

# **Robotic Milkers: What, Where...and How Much!! ??**

*Jack Rodenburg<sup>1</sup>*

Dairy Production Systems Program Lead  
Ontario Ministry of Agriculture and Food

## **Introduction**

In Europe, robotic milking systems, available commercially since 1992, were in use on more than 1000 farms at the end of 2001. Thus the question, “do they work” is more than adequately answered. In North America, the first commercial robotic milking system was installed in Ontario, Canada in March 1999. Together, the provinces of Ontario and Quebec now have 54 dairy farms with robotic systems consisting of 65 Lely Astronaut stalls on 42 farms, 15 DeLaval stalls on 10 farms, and 3 Boumatic stalls on 2 farms. In addition, 1 farm in Nova Scotia milks with 2, 2 box AMS Liberty systems and there is one Boumatic installation in Western Canada. USA robotic milking farms include 3 herds in Pennsylvania and 3 in Wisconsin. Thus the question “are they suited to US conditions?” is still under debate. Early observations gained from working with Ontario herds may be helpful in identifying issues relevant to the adoption of robotic milking in the United States and Canada.

## **Why Robotic Milking in Eastern Canada**

Eastern Canada is well suited to be the first in North America to adopt robotic milking. The typical Ontario dairy herd consists of 58 cows housed in tiestalls. Many producers are now expanding into their first freestall barn for 60 to 200 cows. Most herds are milked 2X and involve exclusively family labor. Herds in this size range have difficulty making efficient use of modern milking parlor technology. They are faced with a “trade off” between investing too much capital in a labor efficient parlor that is under utilized, or spending too many hours milking with low cost but inefficient equipment.(Steevens, 1992). A preliminary economic analysis, using costs typical for the Midwestern US (Reinemann, 2000) estimates the labor and equipment cost for parlor milking 70 to 140 cows at US\$2.15 to \$3.65 per hundredweight, three times as much as for a 400 cow herd. The same study estimates milking costs with robots at \$1.30 to \$2.00 per hundredweight. Robotic milking has the potential to permit a “family farm” to expand to 100 to 150 cows without hiring outside labor. A moderate decrease in the price of robots or an increase in the cost of labor may also make small robotic farms more competitive with larger dairies. In Ontario, friction between an increasing non-farm rural population and shrinking numbers of ever-larger farms threatens the future of livestock agriculture. Society, government, and industry leaders welcome technology that improves the sustainability of the 120 cow family farm.

In interviews, 13 of the first 15 owners of robotic milking systems ranked “avoiding the frustrations of dealing with hired labor” as either their first or second reason for choosing robotic milking. With an average herd size of 94 cows, robot owners feel that hired labor is difficult to schedule, requires multi-skilled employees and would demand new skills in people management and employee training.

<sup>1</sup>Contact at P.O. Box 666, Woodstock, Ontario, Canada, N4S 7Z5, Phone 519-537-8862, Fax 519-537-5351, email jack.rodensburg@omaf.gov.on.ca

Robotic milking allows them to milk more cows while continuing to work with family labor only. The second ranked reason for choosing robots, listed by 9 out of 15 producers, is the opportunity for more frequent milking, with its benefits of higher milk production, lower SCC, lower incidence of clinical mastitis and reduced stress on udders. In their experience 3X parlor milking for a herd of 100 cows is impractical because of scheduling problems for the 1 to 2 hours of midnight labor, 7 days per week. Other reasons given include the flexibility and lifestyle advantages (6 producers) of not being tied to a fixed milking schedule, and the desire to be innovative (3 producers). Four of the herd owners interviewed stated that when the cost of building space was included, capital cost of robots at this herd size was comparable to large milking parlors. Faced with the need to invest in a new milking system these producers are confident that, for them, robotic milking will be economically advantageous.

### **Common Questions Answered:**

Ontario's Outdoor Farm Show, held each year in September (9,10,11 in 2003) has featured an onsite 60 cow dairy herd milked with a Lely robotic milking system for the past three years. Each year 20,000 people visit this exhibit, and generally ask the same questions. Since Ohio dairy producers probably have the same concerns, the following are the ten things we are most frequently asked for:

#### **1. How many cows will I have to cull because robots cannot milk them?**

Ontario farmers reported 0 to 3 extra culls from an average herd size of 94 cows. These were typically cows with very close teat placement, where two rear teats are touching and seen as one by the sensor. Very high rear udders, that make rear teats hard to see in a horizontal plane are also a problem. Other udder shapes that don't work with robots would be culls in a parlor situation as well, and were excluded in this estimate. The more frustrating cows are those that attach readily but refuse to go to the robot for voluntary milking. Since this is more common than in Europe, the use of total mixed rations (TMR) and high grain diets, is a possible reason for this.

Table 1 lists reasons for involuntary milking, reported by Ontario owners (Rodenburg, 2002). The reason, "udder conformation", includes cows moved by the operator because they were programmed for manual milking as well as cows with long intervals due to repeated failure to attach. Recent software improvements have since reduced the number of cows in this category to less than half of that reported here. Cows were described as "lazy", if they did not attend for voluntary milking, but their appearance and behavior were otherwise normal. We suspect most of these cows have a problem with mobility, caused by laminitis or other forms of lameness not obvious to the manager.

