feeding (S) at a milk quota of 15 000 kg per hectare

Milk yield (kg/cow)			7000
Costs of transition from B4 + 3 to S (Hfl/ha)			375
Gross margin increase due to change in milk yield (Hfl/ha)			140
Number of cows	45	75	105
Area (ha)	21	35	49
<u>Low investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	207	198	195
Gross margin increase due to transition from B4 + 3 to S (Hfl/farm)	-7875	-13125	-18375
Gross margin increase due to change in milk yield (Hfl/farm)	2940	4900	6860
Annual costs of alternative milking parlour (Hfl/farm)	9315	14850	20475
Maximum annual costs of automatic milking system (Hfl/farm)	4380	6625	8960
Maximum acquisition value at 20% annual costs (Hfl/farm)	21900	33125	44800
Maximum acquisition value at 25% annual costs (Hfl/farm)	17520	26500	35840
Maximum acquisition value at 30% annual costs (Hfl/farm)	14600	22083	29867
<u>Average investment level of milking parlour</u>			
Annual costs of alternative milking parlour (Hfl/cow)	493	469	418
Gross margin increase due to transition from B4 + 3 to S (Hfl/farm)	-7875	-13125	-18375
Gross margin increase due to change in milk yield (Hfl/farm)	2940	4900	6860
Annual costs of alternative milking parlour (Hfl/farm)	22185	35175	43890
Maximum annual costs of automatic milking system (Hfl/farm)	17250	26950	32375
Maximum acquisition value at 20% annual costs (Hfl/farm)	86250	134750	161875
Maximum acquisition value at 25% annual costs (Hfl/farm)	69000	107800	129500
Maximum acquisition value at 30% annual costs (Hfl/farm)	57500	89833	107917

High investment level of milking parlour			
Annual costs of alternative milking parlour (Hfl/cow)	879	649	554
Gross margin increase due to transition from B4+3 to S (Hfl/farm)	-7875	-13125	-18375
Gross margin increase due to change in milk yield (Hfl/farm)	2940	4900	6860
Annual costs of alternative milking parlour (Hfl/farm)	39555	48675	58170
Maximum annual costs of automatic milking system (Hfl/farm)	34620	40450	46655
Maximum acquisition value at 20% annual costs (Hfl/farm)	173100	202250	233275
Maximum acquisition value at 25% annual costs (Hfl/farm)	138480	161800	186620
Maximum acquisition value at 30% annual costs (Hfl/farm)	115400	134833	155517
Labour economy 0,5 full-time worker (Hfl/farm)			32500
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			108333
Labour economy 1 full-time worker (Hfl/farm)			65000
Increase in maximum acquisition value at 30% annual costs (Hfl/farm)			216666