#### **2. How long does training take and what is involved?**

Typically, when an existing herd is switched to robotic milking it takes 3 to 4 weeks to reach a point where 80 to 90% of cows use the system voluntarily. Younger cows and more aggressive cows seem to adapt most easily. Current philosophy in training is to work cows aggressively for 2 weeks, by chasing every cow to the robot, whenever her milking interval exceeds 8 hours. This training period assures cows have repeated exposure to the milking stall and understand that

frequent visits are possible and rewarded with small allotments of grain fed during milking. After this period cows are left to fend for themselves and only moved by hand if milking intervals exceed 16 hours. Most new heifers learn the routine in 2 or 3 days but a few take longer. A fresh cow may need individual attention for one or two days to assist with initial teat location.

Tools used to encourage cows to attend for voluntary milking include grain fed in the robot stall. The importance of feeding palatable concentrate in the milking box, to attract cows to voluntary milking, is illustrated by a case study on one Ontario farm. Prior to January 2002 a low cost pellet formulated to help balance the needs of higher producing cows was used in two Lely milking boxes. Lower palatability ingredients in the mix included small amounts of added fat, corn gluten meal and canola. This concentrate suffered from poor pellet strength and resulted in a build up of fines in the feeders. In January 2002 a product with high palatability, and good pellet strength was substituted. The new pellet was higher (1.96 vs. 1.56 Mcal/Kg) in net energy lactation, higher in molasses content (3 vs. 0 %) and higher in ingredients rated high in palatability (96 vs. 65 %) and eliminated the problem with fines. Measures of voluntary milking are reported in Table 2 on three consecutive days 2 weeks prior and 2 weeks after the change. The frequency of voluntary visits also increased, but the main impact on herd management was a dramatic decrease in the number of “lazy” cows.

To encourage good cow flow, robot-milking stalls are located in the path from the freestall “resting area” to the feed manger. There is usually a gate in the crossover, which directs cows through the milking stall. With many of the Lely systems in Ontario, this is the only restriction to normal cow traffic. Several 3 and 6 row layouts and other barns with unrestricted cow movement demonstrate that the “free cow traffic” approach is working. This system is favored because “one way cow flow” may restrict feed intake for some cows. With one-way cow flow, one-way gates at all crossovers ensure cows must pass by the robot on each trip from the resting area to the feed manger. Roughly half the robot herds in Ontario use forced cow traffic, but all herds have a holding area with a one-way entrance gate beside the robot. This permits them to chase the “long interval” cows into this area twice daily while still encouraging them to enter the stall voluntarily.

### **3. How will I identify clinical mastitis? And can the system separate unmarketable milk?**

The milking system identifies cows with problems in several ways. One of the best tools is voluntary attendance records. If a new cow appears on the long interval list, she is most likely either lame or has a sore swollen quarter and would prefer not to be milked. The computer also records either whole udder or quarter milk yield and can flag cows which deviate from a “predicted yield” based on milking interval. Electrical conductivity of the milk is measured for each quarter. Large changes in conductivity are helpful in identifying new infections, which often present themselves as clinical cases. Farmers relying on conductivity alone are frustrated by the high number of false alarms. Probably the best tool for detecting abnormal milk and clinical mastitis as well is the recently introduced milk color sensor. Based on European studies, this device does an excellent job of identifying bloody milk. Preliminary reports also suggest it can identify yellow or watery secretions associated with clinical mastitis. Treated cows are identified in the computer and their milk is diverted to waste milk storage or the manure pit. The systems are programmed to rinse all milk contact surfaces thoroughly after a treated cow is milked.

#### **4. How will I spend my time in the barn, if there is no milking to do?**

The routine of the herds in Ontario includes a morning and afternoon trip to the barn to identify “long interval cows” and “cows not attached” These are brought to the robot, examined on the way for possible lameness or udder problems, and presented for automatic attachment. While these cows are milked other chores such as feeding, breeding and stall maintenance can be performed. Robotic milkers include sophisticated warning systems that alert the farmer by mobile phone or beeper when problems occur. In our survey, frequency of these alerts varied from 2 per week to 1 in two months. Farms with frequent alerts reported the common cause was “no milk because a milked cow refused to leave the stall.” Where alerts were less frequent they usually involved twisted or damaged inflations.

#### **5. But isn't this way more expensive than other milking systems?**

On first examination, capital investment in robotic milking appears to be very high, but when the overall economics is assessed there appears to be a niche for these systems on US farms today. In figures 1, 1B and 1C, single box robotic milking systems, with a capacity of 60 cows per box, are compared to a double 8 and double 12 rapid exit parallel parlor and to a low cost 10 stalls per side swing parlor. Labor costs are calculated at \$9 per hour. The amount of labor required for 2x parlor milking is estimated to be the assumed throughput plus 4 minutes per milking stall per day for set up and clean up. The robot data assumes 1 hour of labor per box per day. This would include cleanup, filter changes, and managing the cows that don't attend voluntarily.

The cost of ownership for each of the systems is calculated as repayment of the capital investment at 8% per year over 15 years, or \$116 per year for each \$1000 invested. The assumed costs of the equipment are based on prices quoted by Ontario suppliers, converted to US dollars. Details are as follows:

**2x12** - a double 12 rapid exit parallel with full automation, cow I.D. yield, conductivity and activity monitoring, valued at \$168,000, in a building space of 43 x 80 ft, for the parlor and holding area. Estimated throughput of 110 cows per hour, with 1 operator.

**2x8** - the same parlor as the double 12, with fewer stalls, valued at \$132,000 in a building 43 x 60. Estimated throughput of 75 cows per hour with one operator.

**Robotic Milking** – One single box robot per 60 cows, valued at \$150,000 for one, \$270,000 for two, \$480,000 for four, and 870,000 for eight milking stalls. Barn space is 15 x 20 ft for each milking stall.

**Swing parlor** - 2 x 10 stall layout with 10 milkers on a highline, used milking equipment, with no automation and locally welded stabling, valued at \$18,000. Building space is renovated old barn space valued at \$3.50 per sq. ft. (vs. \$15 for new construction above). Estimated throughput of 60 cows per hour.

One of the differences with robotic milking is that these systems take much less space in the barn. The construction cost of building space is included at a \$15 per square foot. Of course the validity of all of these assumptions is open to challenge. Total actual labor may be higher when problem cows, fresh cows and routine maintenance functions are included, but the impact on all systems is probably similar. Herd sizes of 60, 120, 240 and 480 cows were chosen for this comparison, to facilitate efficient use of milking robots. The single box technology, which has captured much of the market to date, is generally designed to milk 60 cows per box. In some ways this is a drawback of robotic milking, since it makes gradual expansion uneconomical.

As illustrated in fig.1A, robotic milking saves labor regardless of herd size. Since set up and clean up for small herds with big parlors is proportionally greater per cow, the saving is bigger in herds of 60 to 240 cows. Since labor with robots is less, herds of all sizes can justify investing more in robotic milking than in parlors. If labor costs increase the economics of robots will improve.

As illustrated in Fig. 1B, for small herds of 60 to 120 cows, milking parlors that make good use of labor, cost as much as robot technology, especially when the building space for a big parlor and holding area are included. Capital investment in robots on small farms will be no greater than in milking parlors. On large farms the parlor can accommodate more cows with more hours of use. The number of robots needed increases with each 60 additional cows.

In fig. 1C, when labor and capital investment are combined, robotic milking is competitive at 60 and 120 cows and still in the running at 240. Only at herd sizes greater than 240 cows, does the economics clearly favor parlor milking. One other alternative for smaller herds is to keep parlor investment as low as possible, however if this reduces labor efficiency, benefits in reduced capital investment are soon eliminated by increased labor cost. The swing parlor included in these calculations is one such option, however including it is like comparing apples and oranges. The other parlors and robotic systems include management aids such as cow I.D., cow activity, milk conductivity, and milk yield monitoring, as well as uniform milking with automatic detachers. The swing parlor only milks and will require additional management to be applied by other means.

Many other costs of milking may also have a bearing on this comparison, but their impact is probably small. For example, maintenance costs were not included in the above. In Ontario, robotic companies charge \$3000 to \$5000 per year for maintenance contracts. Though there is little information available on what parlor owners spend, it is probably similar. Water and chemical use in robots tends to be less than parlors, especially on smaller farms, and hydro use is similar, though variable with the type of milk cooling system used. One major variable that is difficult to include in this analysis is frequency of milking. The numbers used here, compare robotic systems, which have a typical average milking frequency of 2.4 to 2.7 times per day, to 2x parlor milking. Experience in Europe and Canada suggests production from robotic milking is probably 4 to 6% higher than from 2x parlor milking. This benefit is not included in the figures above. Compared to 3 X, the amount of increase is a bit disappointing, but it is not logical to expect 3x parlor milking results, where milking interval is a fixed 8 hours for all cows, from robotic systems that milk cows with highly variable intervals averaging 2.7 milkings per day.

Some other economic studies have chosen higher depreciation rates for robots than for parlor technology, partly because it is new and therefore more likely to change (Hyde, 2002; Rotz, 2002). Fig. 2A illustrates net return per cow using a whole farm model. Assumptions include 7 year depreciation for robots versus 10 for parlors and \$9 per hour for labor. In this scenario robotic milking resulted in lower net returns per cow at most herd sizes. Sensitivity of the model to changes in inputs in Fig. 2B illustrate the impact of faster depreciation, and suggests that if the life expectancy of robots equals parlors they become competitive at all herd sizes in the study.

In over 3 years of robotic milking in Ontario, the majority of improvements have involved software and chips that have been provided free of charge by the manufacturers. The introduction of any new and different milking technology results in a greater likelihood that today's purchase, whether a parlor or robot, will be obsolete sooner than expected.

Robotic milking is clearly competitive for farms with less than 200 cows. Herds in this size range with limited potential for further expansion should consider robotic milking, especially if labor cost is high. Larger herds or those with good potential to expand beyond 300 cows are better off with efficient parlors. Smaller farms that have a good supply of labor, may want to keep investment in milking equipment as low as possible for the next few years, while the potential for major expansion and cost and effectiveness of robotic systems becomes clearer in the next few years.