ACTUELE RAPPORTEN + JAAR VAN UITGAVE

Nr.		Prijs
93	Het vergisten van rundveemest in een propstroom biogasinstallatie. 1984	25,00
94	Graslandgebruikssystemen op het gezinsbedrijf. 1984	25,00
95	Diepe grondbewerking op veengrasland met schalterlaag. 1984	10,00
96	Rendabiliteit van beregening op melkveebedrijven en waterbehoefte van de Gelderse Landbouwgronden. Basisrapport nr. 4. Rendabiliteit van beregening op gezinsbedrijven. 1984	25,00
97	Opname van Engels raaigras, rietzwenkgras, en Italiaans raaigras door melkvee. 1984	12,50
98	Het dikbilfenomeen bij het rund. Literatuuroverzicht met commentaar. 1985	25,00
99	Opbrengst en opname van gras bij verschillende mengsels en zaaizaadhoeveelheden. 1985	25,00
100	Strooisels in de paardenhouderij en arbeidsverbruik bij instrooien en uitmesten. 1986	25,00
101	Produktie en voederwaarde van gras bij gebruiks- en bemestingsbeperkingen voor natuurbeheer. 1986	45,00
102	Invloed van de afkalfdatum op de voedervoorziening van melkvee. Berekeningen in het kader van een studie naar de bedrijfseconomische gevolgen van verschillende afkalfdata. 1986	25,00
103	Stikstofwerking van geïnjecteerde runderdrijfmest op grasland. 1987	25,00
104	Invloed verhoogd grasaanbod op melkproduktie, ruwvoeropname en graslandopbrengst. 1987	15,00
105	Het groeiverloop van gras gedurende het seizoen. 1987	25,00
106	Effect van monensin op coccidiose bij lammeren. 1987	25,00
107	De invloed van de zwaarte van een snede op de hergroei van gras. 1987	25,00
108	Oogst en conservering van luzerne. 1987	15,00
109	De nawerking van eerder gegeven stikstof. 1989	25,00
110	Invloed stikstofbemesting en zwaarte voorgaande snede op hergroei van gras. 1987	15,00
111	Melkveehouderij en milieu. 1988	17,50
112	Energiebewuste bedrijfsvoering op een melkveebedrijf. 1988	25,00
113	Vorstschade in grasland. 1988	25,00
114	Grasproduktie en benutting bij de beweidingssystemen O4 en B4. 1989	25,00
115	Bodem, vegetatie, produktie en graskwaliteit van grasland met beheersbeperkingen. 1989	25,00
116	Simulatie van voeding en groei van jongvee. Toelichting op een computerprogramma. 1989	25,00
117	Verdeling en toevoegmiddelen bij het inkuilen van gras. 1989	25,00
118	Effect oogstmachines en melasse op de kwaliteit van slecht voorgedroogd kuilvoer. 1989	25,00
119	Invloed van toevoegmiddelen op de kwaliteit van slecht voorgedroogd kuilvoer. 1989	25,00
120	Korrelkeuzen bij de oogst van snijmaïs. 1989	25,00
121	Invloed van het toevoegen van melasse aan gras. 1989	25,00
122	Het schaapmodel. 1989	25,00
123	Bemonstering, kwaliteit en voederwaardering van graskuil. 1990	25,00
124	Grasproduktie en -benutting bij de beweidingssystemen B4 en B4+4. 1990	25,00
125	Opname van diploid en tetraploid in Engels raaigras. 1990	25,00
126	Bedrijfsmodel voor veenweidegebieden met verweving van natuur- en veehoudersbelangen. 1990	25,00
127	Graslandgebruik, bemesting en voedervoorziening op bedrijven met beheersbeperkingen. 1990	25,00
128	Continugebruik van Italiaans raaigras in vergelijking met Mk1-mengsel op komklei. 1990	25,00
129	Vriespunt van boerderijmelk. 1990	25,00
130	Invloed van het toevoegen van mierezuur en melasse aan weinig voorgedroogde graskuil. 1990	25,00
131	Vleesproduktie met Piemontese x zwartbonte kruislingvaarzen. 1991	25,00
132	Invloed van ontwatering van veengrasland en van grasland met gebruiksbeperkingen op de voedervoorziening van melkveebedrijven. 1991	25,00
133	Inpassing melkveehouderij in het geïntegreerde bedrijfsmodel voor veenweidegebieden. 1991	25,00
134	Herstructurering van een veenweidegebied met het geïntegreerde bedrijfsmodel. 1992	25,00
135	Gecombineerd weiden van schapen en pinken. 1992	25,00
136	Invloed tijdstip van toediening op stikstofwerking van dunne rundermest op grasland. 1992	25,00
137	Kuilafdekking en kuilkwaliteit. 1992	25,00
138	Bedrijfseconomische gevolgen beperking stikstofverliezen op melkveebedrijven. 1992	25,00
139	Ammoniak-emissiemetingen met de Lindvalldoos. 1992	25,00
140	Propro Noord-Brabant. 1992	25,00

Rapporten zijn verkrijgbaar door overmaking van het betreffende bedrag op Postbank nr. 2307421 van het PR te Lelystad met vermelding van het nummer van het rapport.