#### **6. Can I use my existing barn for this or do I have to build new?**

Almost any freestall or loafing barn layout can be adapted to robotic milking, if "free cow traffic" is used. Considerations in barn design and location of the milking stalls include placing each milking stall so it is accessible to a group of 60 cows. Cows in a group will be at all stages of lactation to facilitate efficient use of available milking time. Grouping by age may be beneficial in reducing competition. The milking stall should also be easily accessible for the operator. Regulations often require a clean path of access that does not involve walking in manure or cow areas. A location close to the milk house minimizes the length of milk line and facilitates easier cleaning, but research has found no relationship between the length of line and milk quality. Tractor scraping is inconvenient since cows do not leave the barn for milking. Mechanical alley scrapers or slatted floors overcome this issue. If you tractor scrape provide wide alleys and escape routes to minimize interference with cows. With no defined milking times, manger space is not critical. Based on video observation, robotic milking barns with 1 foot of manger space per cow do not result in competition at the feed bunk in Ontario. Sorting problem cows and cows programmed out into a separate pen with a sort gate is quite simple to do, but since milking is continuous, and herd groups are small the benefits are minimal. A sort pen must have access to feed and water since the time cows spend in it is highly variable. If cow management is done twice daily, individual cows could be in the sort pen for up to 12 hours. Locate the milking stall to minimize turns and steps, especially in the immediate entry and exit areas. Nearly all barns with free cow traffic include a holding area of no more than 200 square feet with one-way access gates. This can be used to hold cows that do not attend voluntarily when they are presented to the robot at twice-daily management times.

Forced cow traffic has been shown to improve voluntary attendance, especially during the initial training period. In forced cow traffic, freestalls are laid out so that cows can only move from the feeding area to the resting area through one-way gates and from the resting area to the feeding area through the milking stall. A pre-selection gate at the entrance to the holding area reduces unnecessary visits at the milking stall by cows ineligible for milking and avoids holding these cows away from feed in the holding area. Figure 4A shows a typical layout for forced cow traffic in a four-row barn with one robot and 60 cows and no pre-selection. Figure 4B has two robots and two groups with drive through alleys on both sides.

## **7. Does Robotic Milking require special feeding? Will it work with TMR?**

Grain in the milking stall is one of the factors that motivates cows to visit and be milked 2 to 4 times daily. It will be necessary to feed 2 to 4 pounds per day of a palatable pelleted grain ration in the milking stall, and this should be deducted from the grain in the TMR.

In an Ontario field study (Rodenburg 2002), voluntary attendance for milking was strongly linked to the level of energy and grain in the TMR. As shown in Figure 3 high grain low fiber diets were associated with a higher incidence of “lazy cows”, as well as a lower frequency of visits and milkings by cows attending voluntarily. Among these herds, measures of voluntary milking appear to be impaired in diets with more than 1.66 Mcal per kilogram dry matter Nel or more than 48% concentrate.

Ability to walk comfortably is a key factor in achieving good voluntary attendance in robotic milking. It is well known that high grain diets are associated with laminitis. Perhaps the farms using high grain diets in this study suffer from a level of “subclinical” laminitis, which is decreasing the mobility of cows. Attention to carbohydrate level and fermentation rates, matching rumen availability of protein, and attention to level and form of dietary fiber are key factors which influence rumen acidosis and laminitis. Limits of 25 to 35 % NDF, with 75% from forage, 35 to 40% non structural carbohydrate, and 30 to 40% starch in the diet dry matter, and a ratio of forage neutral detergent fiber to ruminally degradable starch of > 1:1 have been recommended. (Nocek, 1997) Accurate ration formulation with attention to conservative levels of starch etc. will be critical to achieving high milking frequency and fewer lazy cows in robotic milking herds. Since hoof trimming reduces severity of lameness on high grain diets regular hoof trimming may also be more important in robotic herds on TMR rations.

Alternatively it may be possible that cows on high grain diets are less aggressive due to a direct metabolic effect on behavior. It has been reported that cows on high grain diets spend less time eating and ruminating and more time resting (Robinson 1997), and consume fewer TMR meals.

In European dairy herds, computer feeders, often combined with pasture, remain popular. Dairy farms in North America have largely embraced TMR as the feeding system of choice. Improved voluntary attendance with higher forage diets, and the attraction provided by grain fed separately in the milking stall, make group fed TMR rations less compatible with robotic milking. The group feeding concept also conflicts with the “individual management” concept facilitated by robotic milking (Maltz, 2000). If robotic milking becomes common in North America the way we feed cows will likely evolve beyond current practices.

Frequent feeding and frequent trips through the barn to push up remaining feed are often recommended as a way of encouraging more frequent meals and higher feed intake from TMRs. In the field study more frequent feeding of TMR was associated a slight increase in visits to the milking box and fewer lazy cows. When only the 7 forced traffic herds were included, feeding twice per day vs. once per day resulted in 7.2 vs. 11.6 % lazy cows and 2.39 vs. 2.15 voluntary milkings per cow. Feeding fresh TMR several times per day, especially when combined with forced cow traffic, may be an effective way to encourage voluntary milking in TMR fed herds.

### **Are there other issues unique to North America?**

Yes, there are. European experience has taught us little about operating robots in uninsulated barns where freezing conditions occur in winter. Ontario experience indicates that it will be necessary to keep this equipment in a frost free environment. In our cold barns, this has been done by enclosing the “clean side” of the milking stall in an insulated heated and washable room ventilated separately from the rest of the barn.

Stray voltage, not found on European phase to phase electrical distribution, is also a potential concern. Although most recent research suggests that the practical significance of low levels of stray voltage is minimal, a behavioral, “avoidance” response is recognized to be the most likely first effect of exposure (Southwick, 1995). This effect has been observed on farm as refusal to use computer feeders in which cows were exposed to shocks of 2 to 3 milliamps, or 1 to 1.5 volts in a mouth to hooves pathway. If cows experience electric shocks when visiting the milking box, they will reduce their voluntary visits. Measurements taken from cow contact points on all types of systems in Ontario indicate the metal equipment is case grounded and provides a potential cow contact for stray voltage. Since the metal floor is an integral part of the milking box, the cow is on an equi-potential plane while in the stall and therefore protected from stray voltage during milking. Cows are exposed to a “step potential” when entering and leaving the box.

A slatted floor or an equi-potential plane adjacent to the robotic milking stall, or devices on the electrical system to mitigate stray voltage have been described (Rodenburg, 2002) and may be very important to achieving good cow flow in robotic milking systems.

European herds also tend to be smaller than average herd size in much of the US. Adapting the technology to very large herds will involve some further evolution. For example, in parlor milking, it is recommended that cows be housed in groups that can be milked in 1 hour. As milking parlors became larger and more automated, cow groups have increased in size to several hundred cows. Larger groups result in fewer gates, simpler manure and feed handling and simpler barn design. With robotic milking the potential for working with larger groups is largely unexplored. Average herd size of the 10 cooperating herds in our field study was  $98 \pm 30$  cows, with  $57 \pm 8$  cows per milking box. With one exception cows were grouped so that each group of 67 cows or less had access to only one milking box. In one herd a group of 92 cows had access to both a right and left entry box. With few exceptions, individual cows used only the box they were originally trained to use. Multi box systems are theoretically able to handle up to 150 cows in a group, but a trend to fewer boxes per robot and smaller cow groups with multi box systems is apparent in Europe today. Queuing for milking adds a new dimension to interaction between cows in robotic milking herds. For group sizes greater than 100 cows, the ability to recognize all

group mates may diminish (Grant, 1997), resulting in altered behavior at the milking box. Until further research defines this better, group sizes of 100 cows or less may be preferred.

In parlor milked herds it is also customary to group cows by stage of lactation, or milk production, to create groups with more uniform nutritional requirements and milking times. Efficient use of robotic milking systems depends on high utilization of the milking box. Groups with a uniform stage of lactation would be inefficient since the total milking time will be much longer when production is high than in later lactation. Further research is needed to define ideal grouping strategies for large herds using robotic milking. Until such studies are undertaken, single box systems based on groups of 60 cows with varied calving dates and multi box systems with groups up to 100 cows per group may be the only practical choice. Where the herd size results in many groups, grouping strategies that create groups with uniform age, (Phelps, 1992) size or temperament may be beneficial.

### **Are there special regulations for robotic milking?**

Many of the existing regulations for milk handling on the dairy farm are not readily applied to the robotic milking herd. To ensure a high standard of milk quality for this new technology, Ontario has developed guidelines, which are now applied voluntarily by the manufacturers to all robotic milking installations in the province. The guidelines require that detailed plans of the barn layout, location and design of the robot area and milk house be pre-approved and also inspected on completion. The robotic milking stall or stalls must be located so that the control side of the system is in a separate, enclosed room. This room must be positively ventilated with a supply of clean, filtered air from a non-livestock area. It must also be accessible via a clean path free of cattle traffic, and there must be a boot wash at the entrance.

The milk handling and storage system must cool milk to 6.9 °C within 1 hour of harvest, and to 4.0 °C within 2 hours, without freezing. All bulk tanks on robotic farms must be equipped with time-temperature recorders capable of alerting the operator when milk storage or system wash temperatures are outside the acceptable range. Where a 'buffer tank' is used to store milk while the main tank is emptied and washed, switch controls shall be located conveniently for the transporter and proper written instructions for milk pick-up must be posted. Milk from buffer tanks must be transferred by gravity or with a low speed sanitary milk pump. All lines must be sloped to the milk house and must be of food grade material. All systems must be washed at maximum 8-hour intervals. Compressors, which direct air at milk contact surfaces, must use food-grade oil.

Installing dealers must provide training for the operator and a service contract that includes at least 6 scheduled visits at two-month intervals in the first year. Operators commit to keeping stalls and cows clean and taking steps to remove long hair from the udder. Water used in rinsing robotic milking systems must be tested for bacteria at least once every four months, and must not contain more than five coliform, zero E.coli., or 500,000 heterotrophic bacteria per milliliter.

American regulations are still being discussed and all installations involve special permission with intent to gather data on the installation.

## **How good is milk quality from these herds?**

It is noteworthy that none of the more than 30 farms milking with robots in Ontario has ever experienced a penalty for inhibitory substances. Operators are trained to identify a treated cow in the computer, before the antibiotic treatment is administered. The infallible, automated cow I.D. system diverts the milk from treated cows to the waste stream or to a separate container, and thoroughly rinses the system before the next cow is milked. Clearly taking the human element out of diverting milk from treated cows minimizes the risk of accidentally contaminating marketable milk with this waste material.

Somatic cell counts (SCC) of raw milk reflect the level of mastitis infection in the herd, but may also be affected by stress or injury to udder tissue. A study of field data from Ontario herds (Rodenburg, 2001a) showed that after the introduction of robotic milking there is an initial moderate increase in SCC, perhaps reflecting stress on cows during the first few months. By 8 months after installation, SCC's of robotic herds were similar to other freestall herds of similar size. The absence of a "milker claw" in robotic systems and rinsing of liners between cows reduces the risk of contaminating other teats and cows with bacteria from an infected quarter. Limited pre-milking teat cleaning and a limited ability to apply teat spray, may increase incidence of environmental infections especially if the freestalls are dirty.

The freezing point of milk from robotic farms is slightly elevated compared to other farms. Though tests are rarely in the penalty range, higher freezing points may reflect the addition of very small amounts of water left behind in the liners as a result of frequent rinsing. Although rinse water is chlorinated to prevent possible contamination, regular water testing on robot farms is required as an added safe guard.

Bacteria counts of single box robotic milking systems have been similar to the industry average but higher than those of freestall herds of similar size. Failure to cool milk properly and failure to heat wash water adequately are the two most common causes of high bacteria counts. Robot herds have either tow bulk tanks or special chillers, to facilitate continuous milking. Since water heating for washing is done internal to the milking stall these farms have three or four water heaters. All this additional equipment may automatically translate into a greater frequency of problems. Time/temperature recorders on cooling and wash cycles are encouraged to minimize these problems. This and a limited ability to deal with individual dirty teats may explain the higher Bacteria counts. It is clear that producers with robots will need to maintain a high standard of cleanliness in the freestall barn. Detection and separation of abnormal milk is a challenge on all farms. It is noteworthy that recent introduction of color sensing technology on robotic systems provides dramatic new opportunities to flag and separate milk of abnormal color due to udder injury or infection.

Undoubtedly robotic milking technology will evolve further and new management strategies will emerge. In larger herds, automatic attachment devices may have future application in parlor milking without voluntary attendance. Speculation about "robot arms on rotary platforms" has likely been the topic of conversation in more than one farm office or university lunchroom. But

predicting the speed or direction in which new technology evolves is ill advised and will not be attempted here.

### **Summary**

Robotic milking offers the opportunity for dairy herds under 200 cows to reduce labor, milk more frequently and improve the flexibility of hours of work. The current technology functions very well and is able to locate and attach teat cups to 98 % of udders. Since parlor technology is expensive and under utilized at this herd size, robotic milking is economically competitive. Challenges that require special attention include achieving good mobility and high voluntary attendance by cows fed high grain diets, maintaining high bacterial quality of milk, adjusting management styles and barn layouts to heterogeneous groups of 60 cows, and adapting the technology to larger herds.

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	<u>% of cows involved in one or more involuntary milking</u>	<u>% of milkings involuntary</u>
Fresh or New (training)	2.3 ± 2.2	1.8 ± 1.9
Udder Conformation	5.6 ± 2.5	4.2 ± 2.0
Clinical Mastitis	0.2 ± 0.4	0.1 ± 0.2
Clinical Lameness	0.6 ± 0.9	0.3 ± 0.4
“Lazy”	10.3 ± 10.1	6.2 ± 6.4
Total all reasons	19.2 ± 12.5	12.6 ± 8.6

**Table 1. Summary of involuntary milkings.**

	Low Quality Pelleted Concentrate	High Quality Pelleted Concentrate
Voluntary visits/cow/day	3.40	4.04
Voluntary milkings/cow/day	1.72	2.06
% “lazy” cows	27.3	12.7
% “lazy” milkings	16.0	7.1
Production/cow/day (liters)	25.8	26.3

**Table 2. Voluntary attendance in a case study herd switching from low to high quality pelleted concentrate.**

## 2x Milking Labor

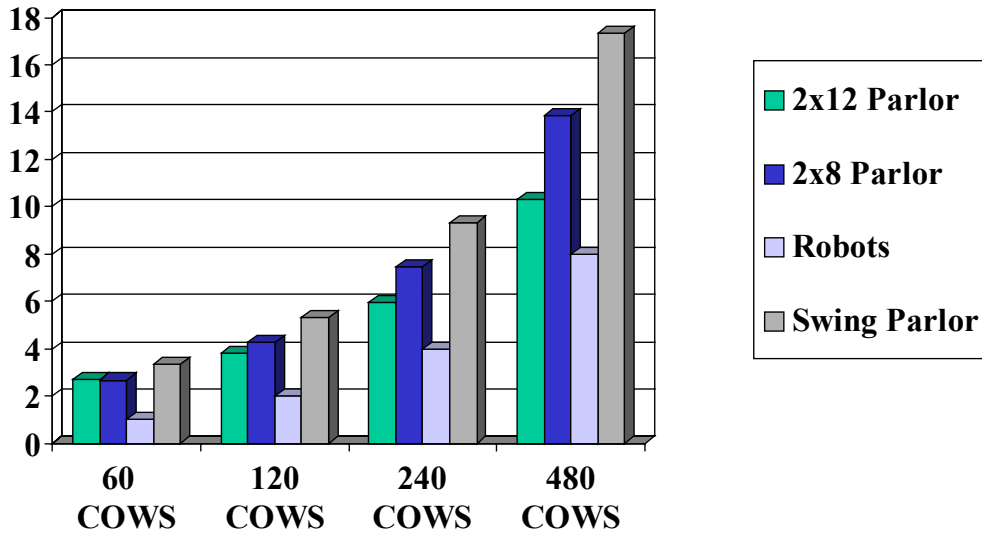


Fig 1A. Milking and clean up labor in parlors and robots (hrs/day)

## Capital Investment in Space and Equipment (\$)

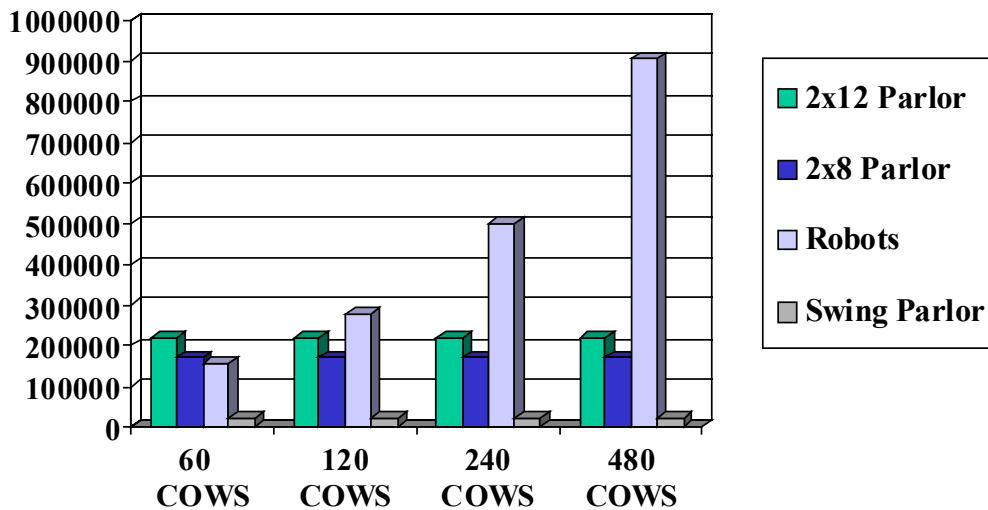
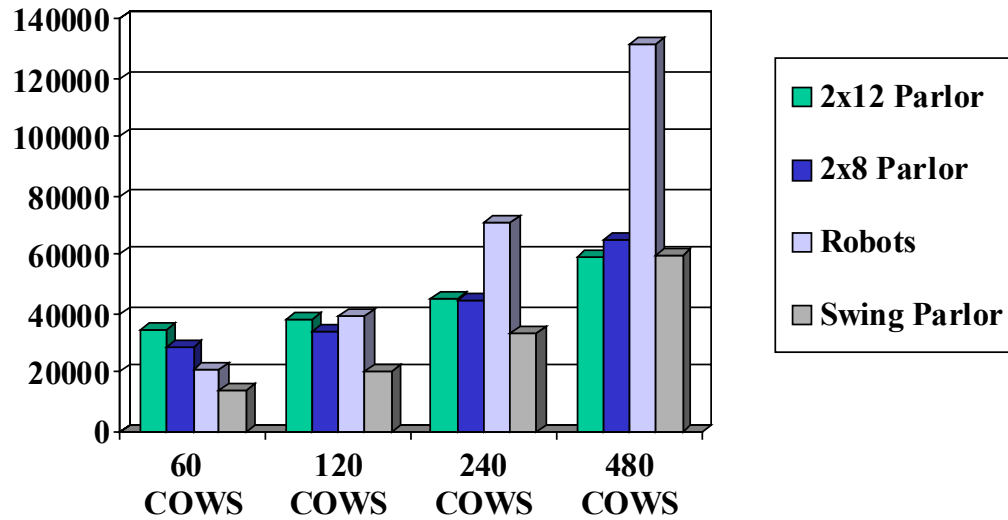


Fig. 1B. Investment in Equipment in parlors and robots (US \$)

# Total Annual Labor and Ownership Cost (\$)



**Fig. 1C Annual operating costs of parlors and robots (US\$)**

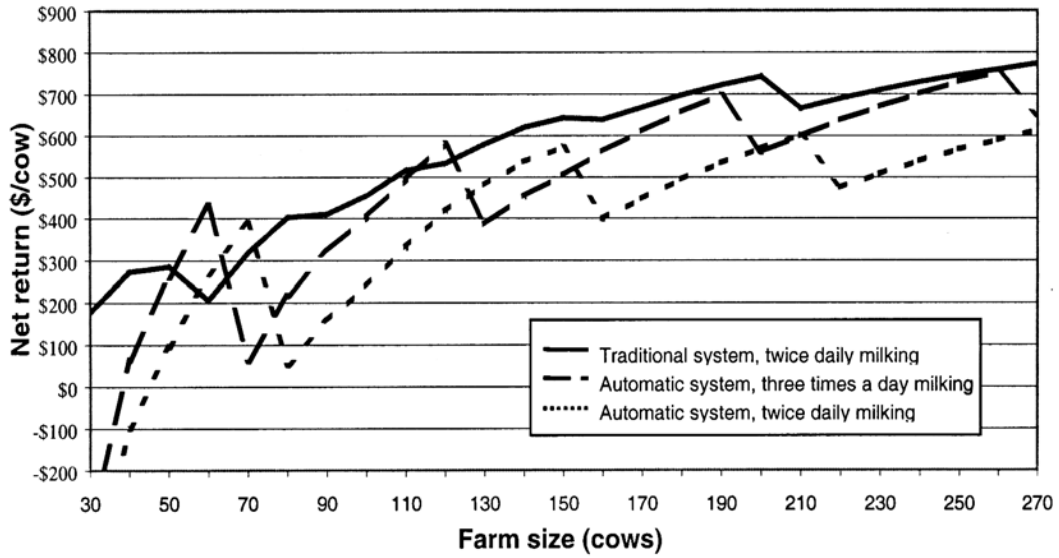


Fig. 2A. Net return per cow with average milk yields and robotic or parlor milking at various herd sizes (Rotz 2002)

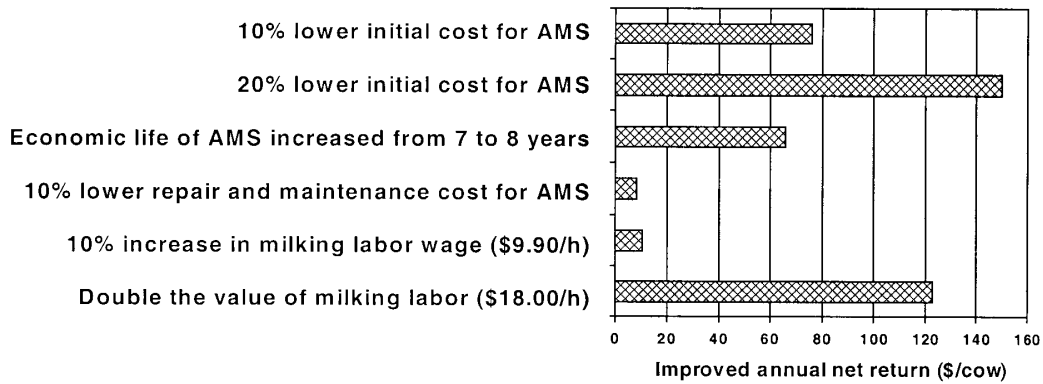
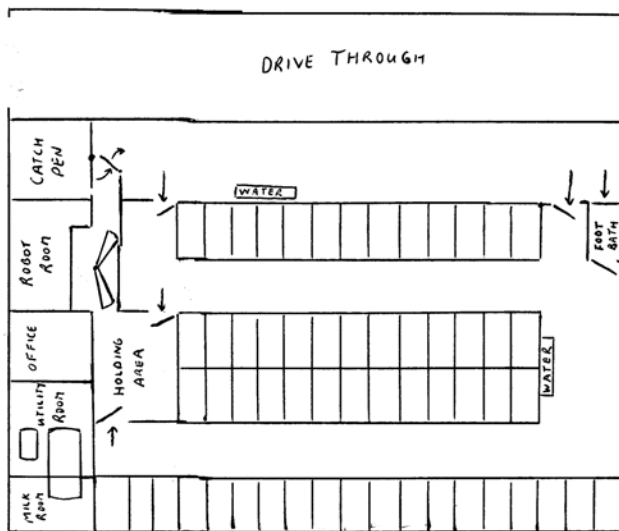
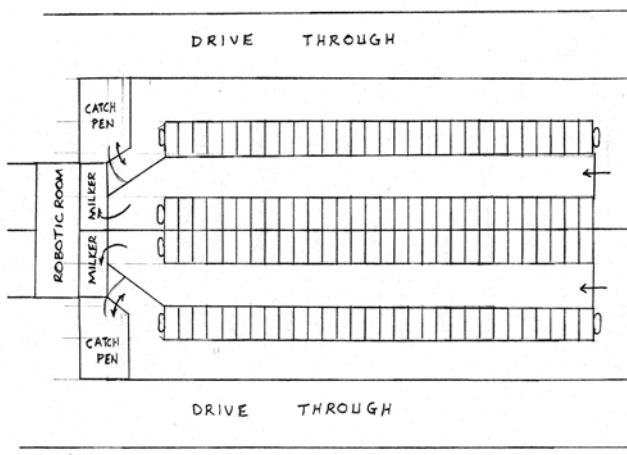


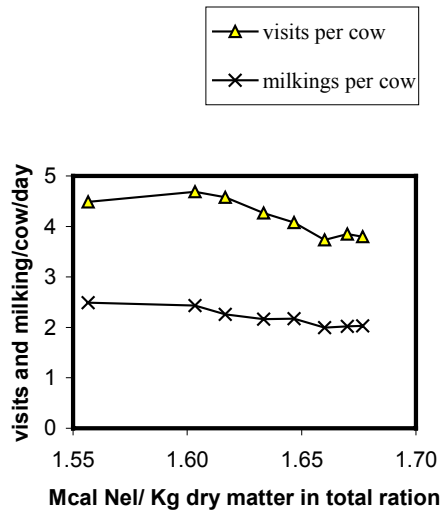
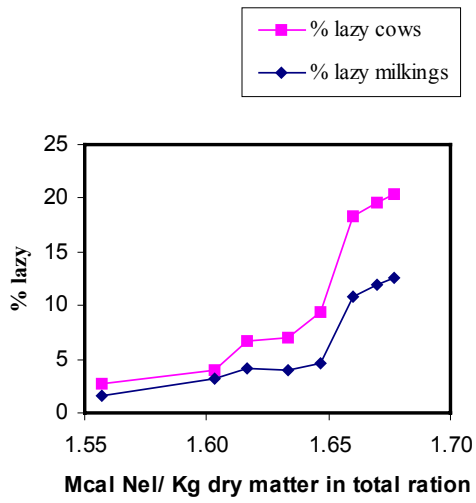
Fig. 2B Variable input changes and net return per cow using robotic milking (Rotz 2002)



**Fig. 4A Four-row layout for one group and forced cow traffic.**



**Fig. 4B Four-row layout for two groups and forced cow traffic.**



**Fig. 3 Voluntary milking and energy level in the total ration**